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History and activities in acoustics at the Civil Engineering faculty of STU Bratislava and in Slovakia during the past 100 years

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Abstract – This paper outlines the history and activities related to acoustics in Slovakia during the 20th century, focusing specifically on the Faculty of Civil Engineering at Slovak Technical University (STU) in Bratislava. The research in acoustics is presented within a historical context that has been notably turbulent in the Central European region. Consequently, the article examines the research and education in acoustics separately for the period before 1989 and the period following the fall of communism. It shows how the development of acoustics as a scientific discipline has been influenced by historical, political, and economic factors, particularly by several waves of emigration from Slovakia to Western EU and North America. The article is based on accessible information in the university library, historical research performance, testimonies of retired professors and colleagues, visits to university archives, and the archives of the Catholic Church. Finally, this paper presents recent research activities at STU Bratislava, the largest and technical university in Slovakia, within national and European frameworks. It outlines the focus of scientific work and education for future architects, civil engineers, and material scientists.

Keywords. Room acoustics, Building acoustics, Subjective perception, Listening tests, Slovak Acoustic Society

1 Introduction and historical context

Acoustics, as an independent discipline, began to gain importance with the advent of modern natural sciences in the 19th century. Although several important scientists in the field of acoustics were born in Slovakia, most of them performed their research work and became famous abroad. Well-known are i.e. inventor and Catholic priest Jozef Murgaš (1864–1929), who emigrated to the USA and established a laboratory at the Slovak parish in Wilkes-Barre, Pennsylvania, and Aurel Stodola (1859–1942), who served as a professor at the Polytechnicum Zurich at ETH Zurich. Many other names could be mentioned, but this would be beyond this paper's scope. Still, it is worth mentioning that the emigration of brains from Slovakia towards the West EU, USA and Canada has been, over the past 120 years, very significant and therefore also the biggest part of research on acoustics performed by Slovakians was performed out of Slovakia. The emigration has had different economic, ideological, and political reasons. During the socialist era in Czechoslovakia (1948–1989), the science and technology field, including the field of acoustics, experienced significant influence from the socialist establishment. This influence extended beyond just research topics and included the organisation and funding of scientific projects. Scientific institutions, including universities and research institutes, were strictly controlled by central state bodies, and political ideologies heavily influenced research in all areas. Notably, individuals of working-class background, often with limited education, were placed in leadership positions in many institutions. For some organisations to function, they were de facto managed by people from the bottom, whose names have long since been forgotten.

Universities implemented a "numerus clausus" policy, limiting the number of non-communists relative to the number of communist party members. Senior staff in managing or leading positions could not be non-party members. Furthermore, becoming a professor was expedited for communist party members, who did not have to prepare a habilitation thesis and were directly named professors. At the same time, non-communists faced longer waits for rehabilitation. Additionally, the head of the department or the research team leaders had significant control over the publications. As a result, the authors mentioned in several publications may not always

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accurately represent the entire team responsible for the research. In the acoustics field, research was carried out in collectives, and there was essentially no recognised individual authorship. This was due to nationalisation in 1948.

After the fall of communism in 1989, the primary focus of engineering faculties became the preparation of engineers for the building industry and civil engineering practice in Slovakia. Due to changes in the political system in the nineties, many large companies went bankrupt, were privatised or bought by international investors, moving the R&D departments to more developed countries. This situation has caused a lack of positions for engineers interested in innovations and applied research in Slovakia and initiated a next-generation emigration wave, as the researchers interested in product/technology development on the industrial level searched for positions abroad. In academia, the situation changed after 1990, too. Since the political changes in the 1990s suddenly allowed for the establishment of private businesses, many professors have taken the occasion to establish their own consulting companies while teaching at the university. This was and still is one way of surviving in Slovakia's profoundly underfinanced academia. Although the connection between academia and praxis is important, this situation has dramatically deformed the whole university education by minimising and almost abandoning science and research while focusing only on daily civil engineering and architectural praxis. The given situation has resulted in a lack of PhD supervisors who would be genuinely interested in the research, also in acoustics.

