International Journal of Scientific & Engineering Research, Volume 8, Issue 8, August-2017
ISSN 2229-5518

Environmental and Technical Problems of Test Room Spaces in Cultural Buildings

Dušan Katunský, Jana Katunská, Lenka Kormaníková, Iveta Bullová, Richard Germánus

Abstract — Aim of the article is a description and characteristics of typological, structural and acoustic requirements of test room spaces for presenting rock and pop music. It includes initial requirements for the spaces, the suitability of their combination with other functions, or spaces, as well as their integration into the environment. It presents a case study, points to the problems in the acoustic design of a music rehearsal space in a music centre building.

Index Terms — Cultural buildings, Indoor environment, Music centers, Music rehearsals, Test room, Room acoustics, Typology of buildings

1 Introduction

THIS contribution describes environmental, architectural, technical, structural etc requirements of the premises of cultural buildings, musical centers, in particular test rooms for music (rehearsals).

Mankind has always been interested in music. From the prehistoric times when the music was represented by beating on something with a hammer, through a composition of similar rhythms together, to today's music, consisting of a number of harmonies. Today, there are many music genres and thus a variability of music bands. This expansion requires the construction of buildings adequate for this purpose. The focus of designers is moved from classical theaters and opera buildings to the buildings characteristic for modern music, providing a space for rehearsing and community meetings of professionals, amateurs as well as music fans.

2 State of Art

2.1 Literature Review

There is not much research done on the problematics of the acoustics of music rehearsal rooms. A design of such space fulfilling all acoustic requirements is a complex task. The requirements for soundproofing of the interior walls have to be met and, together with the right value of the reverberation time. Rehearsal spaces have their special characteristics for the typology of the space (Neufert 2000), requirements for the building structures (Neumann 2005) and for the room acoustics (Kuttruff 2009).

Music rehearsals for young music bands or soloists are usually small spaces. It is not just a feature of the past decades, young music bands are still failing to find a professional space for music rehearsing. They use old attics or garages, cellars or abandoned buildings. It is clear, that the conditions for music rehearsing should be improved (Brausch 2015). It is certainly difficult to produce music in the spaces that don't meet requirements for the physical interior environment (Lopušniak 2006) and the requirements for building structures (Jablonska 2015), (Katunský 2013). It influences the subjective perception of the space for rehearsing (Sotiropoulou 2011).

Spaces for music rehearsing should be a part of cultural centre buildings in the inner city, even in its historical centre (Perez 2013) they should follow the rules for building placement into the urban context (Titley 2013, Yehia 2013). If the acoustical properties of building envelopes are not met, there is a noise pollution which not only affects the old and sick people (Gaines 2013) but also bothers the neighbors and passers-by.

To obviate these problems, a necessary attention has to be paid already during the design of music rehearsal spaces. Orlowski is one of the authors researching this field (Orlowski 2014). There are many authors engaged in the problematics of the reverberation time in cultural buildings (Aretz 2009), (Nijs 2011), (Adelman-Larsen 2010, 2011), (Van Dorp Schuitman 2013), (Beranek 2014), (Kato 2015) and others.

2.2 Examples of Cultural Buildings

Buildings and spaces that are not primarily intended for the purpose of music rehearsing are often used as alternative music rehearsals. Such spaces are usually not suitable, as the important requirements are not met. The main problems are the environmental humidity, an inconvenient location and improper constructions that do not meet the criteria of sound insulation.

The finances needed for the lease can also be an issue. This area, therefore, calls for more knowledge and a deeper exploration and becomes more and more relevant. A good strategy is a reuse of existing buildings, such as outworn cultural houses, industrial buildings, etc. Choosing a building suitable for a music centre, sometimes including rehearsal spaces and a method of rehabilitation and reconstruction depends on the position and the desired use. There are many good examples in the world; among all of them, Arena Wien is an interesting representative worth mentioning.

