44º CONGRESO ESPAÑOL DE ACÚSTICA
ENCUENTRO IBÉRICO DE ACÚSTICA
EAA EUROPEAN SYMPOSIUM ON ENVIRONMENTAL
ACOUSTICS AND NOISE MAPPING

ACOUSTICAL DESIGN OF NEW MUSIC FACILITIES OF THE MUSIC ACADEMY IN ZAGREB

PACS 43.55.Fw

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ABSTRACT

The Music Academy of the University of Zagreb has a long educating history, but only in 2013 a building built just for their needs will be finished for the first time. On an area of 12,000 m^2 many music facilities will be hosted, such as rehearsal rooms, studies and 3 concert halls. This paper gives an overview of the design process of these spaces with respect to the planned acoustical characteristics. Odeon was used for auralization to help the musicians to define their preferences of room acoustics.

1. INTRODUCTION

The University of Zagreb Music Academy is the oldest and largest college of music in the Republic of Croatia. Its graduates have conveyed and confirmed the Academy's reputation for providing a high level of musical education throughout the world. Through their professional endeavors as musicians, teachers, musicologists, critics etc., they make a significant contribution to the cultivation and development of musical tradition and the general cultural good [1].

The Music Academy has a long and distinguished history. It is the direct successor of the Music School of the Croatian Music Institute, which opened on February 16, 1829. After a dynamic history, the Music Academy is today organized into eight departments (Composition and Music Theory; Musicology; Conducting, Harp and Percussion; Voice; Piano, Harpsichord and Organ; String and Guitar; Wind; Music Education), in which approximately 150 teachers teach over 500 students.

The Academy currently occupies four buildings in Zagreb. All departments which are currently scattered around Zagreb are expected to move into the restored and upgraded Ferimport building at Marshal Tito Square, a former office building build in the early 1960's in the famous square with the national opera house surrounded by old, 19th century buildings. The Academy had signed a 100-year lease contract with the City of Zagreb in 2009. The restoration is expected to finish end of 2013, and the total price of the renovation could go up to 30 million Euro.

2. THE NEW BUILDING OF THE MUSIC ACADEMY IN ZAGREB

The winning project of the new building was developed by the architect Milan Šosterić in 2003. The building has almost 11,900 m^2 of gross area (around 8,850 m^2 net area) where not only all departments of the Academy will find their place, but also the Academy administration, library, rehearsal rooms, studies, and 3 concert halls. The new building will have 2 floors below ground, one ground floor and 7 upper floors. The visual solution of the building itself is shown in Figure 1.

Figure 1 – Visualization of the new building of the Music Academy of the University of Zagreb.

The initial acoustic project was made by Ing. Ivica Stamać and Prof. Hrvoje Domitrović. 10 years have already passed from the start of the project and the final interior acoustic design for all musical facilities of this building was done by the authors of this paper.

The building itself contains a large number of various rooms that had to be treated acoustically. From the 8,850 m^2 net area of the building, around 4,950 m^2 of net area (99 different rooms) is to be acoustically treated. The acoustic design of musical facilities is certainly very important and well presented in literature by other authors [2-5]. The project of interior acoustics covers the following facilities:

- a concert hall with 300 seats and a stage with polyvalent functionalities (changeable geometry) – 700 m^2
- an audio control room + a video control room connected to the concert hall
- an electronic recording studio (multimedia studio and sound synthesis) – 190 m^2
- two smaller concert halls for multiple purposes – 220 m^2
- classrooms for theoretical lectures – over 1000 m^2
- rehearsal rooms – 560 m^2

3. DESIGN PROCESS FOR THE MUSICAL FACILITIES

Besides the interior design, the architectural project addressed also the problem of sound insulation between rooms, and between the rooms inside the building and the open space outside the building where a lot of transport noise exists (multiple lane streets on two sides of the building, city tram passing near the building). The design process consisted of several phases. In the first phase, for each room the following was defined:

- maximum expected sound pressure level produced by musicians (students and teachers, or group of musicians with musical instruments, or vocalists),
- maximum allowed sound pressure level of sound arriving into the room from neighboring spaces (musical performance in other rooms in the building, conversation of people in rooms and corridors, traffic noise from outside the building, HVAC noise, etc.).