As is well known, in 1918, a common state of Slovaks and Czechs was established, and Slovak acousticians shared the history with Czechs as they belonged to the Czechoslovakian acoustics society.

Acoustics in Czechoslovakia began to develop systematically as a discipline within the broader physics, engineering and technology fields at the turn of the 1950s and 1960s. Among the most important publications from this period are mainly textbooks, monographs and proceedings dealing with various aspects of acoustics as book chapters [1]. These books were mainly meant as study material for university and high school students.

During the 1960s, acoustics in Czecho-Slovakia was included in the broader context of research in applied science and technology [2], focused on technical acoustics and its applications in electroacoustic systems. In the field of building acoustics, a publication was published in the 1960s [3]. Slovak authors, such as Emil Kašpar, have profiled themselves, especially in didactics of physics [4].

Due to Slovakia's political system, information about many researchers is limited, as the former regime's censorship suppressed names and achievements. One such researcher in the field of acoustics was Slovak priest Michal Kumorovitz, whose contributions remain partially undocumented at a state level. Fortunately, lots of information on his work has been archived by the Jesuits. After finishing grammar school in Slovakia, he studied theology at the KU Louvain, Belgium. Due to World War II, he finished his last year of studies in Lyon, where he was ordained a priest in 1940. After returning to Slovakia, he taught physics at a Jesuit gymnasium. Later, he was an assistant professor at the Department of Mathematics at Comenius University, earning a mathematics and physics degree in 1945 and a doctorate in mathematics in 1947. Following political persecution, he could no longer work in education and found employment at TESLA-Electroacoustics until his retirement in 1976. He has worked as a specialist in room acoustics and sound systems for theatres, classrooms for health-challenged students, including the deaf, and the acoustic design of stadiums. He is the author of many scientific studies on room acoustics and electro-acoustics: On directivity characteristics [5], on a solution of the homogeneous linear system of first-order differential equations with constant coefficients [6], and the role of electroacoustics and pure acoustics in the education of the hearing-impaired [7]. In 1991, he actively participated in the conference with foreign participation on Sacral Architecture with two papers: On the acoustics of churches and On the spatial acoustics of churches [8, 9]. He co-authored the book Practical Electroacoustics [10]. As a collaborator, he participated in the sound system of the Strahov Stadium in Prague for the first national Spartakiada in 1955. Based on his expert study, the sound system of the Moscirk Circus in Moscow was carried out, and later, also, the sound system of the venues associated with the Moscow Olympics in 1980. He was also part of a working group preparing CSN standards – CSN 34 2570-07P for sound equipment for railway stations in Czecho-Slovakia.

2 History and activities in acoustics at the Faculty of Civil

Engineering at STU Bratislava before 1989 The Faculty of Civil Engineering (SvF) is rooted in an academic institution founded in 1937 as the Technical College of Dr. M. R. Štefánik in Košice. As a result of political events before World War II, it moved to Martin, where the first academic year was opened in 1938. In 1939, the school moved to Bratislava. In 1960, the Faculty of Engineering Constructions and the Faculty of Architecture and Civil Engineering were merged into one Faculty of Civil Engineering. In 1991, the Slovak Technical College adopted the name Slovak Technical University in Bratislava. During 85 years of its history, the Faculty of Civil Engineering has educated 9583 bachelors, 34,725 engineers and 1571 doctors of science. Its graduates have made their mark in the history of the Slovak building industry, and many of their buildings are still admired today. Today, with 19 departments, the Institute of Forensic Expertise and other research centres, the faculty is the largest educational and scientific centre in the field of civil engineering and geodesy in Slovakia. It employs 379 people, including 34 professors and 66 associate professors. More than 2300 students, including approximately 150 PhD students, study at the

faculty. The Faculty of Civil Engineering is a university faculty, but it prepares both types of student profiles: vocational and university-level. This is because technical vocational education in Slovakia is only available at the secondary school level.