It is located in the Austrian capital Vienna, in a former industrial complex. It is the largest alternative cultural and musi-

- *Prof. Ing. Dušan Katunský, CSc. Professor, Technical University of Kosice, Slovakia, Faculty of Civil Engineering, Department of Architecture and Building Structures, dusan.katunsky@tuke.sk*
- *Ing. Jana Katunská, PhD., Iveta Bullová, PhD. Assistant Professor, Technical University of Kosice, Slovakia, Faculty of Civil Engineering, Department of Architecture and Building Structures, jana.katunska@tuke.sk, iveta.bullova@tuke.sk*
- *Ing. Arch. Lenka Kormaníková, PhD-Candidate. Technical University of Kosice, Institute of Architectural Engineering, lenka.kormanikova@tuke.sk*
- *Ing. Richard Germánus, Within Silence group, Slovakia, withinsilenceband@gmail.com*

International Journal of Scientific & Engineering Research, Volume 8, Issue 8, August-2017
ISSN 2229-5518

cal centre of the country. The Arena complex consists of four spaces - a large hall with a capacity of 1,000 people, an open-air stage for 3,000 visitors, a small hall for about 240 and Drei Raum for 160 people. The industrial charm of the past is still present in the walls of the building. The old brick walls are decorated with graffiti, while modern technical equipment guarantees a unique concert experience in a subcultural environment.

In Slovakia, the history of such spaces is relatively short and they can hardly compete with the size of Vienna arena. However, we have managed to create a few music sites, or centers that breathe with an alternative atmosphere.

Fig.1. YMCA Building in Bratislava, Slovakia
Source: https://budovaymca.wordpress.com/2013/03/06/dielo-architekta-aloisa-balana-v-bratislave/.

In Bratislava, there is a cultural centre called YMCA with a deep and interesting history (Fig. 1). The YMCA building (Young Men's Christian Association - Project architect Alois Balan) serves as a multifunctional cultural and public centre with a focus on diverse groups of young people. Among other things, it contains the biggest music club in Bratislava, a non-commercial cultural centre, a small alternative club, a theater, a bunch of public associations and initiatives have their headquarters here, there are music rehearsal spaces, small clubs, and several cafes. Two floors of the main building serve as hotel suites.

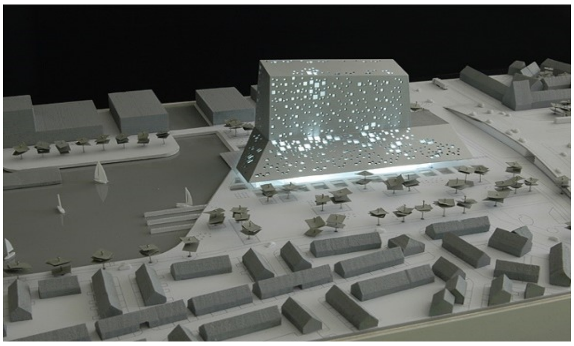

Fig.2. Centre for Creators of Music, Amsterdam
Source: http://www.sebastiaanjansen.nl/portfolio/centrum-voor-muziekmakers-amsterdam/.

A breakthrough project in this area is the project of the Dutch architect Sabastian Jansen - Centre for creators of music ("Centrum voor muziekmakers Amsterdam"), containing rehearsal spaces and studios of various types and sizes. In 2010 the project was nominated for the Archiprix (Fig. 2).

In Košice (Slovakia), there are two places serving this purpose. Music House building located in the city district Barca offers ten rehearsal spaces. The load-bearing structure of the building is made of steel with the self-supporting building envelope. It's a renovated old building that formerly served as a building with changing rooms. Another building that also offers ten rehearsal spaces is located on Priemyselná Street. It is a brick building. Both buildings have their security systems and are located in residential areas, which is a plus. However, a big negative is a poor technical condition of buildings and poor room acoustics. Therefore, it is the tenants who have to make an additional acoustic insulation.

Until it was closed in 2012, a building called "Cvernovka" in the city centre of Bratislava was used as an affordable music rehearsal space where the bands could make noise 24/7 without disturbing any neighbors. There is another place in Bratislava called Bunker Music House, with renovated music rehearsal spaces for bands. The building consists of two rooms with perfect acoustics, separated from each other by a one-meter thick wall and two soundproof doors.

3 Requirements for cultural buildings

A music centre is a complex of different functions including gathering spaces, music rehearsal spaces, and other associated functions. The most important are the typology requirements for two main functions – gathering spaces and rehearsal spaces.

Requirements for the buildings, gathering a bigger amount of people are described in the Decree of the Ministry of Environment of the Slovak Republic 532/2002 Z. z. specifically, the third part – Specific requirements for some types of buildings, Section 54 – Buildings for gathering more people. A building for gathering more people is a building with at least one compartment designed to gather at least 200 people in which an area for one person is less than 4 square meters (Directive 2002).

