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ACOUSTIC TEAM AT THE FACULTY OF CIVIL ENGINEERING, STU BRATISLAVA, SLOVAKIA

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ABSTRACT

The main activities of the acoustic team from the Faculty of Civil Engineering, STU Bratislava, Slovakia, are focused on research and education in the room and building acoustics and related areas such as environmental acoustics, archaeoacoustics, noise and health issues etc. During the past years, expertise in psychoacoustics and perception of sound was developed, which resulted in the establishment of a new laboratory that contains a sound-proofed semi-anechoic room suitable also for the performance of the listening test. This paper (1) introduces the acoustic group at SvF STU Bratislava in national and European contexts, (2) describes the evolution of the performed scientific work and education of future architects, civil engineers and material scientists, and (3) shows the interdisciplinary, intersectoral and international dimension of the activities performed here, through collaborations on research projects. Finally, a very tide and essential collaboration with the researchers from KU Leuven (Belgium) and TGM Vienna (Austria) are shown.

Keywords: *acoustics, room acoustics, building acoustics, subjective perception, listening tests*

1. INTRODUCTION

Research and education on acoustics in Slovakia are present at different institutions. The Room and Building acoustics field is covered mainly by the Faculty of Civil Engineering, STU Bratislava. This Faculty was established in 1939 as a part of the Slovak Technical Highschool (Slovenská vysoká škola technická). In the nineties, the school got a new name: Slovak University of Technology in Bratislava. It has always been one of the most important academic institutions in Slovakia, offering technical education in civil engineering, architecture, water engineering, geodesy, and cartography. The Faculty of Civil Engineering is university faculty, but it prepares booth types of student profiles: vocational and university level. (This is because the technical vocational education in Slovakia is present only at secondary school level.)

From historical point of view, after communism fell in 1989, the primary focus of the faculty became the preparation of engineers for the building industry and civil engineering praxis in Slovakia. Due to changes in the political system in the nineties, many large companies have bankrupted or were privatised, sometimes bought by international investors, moving the R&D departments to more developed countries with well-established research & development departments. This situation has caused lack of positions for engineers interested in doing applied research in Slovakia.

Many researchers interested in product/technology development on the industry level have therefore emigrated from Slovakia abroad. In academia the situation after 1990 has changed too. The political changes in the nineties suddenly allowed for the establishment of private businesses. Many professors have taken the occasion of having their own companies while teaching at the

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university. This was (is) one of the ways of surviving in the profoundly underfinanced academia in Slovakia.
This situation has however dramatically deformed education by abandoning science and research and focusing very much on daily civil engineering praxis and resulting in a lack of PhD-supervisors that would be genuinely interested in the research (on acoustic).
Consequently, many doctoral students left the country during the past 20 years and went to study in Western Europe or the USA. One of those PhD students was also Monika Rychtáriková, who, in the year 1999 first visited TU Wien (half a year) and later performed longer research stays at KU Leuven, TU Delft and RWTH Aachen. In 2005 she got a researcher position at KU Leuven and also received students from STU Bratislava. Her very first PhD students were Michal Jelínek and Martin Jedovnický [1]. In 2011, Monika became the main supervisor of Vojtech Chmelík (recently assoc. prof. at STU Bratislava), followed by many other young researchers. critical having a dedicated team of experts is crucial. Over the past 10-15 years the acoustic team at STU Bratislava has been formed around Prof. Monika Rychtáriková. The 3 main collaborators (co-authors of this paper) can be considered the main pillars of the acoustic research team at the Faculty, each bringing slightly different expertise (Figure 1).

Figure 1. Acoustic team at the Faculty of Civil Engineering, STU Bratislava, Slovakia

Vojtech Chmelík has finished his PhD thesis "Principles of inclusive design in Architecture and room acoustics" in 2013. He is nowadays dealing with research topics related to room acoustics, acoustic comfort, and speech intelligibility predictions. Daniel Urbán, has finished his PhD thesis in 2015 on Sound propagation within double transparent constructions; and nowadays performs research in sound transmission, sound insulation. Lukáš Zelem has finished his PhD thesis on the prediction and assessment of acoustic comfort in restaurants (2018). His main research interest lies in psychoacoustics and topics that tackle subjective assessment of sound insulation and standardisation.