The first publication in the field of acoustics at the Faculty of Civil Engineering in Bratislava was published in 1970 [11]. As this scientific field was only developing in the country, specialists focused mainly on preparing education on acoustics.

The publication offers a comprehensive technical overview of three fundamental areas of building physics. It addresses the principles of heat transfer in building structures, calculations for thermal protection of buildings, and the design of energy-efficient solutions. The section on lighting covers both natural and artificial lighting of interior spaces, including photometric calculations. The acoustics part explores sound propagation, reverberation, sound insulation, and the design of indoor environments toward higher acoustic comfort.

It is said that the victors write history, and since the dictatorship erased the names of those who opposed the regime, information is very difficult to trace. Thus, the following paragraph summarises the names of professors at the faculty who contributed to the development of acoustics and could be traced from existing sources and the recollections of colleagues at the Faculty of Civil Engineering of STU Bratislava.

Martin Halahyja has been active since the 1960s, focusing on building physics and thermal engineering. His works [12, 13] became a basis for developing thermal protection of buildings and energy efficiency. His publications played a key role in energy efficiency and technical solutions for Slovak buildings during the socialist regime, where energy efficiency was often underestimated.

Július Puškáš started his publishing activity in the 1970s, when he focused on acoustics and building physics. The first publications [14] and [15] dealt with acoustic and thermo-physical problems in the context of buildings.

Július Puškáš became a key figure in the field of building acoustics in Slovakia, where he contributed to the development of acoustical standards and methodologies, as well as to the training of new professionals. He also collaborated in developing methodologies for assessing the effectiveness of noise barriers.

In 1990, Jozef Zajac published a manuscript on Reducing Noise and Vibration in Engineering Operations [16] in which he dealt with acoustic problems of industrial and residential buildings. During the 1980s, the first laboratory facilities for measurements in sound insulation were built, followed by the construction of laboratories in accordance with ISO standards for measurements in building acoustics according to ISO 10140 and ISO 354.

Klára Szomolányiová began her career in the 1980s. She has been a co-author of textbooks on civil engineering and structures at the Slovak Technical University (SVŠT) in Bratislava. Although her official publications mainly refer to building constructions and design [17–19], it is widely known that she was one of the first women in acoustics at the Faculty and also in Slovakia. She continued to navigate new knowledge even after her retirement. During her active career, she was a member of scientific teams that focused on the investigation of sound insulation properties of doors, etc. From the archival documents that have been preserved and her handwriting recognised, it is clear that the work on acoustics, sometimes published by other authors, was often originally performed by her. Despite her high expertise in building physics and her passion for building acoustics, she was not given the opportunity to participate in publications and education focusing on acoustics, which was probably also related to the status of women in Slovakia. Klára Szomolányiová is one of the few women who established themselves in the field of building physics, construction and architecture in this period, which shows her important role in a traditionally male-oriented discipline. She is now retired but sometimes participates as an external assessor in PhD juries.

Peter Tomašovič belonged to the professors of acoustics at the Faculty of Civil Engineering. His publication output can be mainly seen in various educational books and course texts (e.g. [20]). His manuscripts explain theoretical and practical aspects of acoustics and noise protection in buildings. Tomašovič established himself as an expert in acoustics in the field of building and urban acoustics in Slovakia. In addition to teaching and research, he has been involved in developing technical norms and standards in the field of building, room and urban acoustics in Slovakia.

In addition to the professors who worked directly in the acoustics field, others contributed indirectly to the field's development. Among them is, for example, František Ohrablo, who has been for many years creating conditions for the professional growth of students interested in acoustics (such as Monika Rychtáriková, now professor at KU Leuven and STU Bratislava).

3 Research in the field of acoustics

Over the past 10–15 years, the acoustic team at STU Bratislava has been formed around, assoc. prof. Vojtech Chmelík and assoc. prof. Daniel Urbán, with the support of M. Rychtarikova. The acoustic team's research aims to address three main areas: (1) building acoustics, (2) room acoustics, and (3) perceptual acoustics/psychoacoustics.