The sound levels from musical instruments and vocals are compiled from known data in the literature [6-8]. In order to estimate the sound levels produced by orchestras of various sizes, sound levels of individual instruments were simply added together. All data were compiled in octave frequency bands in the range from 31.5 – 8000 Hz. The maximum allowed sound pressure levels of disturbing sources were taken from Croatian and international norms and recommendations [9-11].

The NR values were defined for each room depending on its use. For constant noise sources (e.g. HVAC noise), the NR values were specified as constant numbers. For sources with noise levels changeable over time (e.g. traffic, music, speech), the NR values were given as L_5 values (levels that cannot be exceeded in more than 5% of the time). After the maximum expected sound levels in each rooms were calculated and the recommended NR values were defined, the needed sound insulation for each room in each octave band was calculated as a simple difference between these values. The recommended NR values are:

- NR15 – recording studios, sound synthesis, audio control room
- NR 20 – most other rooms (including the big and two small concert halls)
- NR 25 – individual rehearsing rooms, studies, theoretical lecturing rooms

The required sound insulation index varies from room to room, but it can reach 90 dB in extreme cases! To achieve these exceptionally high sound insulation levels between adjoining rooms, special care was taken in the floor and wall design. First of all, rooms more sensitive to noise were placed in the new part of the building (Figure 2 in blue) with double walls (green circle) and special anti-shock layers between walls and floor, Figure 3.

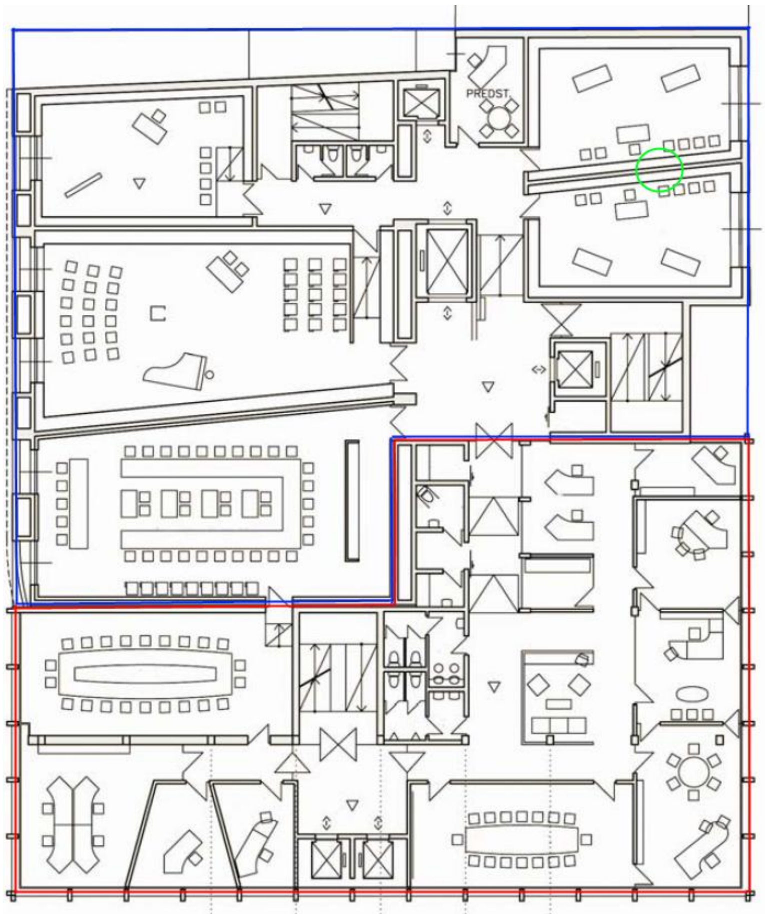

Figure 2 – Plan of the 3rd floor of the new building [12]. The old office building is shown in red, and the newly added part in blue. The green circle indicates a detail of a double wall construction.