3.1 Basic Requirements

Music rehearsal spaces should meet the following requirements:

- must be adequately and appropriately soundproofed to create a comfortable environment for music playing and to eliminate noise,
- air exchange and ventilation is required,
- ensure the required humidity of the environment (excessive humidity damages musical instruments or music equipment, it may cause condensation in the electrical circuit),
- ensure the required indoor air temperature θi = 20-22 ° C in the winter, or keep a minimum necessary temperature (sudden changes in temperature have fatal effects on musical instruments),
- musical instruments shouldn't be placed near the heating elements (consequences are: an undesirable deformation of wooden parts, consequential damage, and destruction of a musical instrument,

International Journal of Scientific & Engineering Research, Volume 8, Issue 8, August-2017
ISSN 2229-5518

instruments can also become out of tune, e.g. drums, guitars, etc.),

- ensure the requirements of thermal comfort in the summer,
- suitable urban design (location of the building for music rehearsing in a non-residential zone, or its edge or interface, with an emphasis on solving acoustic barriers),
- Unlimited access (24/7) to the rehearsing area.

There are two types of rehearsal spaces in terms of function:

Shared rehearsal space – is fully equipped and sound-proofed, the rental period is limited. Music groups use common equipment and instruments.

Non-shared rehearsal space – a music group rents a rehearsal room that is not equipped and uses own instruments and equipment. The room must be soundproofed.

Typologically, rehearsal spaces can be designed as individual rooms or as a part of a bigger complex. A complex has to be secured against a burglary and robbery. In Slovakia, such spaces are in their beginnings and their equipment is minimal. The current number of properly equipped spaces is still insufficient.

3.2 Typology

From the typological point of view, it is crucial to find a connection between a planned music centre building and the existing buildings for culture and public entertainment – social and multipurpose buildings. A contemporary building complex for music is a modern alternative to the former cultural and public entertainment buildings. For cultural houses and multipurpose buildings that were used mainly for public entertainment (formerly known as houses of culture), a settlement survey was carried out and was used to create elaborating programs for these institutions. The main goal of the survey was to obtain information to develop optimal construction programs for the different size categories of the institutions. It was important that an architect was considering the local conditions (village, city) and the immediate surroundings of the proposed building (amphitheater, a summer reading room, terraces, lakes, statues, meetings, etc.) (Neumann 2005).

A music complex, which consists of a music rehearsal space, concert halls, and other associated functions, also requires a survey that will determine the capacity and suitability of the functions and associated functions. An example of the typology is shown in the Figure 3. The building's surroundings have to be designed depending on the use of the building. When selecting a site of the planned cultural centre building, vast areas are the most suitable, as there is a possibility to organize summer "Open Air" festivals and other events. It is suitable to have an area around the building for tree planting and creation of so-called sound barrier, to eliminate the distribution of noise. Entrance areas in the music complex buildings are usually used as promotional spaces or sales rooms. During the performances, bands have their promotional items (clothes, CD media, fashion accessories), which are advertised and sold here.

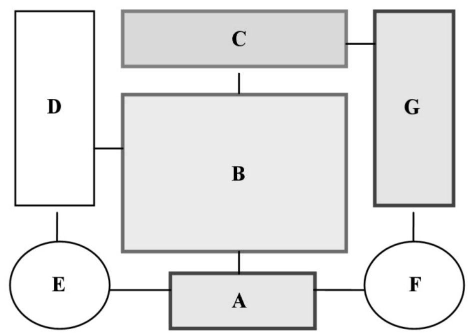

Fig.3. Typology of a Music Centre Building
(A) Entrance, (B) Music hall, (C) Complex of the stage, (D) Technical background, (E) Library (space for rent), (F) Free time activities (space for rent: workshops, training,...), (G) Club (music rehearsal spaces)

The performance hall is a focal point and thus the most important part of the building's design solution. It is an advantage when the hall is designed for a multi-purpose use. In the design process, this part of the project requires a special attention. Good architectural and functional solutions must have reasonable construction costs, and economic results, while aiming for an impressive interior design. The floor is not elevated, suitable for standing with a possibility for mobile seating. The more sophisticated the division of the space, the less important is the question of the form of the hall in terms of acoustics. Acoustically inadequate forms can be also solved by the right division of the surfaces. The most suitable are the modern acoustic cladding structures designed into desired surface shapes. Uneven shapes of the surfaces are particularly important. These surfaces act as sound diffusers.