2. RESEARCH IN THE FIELD OF ACOUSTICS

The aim of the research of the acoustic team can be seen in three main lines (1) building acoustics, (2) room acoustics and (3) perceptual acoustics/psychoacoustics.

2.1 Building acoustics

In the field of building acoustics, the team deals with various research topics. It is well known that ETICS used for improving of thermal insulation of buildings does not always help to improve the acoustic insulation as well. Researchers prepared theoretical case study, which helps in understanding the relationship between thermal and acoustic performance in building envelopes [2-3].
The team performs both, laboratory measurements as well as theoretical calculations and simulations of building constructions performance also aimed at the low-frequency sound insulation. They also emphasize the evaluation of airborne sound and impact sound insulation, which focuses on assessing the effectiveness of materials and systems in reducing unwanted sound transmission. This research contributes to the development of more efficient sound insulation solutions for various building types and applications as well as measurement techniques for sound insulation evaluation [4-5].
Members of the team have been involved in development of a new method for assessment of sound insulation of walls by means of Laser Doppler Vibrometry. This method offers several advantages over traditional laboratory measurements. Its non-contact nature spatially resolved measurements, and non-invasive characteristics make it a valuable tool for accurately assessing the sound insulation performance of partition walls in various applications [6].
The team also explores the performance of light weight façade constructions, such as double transparent skin facades [7-8].

2.2 Room acoustics

In case of room acoustics, the team addresses several key topics. Large gathering spaces, such as atria and shopping streets, pose unique challenges due to their size and architectural characteristics. Such large public spaces could cover various purposes. The team endeavours to

comprehend the acoustics of these environments, examining aspects such as sound propagation, diffusion, and intelligibility depending on the required function. More often, such spaces are covered with lightweight roofs, including ETFE membranes, which are getting very popular among architects [9-12].

Another topic connected with ETFE membranes, which the group is trying to address, is noise from rain, which is typically radiated into building interior. Depending on an function of given interior space, rain noise can be rather disturbing, especially in terms of communication, since the frequency spectrum of rain noise generated from lightweight roofs in general is often similar to spectrum of human voice. Therefore, it may mask speech, even if the sound level is not too high [13].

Noise in restaurants is another critical aspect investigated by the team. Understanding the sources, characteristics, and propagation of noise in restaurant settings enables the development of strategies to mitigate its impact. By exploring noise reduction techniques and solutions, the team aims to create more pleasant and comfortable dining environments [14-15].

Recognizing 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 [16] and professionals, they aim to integrate acoustic principles into architectural and engineering practices more effectively [17].

2.3 Sound perception

A large part of the research in the group involves sound perception and investigation of different phenomena through laboratory listening tests.

Laboratory listening tests help to understand how people perceive sound in different environments and situations [18-21]. Performed studies provided valuable insights into the factors that affect the subjective experience of sound and are essential tool for verification of proposed single number evaluations of sound insulation in building. The topic of single number quantities (SNQ) development in terms of sound insulation quality rating is another aim of the research team [18], [21-22].

The main recent research effort concern speech intelligibility of the Slovak language [23-24] in different architectural settings, such as classrooms etc [25-26], other investigated questions involve different acoustic comfort issues, and during COVID pandemics also the influence of wearing face protection on speech [27]. 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 inclusive design of buildings, which serves not only for healthy people and mobility-challenged people but also hearing and sight-impaired individuals [28-30].

3. EDUCATIONAL ACTIVITIES

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 are able to 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 being 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 acquires also theoretical and practical knowledge necessary in the design of 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, its essential functions and properties and will learn the correct interpretation of results. The aim is to create own virtual acoustic 3D model, calculation of acoustic quantities and so-called “space auralization”. The idea is to use a simulation result as input to the design of building 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 the architects in Slovakia, we have published a book on architectural acoustics [31]. 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 optimized spaces.