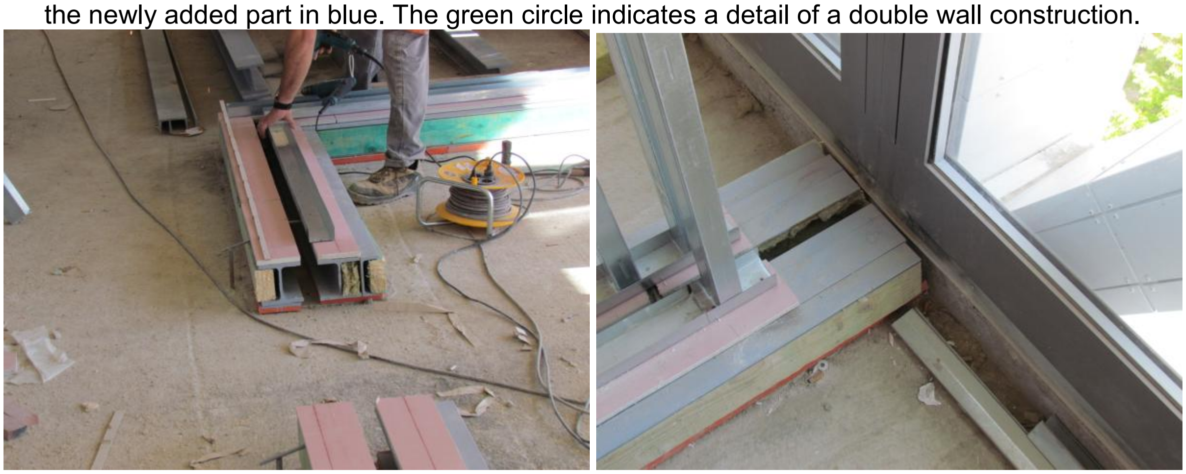

Figure 3 – Details of the double wall construction between rooms, with an underlying anti-shock material for additional sound insulation.

The next parameter used in the design process was the reverberation time. Although, the reverberation times were defined in the project in the frequency bands from 125 Hz do 4000 Hz, musicians and Academy professors were consulted about the optimum reverberation in rooms of various purposes. For this reason, one of the rooms was modeled in the Odeon® room acoustic software [13] using different quantities of absorbing and diffusing materials, and different music pieces were auralized and afterwards reproduced using an 2nd order Ambsonics system with 16 loudspeakers in a 3D setup [14]. Figure 4 shows the 3D wireframe mesh of the test room, with the position of the listener (blue dot), the musician (red dot), and the possible locations of the acoustic elements on walls and the ceiling (elements are of standard size 60 x 60 cm).