The reverberation time for multi-purpose halls depends on the function of the given space; however, a diffuse sound field is an important requirement.

Halls are normally designed as rectangular, with a horizontal ceiling. The ratio of the height, length, and width of such space can differ, but should be an integer multiple of the other two dimensions. No ratio, not even the ratio of the golden section, however, guarantees a perfect sound solution. There is a clear need to avoid such shape that forces the sound to travel in one direction. It is also necessary to create a sound insulation from the exterior noise and the noise from neighboring areas. The stage complex is an important and separate typological group. This includes the stage with accessories and ancillary spaces, changing rooms and sanitary facilities. The production on the stage is trying to achieve certain visual and audible effects on the audience. Therefore, these areas have different prerequisites than the other spaces. It is necessary that there is a structure to hang the lights and sound equipment above the stage.

A music rehearsal space is a space used for rehearsing, coaching and making music. Acoustic requirements for cultural music spaces are already known, however, a typology of music rehearsal spaces has not yet been explored.

International Journal of Scientific & Engineering Research, Volume 8, Issue 8, August-2017
ISSN 2229-5518

It is important to know the functions of a music rehearsal typology block within a cultural building. It consists of separate rehearsal rooms which, according to the demand, can be used as shared and unshared. A part of such rehearsal block must contain sanitary facilities and stairs if they are needed as a link between the separate rehearsal spaces. In terms of typology, it is convenient when there are also relaxation areas (lounges, balconies, etc.) close to the rehearsal spaces. For safety reasons, this part of the building has to have a possibility to be locked. An access is allowed only to tenants or to front desk security guards. An alarm system linked directly to police and a security camera system in the cultural centre buildings are a necessity.

4 Case Study

4.1 Architectural Design

Figure 4 shows an architectural model of the proposed music rehearsal space. From the diagram shown in Figure 5 it can be seen that there can be both, exterior and interior spaces surrounding music rehearsal spaces. A hall as an entrance to the rehearsal spaces creates, in addition to the function of storage, a closed room to prevent the transfer of noise within the interior in the horizontal direction. A part of interior spaces are sanitary facilities, relax zones and stairways.

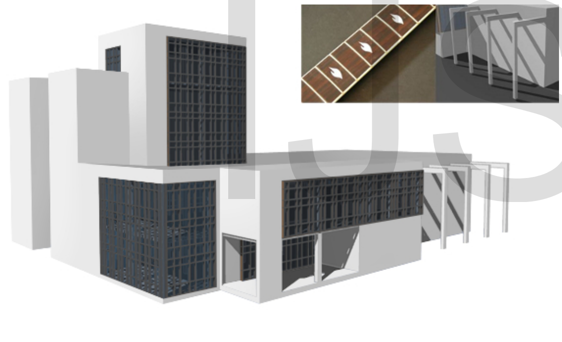

Fig.4. Architectural Model of the Case Study Music Building a Guitar Neck as an Inspiration

The interior of the designed concert hall is shown in Figure 6. All structures (wall composition, materials) must be designed to maximize the elimination of sound propagation in the environment, in the horizontal (interior, exterior), as well as in the vertical direction (ceiling, floor). It is also necessary to aim for excellent acoustic conditions (using acoustic absorbing walls, to absorb the frequencies to the greatest extent possible). This is a subject of spatial acoustics.

Besides layout-design solutions and acoustic solutions for rehearsal spaces, the spatial arrangement of the room is also very important. It affects the performance comfort in terms of acoustics (inaudible frequencies). It is important that the room is big enough and there is enough space for playing an instrument.

The size of the designed rehearsal space is 5.2 * 5.3 m which is a surface area of 28 square meters. The height of the space is 3.2 m. The layout is shown in Figure 7.

The rehearsal space is designed optimally for six musicians with an area of 4.6 square meters per person, allowing a freedom of movement in space, a communication between musicians while playing and a simulation of a concert stage and practice of choreography. In the case there is a higher number of band members, sometimes even ten (e.g. the style of rock music, folk metal) the possibility of movement while playing is slightly reduced, however, there is still an area of 2.8 square meters per person, which is sufficient for a comfortable music rehearsing.