3.1 Building acoustics

The team deals with various research topics in building acoustics. It is well known that ETICS, used to improve the thermal insulation of buildings, does not always improve the acoustic insulation as well. A theoretical case study has been developed that helps understand the relationship between thermal and acoustic performance in building envelopes [21, 22]. The research

of the team also contributes to developing more efficient sound insulation solutions for various building types and applications, and measurement techniques for sound insulation evaluation [23, 24]. The group has been involved in developing a new method for assessing wall sound insulation using Laser Doppler Vibrometry. This method offers several advantages over traditional laboratory measurements. Its non-contact nature, spatially resolved measurements, and noninvasive characteristics make it a valuable tool for accurately assessing the sound insulation performance of partition walls in various applications [25]. The performance of lightweight façade constructions in terms of sound insulation, such as double transparent skin facades, has been studied in [26].

3.2 Room acoustics

Regarding room acoustics, several key topics have been addressed at STU. Large gathering spaces, such as atria and shopping streets, pose unique challenges due to their size and architectural characteristics. Much work has been performed on acoustic comfort in spaces covered by structural skins such as Ethylene tetrafluoroethylene (ETFE) cushion systems [27, 28]. One of the recent PhD works deals with rain noise radiated by such lightweight roofs [29]. Another research topic in the field of room acoustics has been noise in restaurants [30].

3.3 Sound perception

A large part of the group's research involves sound perception and investigating different phenomena through laboratory listening tests.

Laboratory listening tests help to understand how people perceive sound in different environments and situations [31–34]. Performed studies provided valuable insights into the factors that affect the subjective experience of sound and are essential tools for verifying proposed single-number evaluations of sound insulation in buildings. The topic of single number quantities (SNQ) development regarding sound insulation quality rating is another aim of the research team [31, 34, 35].

The main recent research effort concerns speech intelligibility of the Slovak language [36] in different architectural settings, such as classrooms, etc. [37]; other investigated questions involve different acoustic comfort issues, and during the COVID pandemic, also the influence of wearing face protection on speech [38]. Recently, a semantically predictable set of sentences has been developed [39]. Additionally, the team has investigated sound source localisation, which involves accurately determining the position of sound sources in various spaces. The motivation for this research topic is the inclusive design of buildings, which serves not only healthy people and mobility-challenged people but also hearing and sight-impaired individuals [40].

4 Education activities

Recognising the significance of acoustic education, the team focuses on developing methodologies and techniques for teaching and learning acoustics. By promoting an understanding of acoustics among students [41] and professionals, they aim to integrate acoustic principles into architectural and engineering practices more effectively [42].

One of the key activities of the team is the development and delivery of educational programs for architects and civil engineers. These programs focus on the principles of acoustics and the design of buildings regarding the acoustic comfort of users. In particular, two courses on acoustics are offered for future designers of buildings – (1) Building Physics 1 – acoustics, which is being taught at the Faculty of Architecture and Design. The course is designed to provide students with a comprehensive understanding of the principles and applications of acoustics in the built environment. This course will equip students with the knowledge and skills necessary to create acoustically optimised and aesthetically pleasing architectural spaces. Throughout the course, students delve into the multifaceted world of acoustics and its significance in architectural design. They explore the fundamental concepts of sound, including its propagation, transmission, absorption, and reflection. By understanding these principles, students can manipulate sound in various architectural contexts, such as concert halls, theatres, lecture halls, offices, and residential spaces regarding room and building acoustics. The main aim of the course is awareness of the influence of architectural design on sound propagation, including room acoustics, sound isolation, and control of unwanted noise. The second course is taught at the Faculty of Civil Engineering – (2) Comfort of indoor and outdoor building environment – acoustics.