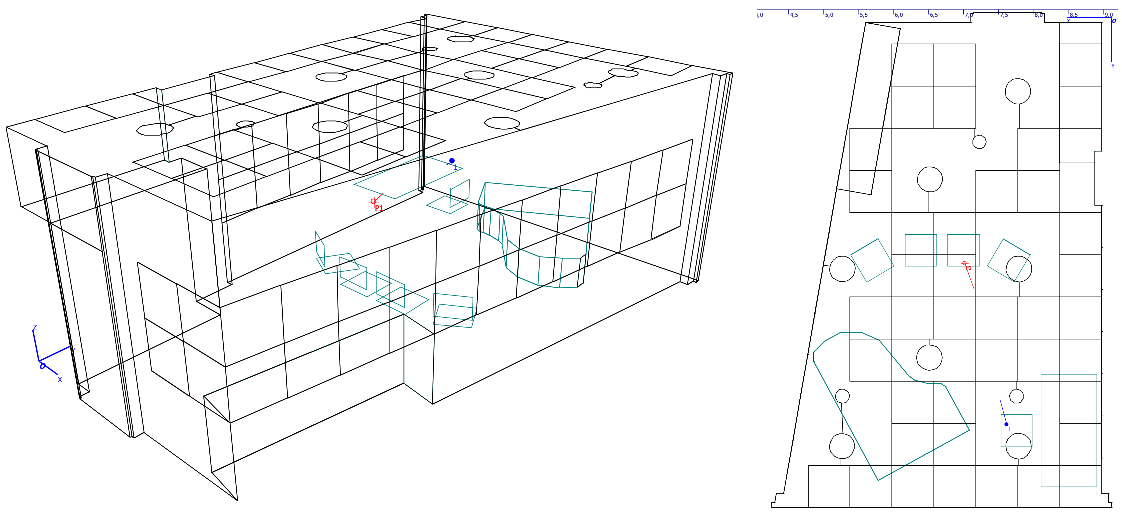

Figure 4 – Test room used for auralization. The number and position of acoustic elements were varied (type 1 – type 6).

Following examples of acoustic finishing were presented to the musicians:

- type 1 – empty room (only chairs, table, lockers and a piano), Figure 5
- type 2 – added 15 binary diffusing elements on the ceiling, Figure 6
- type 3 – additional 3 low freq. and 5 medium freq. perforated absorbers on walls, Figure 7
- type 4 – in total 15 binary diffusers, 6 low freq. and 10 medium freq. absorbers, Figure 8
- type 5 – same as type 4, but all elements were grouped in the far side of the room, Figure 9
- type 6 – in total 15 binary diffusers, 9 low freq. and 19 medium freq. absorbers, Figure 10

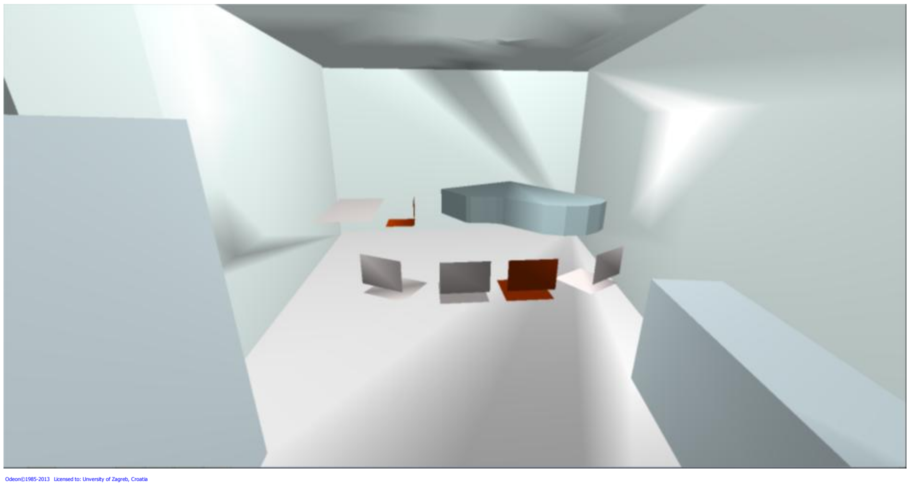

Figure 5 – Empty test room.