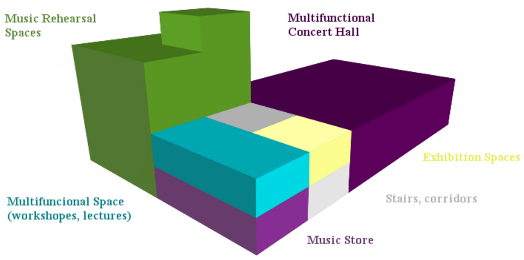

Fig.5. Typological Model of the Music Centre Building

5 Evaluation of Physical and Structural Conditions

5.1 Acoustics of Music Rehearsal Spaces

The subject of this paper is the solution of spatial and building acoustics of the model music rehearsal room within a music centre building. The calculation fully respects STN 73 0525 and STN 73 0527 valid for the design of spatial acoustics, as well as hygiene regulations for noise pollution. This acoustically treated room should serve as a music rehearsal space. If the building contains more rehearsal spaces, it is necessary to design a sound insulation (building acoustics) in order for the different sounds to not interfere with each other.

Addressing the acoustics of rehearsal spaces there is no bad or good acoustics of a space, the problem is whether the acoustic solution is suitable or not for the particular space and for the activities within it. The basic prerequisite for improving the acoustic conditions in a music rehearsal space is a common understanding and intention, whether the sound should be clean without echo, as in a recording studio or there is just a need to suppress unwanted high frequencies or a need for some complex solutions for the frequencies from bass to treble. As it is with other buildings or rooms, when designing a music rehearsal rooms, two major problem areas have to be solved: spatial acoustics and acoustic engineering. Each space has to be approached individually.

5.2 Room Acoustics of Music Rehearsal Spaces

Room acoustics in the design of a rehearsal space is a very important field of acoustics. The oldest and most famous assessed value of room acoustics is the reverberation time. It is measured in seconds and is defined as the time in which after switching off the sound source in a room, sound pressure decreases by 60 dB. The reduction of sound energy is described as absorption of sound. The so-called coefficient of sound absorp-

International Journal of Scientific & Engineering Research, Volume 8, Issue 8, August-2017
ISSN 2229-5518

tion (sound absorption factor) defines a ratio of reflecting and absorbing sound energy. The value of 0 corresponds to the full-scale reflection - while the value of 1 corresponds to the complete absorption. If the degree of absorption of sound is multiplied by 100, we obtain the percentage of absorption of sound (e.g. $\alpha = 0.65 * 100\% = 65\%$ of sound absorption, reflection is then 35%).

Fig.6. Interior View of the Designed Music (Concert) Hall

To create the desired acoustic environment of each space, usually special acoustic materials are placed in this space. Types of acoustic materials, their number, and distribution in the space so that the required frequency range meets the standards or the proposed set target parameters of room acoustics are determined by the calculation. An important role is played by the very geometry of the space and knowledge of acoustic properties of building materials out of which this space is made, the distribution of sound sources, the use of an electro-acoustic sound system and so on. In order to use the room for understanding the spoken language and, at the same time for performing music, a compromise between the spatial and sound solution is needed.

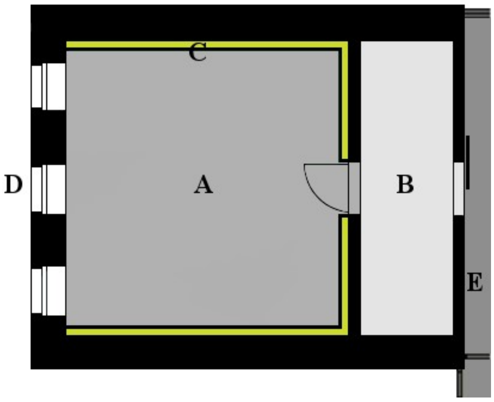

Fig.7. Scheme of the Designed Music Rehearsal Space (A) Rehearsal room, (B) Entrance hall, (C) Air gap in the sandwich wall, (D) Exterior, (E) Interior

The most important factors affecting the spatial-acoustic characteristics of a room are:

- the position of the room within the building, the shape and size of the space (primary structure),
- properties of surfaces bounding the space (secondary structure), the design and spatial distribution of sound absorbing and reflecting surfaces,
- Equipment of the room such as musical instruments (secondary structure).

Although each type of space has specific requirements, there are basic parameters of room acoustics of rehearsal spaces:

- optimal value and frequency of reverberation time,
- minimal and optimal volume of the space, - optimal shape of the space,
- maximal capacity of the space,
- Maximal disturbing noise level [dB].