Another part of educational activities of the team is contribution to lifelong learning process for architects and building designers as well as noise awareness. Since past 10 years authors cooperate with companies EUROSTAV, Forum Media, etc. on preparation of lifelong learning conferences aimed at acoustic issues during the building process [32-33].

Among other things, the team has worked to develop teaching materials, case studies, and interactive exercises in the framework of European Erasmus+ Strategic partnerships project "Acoustic Course for Engineers" which is placed on common educational platform ACOUCOU [17]. The platform helps not only architects to better understand the importance of acoustics in building design.

4. COLLABORATION ON 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 national level, members of the team are part of the Slovak acoustical association [34], 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 [35].

The acoustic team (at Faculty of Civil Engineering, STU Bratislava) cooperates intensively also on an international level. There is strong collaboration especially with 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 up an effective consortium and have already participated together in several international projects. The most important project where the acoustic team took part was the H2020-MCSA-RISE project PaPaBuild [36], (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 on-going project HE-MSCA-DN project ActaReBuild [37] focuses on Acoustic and Thermal Retrofit of Buildings in the EU. It provides research and training by means of new generation of sustainable materials and building components. Doctoral candidates are learning how to improve and guarantee acoustic and thermal performance of buildings undergoing renovation while minimizing embodied carbon production. The project offers 10 doctoral positions.

There were many other projects that the acoustic team took part of. VisegradFund – Noisy Exchange, COST TU0901, COST TD0804, Erasmus+ Strategic partnerships – ACE (Acoustic course for engineers) and others, such as national grants VEGA/ KEGA.

To keep connected with the practical world of acoustics, we cooperate with architects, engineers and especially with acoustic consultancy companies in Slovakia and abroad. They often belong to project partners in research projects.

5. INFRASTRUCTURE

In April 2019, the first part of the acoustic laboratory was built that consists of a semi-anechoic, well-insulated room and serves mainly for perceptual experiments (Figure 2). The low background noise is essential for listening tests related to subjective perception of sound insulation. The $L_{A,95}$ in the listening room, is around 16 dB [38].

The laboratory was sponsored by Saint-Gobain company, and it serves all team members including all PhD students dealing with topics related to acoustics – Dominika Húdoková (*Speech intelligibility),* Majid Lavassani

(*Assessment of rain noise in rooms covered by structural skins*), Michiel Geluykens (*Qualitative assessment of sound insulation of building envelopes and development of an adapted noise annoyance construct applicable for building acoustics issues*).

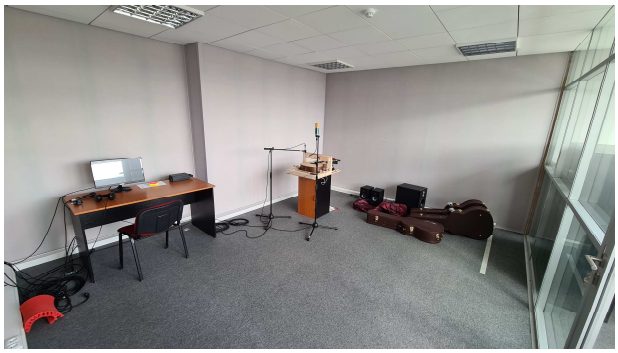

Figure 2. Acoustic laboratory – perception room at The Faculty of Civil Engineering, STU Bratislava, Slovakia

Except for the abovementioned perception room, the laboratory contains classical equipment for in situ measurements (room and building acoustics), set up for measurement of vibrations and several small set-ups such as impedance tube, kit for measurements of dynamic stiffness etc.

6. CONCLUSIONS

In this paper, we have introduced the relatively young acoustic team from the Faculty of Civil Engineering, STU Bratislava, Slovakia, which at the moment consists of 4 senior staff members and 7 PhD students and is well integrated into the Department of Materials sciences and Physics. We intend to explore the present infrastructure and scientific network in the EU, and educate new young researchers, to let them experience the passion for science. Finally, our greatest ambition is to show (by our own example) that also in Slovakia, it is possible to perform a research on acoustics of good quality, in line with research integrity.

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