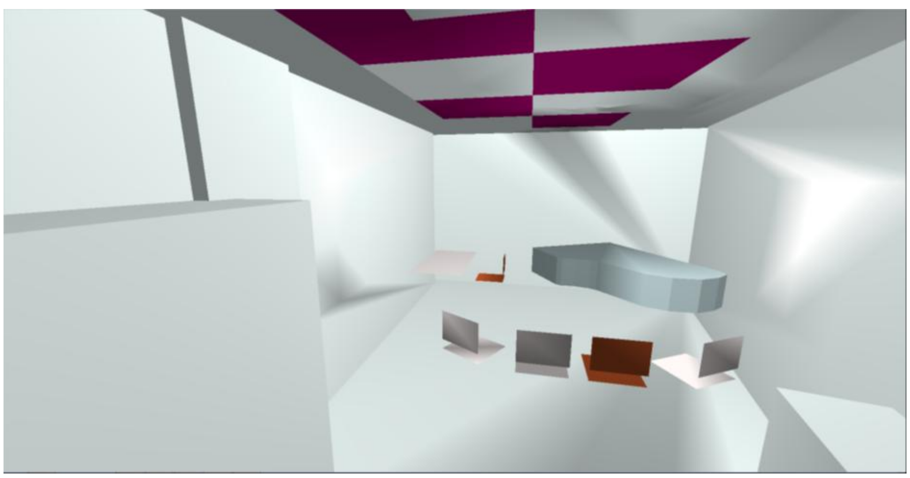

Figure 6 – Test room with added 16 binary diffusers on the ceiling.

Figure 7 – Test room with additional 3 low freq. and 5 medium freq. absorbers on the walls.

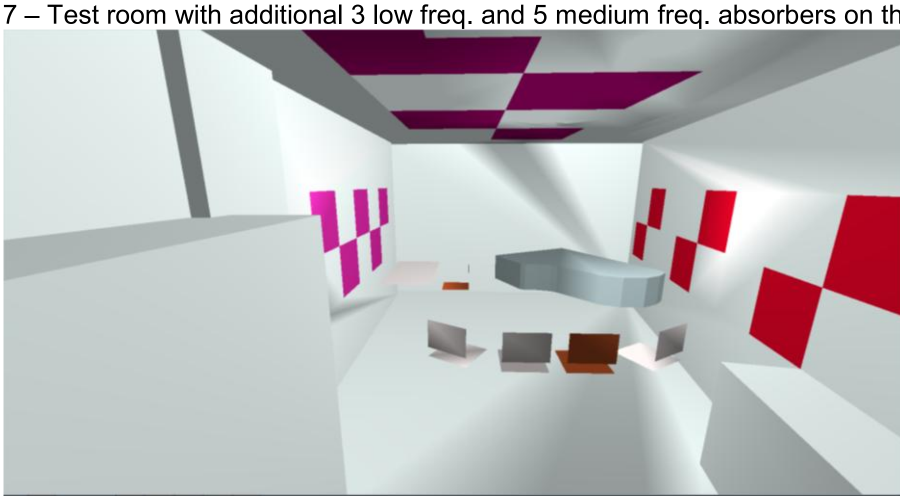

Figure 8 – Test room with 15 binary diffusers, 6 low freq. and 10 medium freq. absorbers.

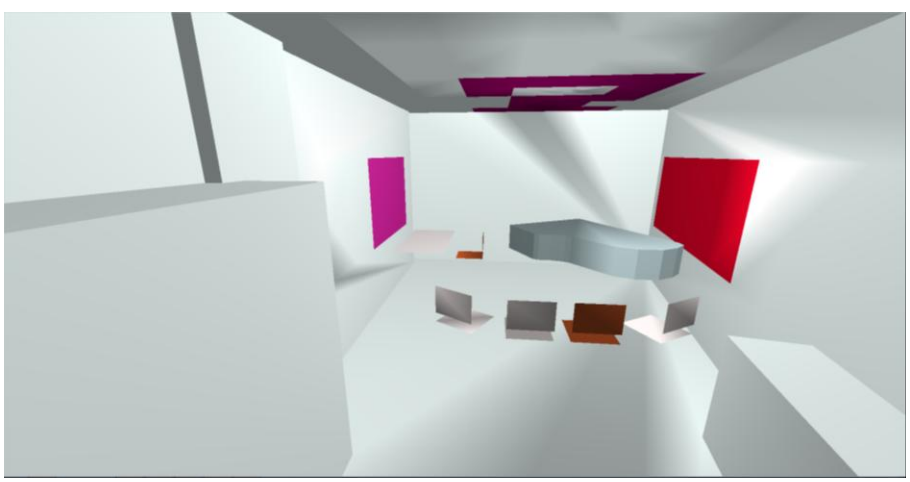

Figure 9 – Test room with 15 binary diffusers, 6 low freq. and 10 medium freq. absorbers, all grouped around the listener and the musician.