Within this course, students acquire the knowledge necessary for designing buildings' interior and exterior space in terms of acoustics. Based on the calculation, computer simulation, and measurements, one also acquires theoretical and practical knowledge necessary to design schools, office buildings, sports buildings, spaces for musical performances, etc. They are acquainted with the principle of acoustic prediction, the user interface of simulation software, and its essential functions and properties and will learn the correct interpretation of results. The aim is to create its own virtual acoustic 3D model, calculation of acoustic quantities and socalled "space auralisation". The idea is to use a simulation result as input to the design of buildings for their master's theses and design studios.

Students also have the opportunity to collaborate in research in the field of architectural acoustics and the opportunity to present the results at an international conference in the form of a lecture or speech. The educational programs have been well-received by the architecture community and have helped raise awareness of building design's importance towards increased acoustic comfort.

In response to the growing demand from architects in Slovakia, and in line with lifelong learning programs, a book on architectural acoustics has been published [43]. The book explores the principles, theories, and practical implementation of acoustic solutions in architectural acoustics. Through its analysis of sound propagation, absorption, and control, as well as its examination of case studies and design strategies, this book aims to empower architects and designers with the knowledge and tools necessary to create acoustically optimised spaces.

Another part of the team's educational activities is contributing to the lifelong learning process for architects and building designers, and raising noise awareness. For the past 10 years, authors have cooperated with companies such as EUROSTAV, Forum Media, etc., on preparing lifelong learning conferences aimed at acoustic issues during the building process [44, 45].

Among other things, the team has worked to develop teaching materials, case studies, and interactive exercises in the framework of the European Erasmus+ Strategic partnerships project "Acoustic Course for Engineers", which is placed on the common educational platform ACOUCOU [42]. The platform helps not only architects to better understand the importance of acoustics in building design.

5 Collaboration on a national and international level

In addition to their research and educational activities, the team has also been actively pursuing opportunities for funding and collaboration in acoustics. They have applied for several educational and research projects and have collaborated with other institutions and organisations to advance the field of acoustics.

On a national level, members of the team are part of the Slovak Acoustical Association [46], which is also a member of EAA, ICA and I-INCE. Monika Rychtáriková is the president of the association. Vojtech Chmelík represents the Slovak association in the Association of Slovak Scientific and Technological Societies (ZSVTS), a voluntary, non-profit association of public interest, gathering expert scientific and technological societies, associations, committees and regional coordination centres [47].

The acoustic team (at the Faculty of Civil Engineering, STU Bratislava) also cooperates intensively on an international level. There is strong collaboration, especially with the Laboratory of Acoustics and Faculty of Architecture at KU Leuven in Belgium and the Department of Acoustics and Building Physics at TGM Vienna in Austria. These three institutions have built an effective consortium and already participated in several international projects. The most important project in which the acoustic team took part was the H2020-MCSA-RISE project PaPaBuild [48] (2016–2020), which was aimed at (1) improving the diagnostic methods for more precise determination of physical properties of building elements, (2) involving subjective assessment of sound insulation to help propose a suitable single number quantity and (3) enabling sustainable product innovation as the result of improved diagnostic methods. The recently ongoing project HE-MSCA-DN project ActaReBuild [49] focuses on the Acoustic and Thermal Retrofit of Buildings in the EU. It provides research and training using a new generation of sustainable materials and building components. Doctoral candidates are learning how to improve and guarantee the acoustic and thermal performance of buildings undergoing renovation while minimising embodied carbon production. The project offers 10 doctoral positions.

The acoustic team participated in many other projects, such as VisegradFund-Noisy Exchange, COST TU0901, COST TD0804, Erasmus+ Strategic partnerships-ACE (Acoustic course for engineers), and national grants VEGA/ KEGA. To keep connected with the practical world of acoustics, we cooperate with architects and engineers, especially with acoustic consultancy companies in Slovakia and abroad. They often belong to project partners in research projects.

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Conflicts of interest

The authors declare no conflicts of interest in regards to this article.

Data availability statement

No new data were created or analysed in this study.

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