Figure 10 – Test room with 15 binary diffusers, 9 low freq. and 19 medium freq. absorbers.

The obtained reverberation times for all types of finishing in the test room are shown in Figure 11. After the musicians listened to all auralized types of the test room, the general conclusion was that for studies with pianos, the preferred acoustics is type 3, for studies for strings and flute type 4, for individual rehearsing rooms with piano type 5, and for individual rehearsing rooms without a piano type 6. It is evident that the optimum reverberation time can vary quite a lot depending on the use of the room, number of musicians, and the type of musical instruments played in the room.

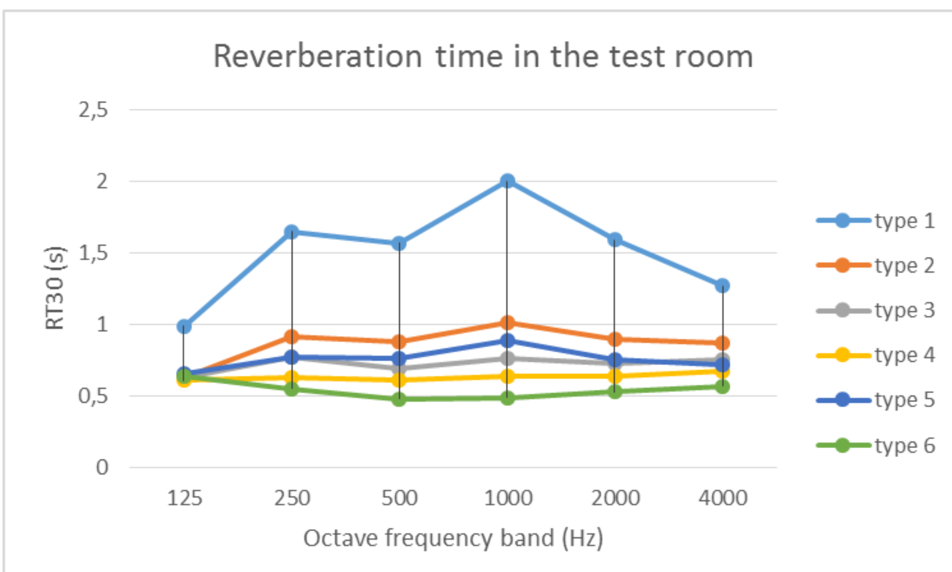

Figure 11 – Reverberation times of the test room depending on the type of acoustic finishing.

In the final stage, a number of rooms, especially studies, will be equipped with elements that allow the change of reverberation times in the rooms, e.g. elements for changeable acoustics. Such elements were designed and implemented in the project in all required room. For example, the same test room showed in Figure 4 will have the possibility to change its reverberation time in a range as shown in Figure 12.

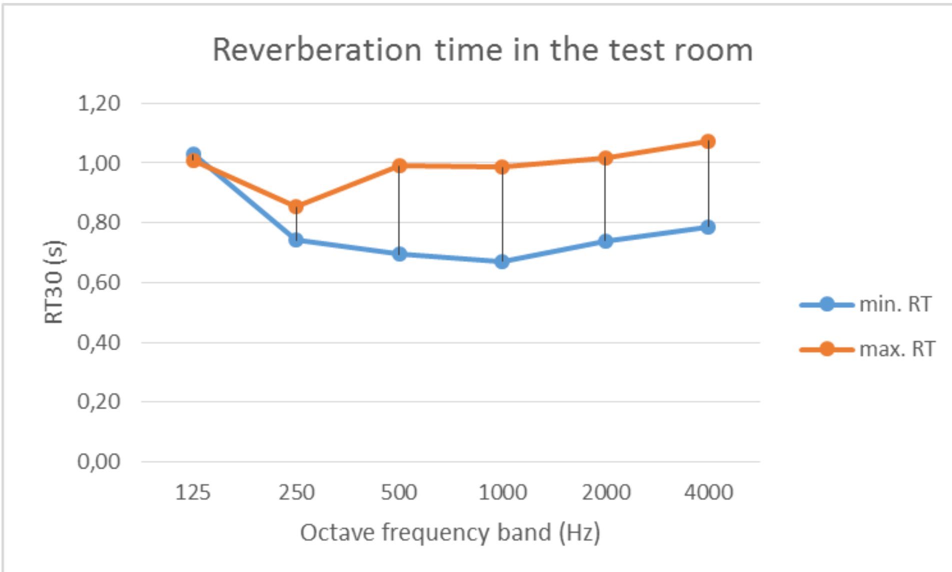

Figure 12 – Variations of the reverberation time in the test room with changeable acoustic elements.

4. CONCLUSION

Designing music facilities is always a challenge. This is especially true for music rehearsal and teaching rooms as many playing techniques depend on the "interaction" between the room and the player. This interaction mostly depends on the room size, but also on its acoustics. More damped rooms require the musicians to play harder and louder, possible playing errors are more audible. This is often required by the music teachers because such rooms help the students to prepare for playing in bigger concert halls and in orchestras.

In the described case of the new building of the Music Academy in Zagreb, the challenge was even bigger as there were 99 rooms to care about, often with very different demands. There are almost no two equal rooms due to the design with non-parallel walls for lowering the danger of flutter echo. The demand on changeable acoustics made the challenge even bigger, so does the polyvalent concert hall which can be adapted for smaller up to big orchestras, playing on a normal stage, or even on a lowered stage for opera-like performances.

Final measurements and tuning are planed after the finish of all construction works in the building. These measurements should verify the acoustic properties of all sensible rooms in the new building, hopefully to the benefit of all musicians, teachers and students, that will be working in future in the building.

ACKNOWLEDGMENTS

This research has been partly supported by the ACROSS project, 285939 FP7-REGPOT-2011-1.

REFERENCES

1. University of Zagreb Music Academy, http://www.muza.unizg.hr/
2. Building Bulletin 93, "Acoustic Design of Schools. A Design Guide", Architects and Building Branch, London, 2003, http://www.bb93.co.uk/
3. M. Long, "Architectural acoustics", Elsevier Academic Press, 2006
4. "Planning guide for school music facilities", Wenger Corporation, 2008, http://wengercorp.com/
5. "Acoustic problems & solutions for rehearsal and practice spaces", Wenger Corporation, 2000, http://wengercorp.com/
6. H. F. Olson, "Modern Sound Reproduction", Van Nostrand Reinhold Co., New York, 1972
7. J. Meyer, „Akustik und musikalische Aufführungspraxis", Verlag das Musikinstrument, Frankfurt am Main, 1972
8. C. Gilford, "Acoustics for radio and television studios", Peter Peregrinus Ltd., London, 1972
9. Draft Technical Recommendation N12-A, "Sound control rooms and listening rooms", Nordic Public Broadcasting Corporations, 1992
10. "Akustika, preporuke P1, P2 i P3", Komisija za tonsku tehniku JRT, Beograd, 1979
11. Z. Maekawa, P. Lord, "Environmental and architectural acoustics", E & FN Spon, London, 1994
12. B. Nadilo, "Zgrada muzičke akademije u Zagrebu", Građevinar, vol. 61, no. 12, pp 1163 – 1174, 2009
13. Odeon Room Acoustics Software, http://www.odeon.dk/
14. M. Horvat, K. Jambrošić, H. Domitrović, "Construction of an auralization laboratory based on multichannel loudspeaker system", Proceedings of the International Conference on Acoustics AIA-DAGA 2013, pp 2356-2359, 2013