According to DIN 18041 "Hörsamkeit in Räumen - Hörsamkeit in kleinen bis mittelgroßen Räumen", a music rehearsal space is defined as a relevant room with the volume V up to 5000 m³, characterized as a group "A" spaces with audibility in medium and long distances. There are specific requirements in terms of acoustics set for this category, contrary of the group "B" spaces (audibility in short distances - e.g. offices, reading rooms, etc.) for which there are only recommendations.

Factors Influencing the Echo Duration within an Enclosed Space

The greater is the level of absorption surface of an enclosure, the shorter is the reverberation time in the space.

The dependence of the duration of the reverberation, the volume of the enclosed space and the surface absorption and intermediate absorption capacity is determined by the following relationship STN 730525, STN 730527. Calculation of the reverberation time is according to the formula:

When $\alpha_S \geq 0.2$

$$T = 0.164 \frac{V}{\alpha_S + 4mV} \tag{1}$$

When $0.8 \geq \alpha_S \geq 0.2$

$$T = 0.164 \frac{V}{-S\ln(1-\alpha) + 4mV} \tag{2}$$

When $\alpha_S \geq 0.8$

$$T = 0.164 \frac{V}{-\sum_{i=1}^{n} S_i \ln(1-\alpha_i) + 4mV} \tag{3}$$

For enclosed spaces with the volume greater than 2000 m³ it is necessary to consider the absorption of the air for the frequencies above 2000 Hz. This absorption is defined by the equation:

$$A = 4mV \tag{4}$$

Sound absorption of different materials is characterized by their sound absorption coefficient α (5).

$$\alpha = \frac{absorbed\ sound\ energy}{incident\ sound\ energy} \tag{5}$$

International Journal of Scientific & Engineering Research, Volume 8, Issue 8, August-2017
ISSN 2229-5518

The coefficient α is expressed as a number between 0 and 1. An instructive comparison is e.g. the absorption of the considered surface and the absorption of an opening of the same size (e.g. an open window). The sound absorption coefficient of an open window equals 1. The coefficient of a completely rigid and inflexible substance with a perfectly smooth surface is close to 0. The values of the sound absorption coefficient of commonly used substances lie

6 CALCULATIONS

6.1 Acoustic properties of the space in this Case Study

In the proposed model music rehearsal space, the following composition of structures, acoustic insulation, acoustic wall and ceiling cladding is used in the calculations (Table 1):

TABLE 1
SELECTED MATERIAL FOR CLADDING

Structure Construction	Material
1 Cladding	External wall made of ceramic blocks Porotherm Profi 44, 440 mm thick, with an index of sound insulation Rw = 48 dB. Insulation from the exterior side using a contact insulation system - rock mineral wool NOBASIL FKD, 150 mm thick. Acoustic insulation from the interior side using the acoustic reinforced plasterboard Rigips Gyptone Acoustic.
2 Internal partitions	Internal partition wall made of ceramic blocks Porotherm 20 Aku Profi, 200 mm thick, Rw = 54 dB. Insulation from the interior side using acoustic reinforced plasterboard Rigips Gyptone Acoustic.
3 Ceiling structure	The load-bearing ceiling structure is a 150 mm thick, reinforced concrete slab. The room has a suspended soundproof ceiling Gyptone soffit Rigips; it is lowered by 800 mm from the concrete ceiling and creates an acoustic cavity barrier. The second layer of the suspended ceiling is made out of Rigips Gyptone placed at a distance of 1050 mm from the concrete ceiling and is without a sound insulation. At this level there are capillary mats used for cooling and heating of the room. Clear height of the room is 3200 mm. For the acoustic cladding of the ceiling, Gyptone Big Quattro 41 panels with regular perforations are proposed. The front side of the board is without a surface treatment. The back side is laminated with acoustically active non-woven fabric in white color. The perforation of the board can be square, hexagonal or linear. The boards are used for acoustic ceilings and offset walls with high sound absorption.
4 Floors	The floor structure consists of insulation against impact sound NOBASIL PVT, 40 mm thick. The top layer is wooden. Layer of a large bearing plate. Between the bearing plate and the PVT is a flexible attenuation foil.
5 Windows	Window system Inoutic Eforte with hexacameral plastic profiles. Heat transfer coefficient is Uf = 0.95 W / (m2.K) and glazing thickness up to 56 mm. Insulating triple glazing with Ug = 0.6 W / (m2.K) Ug = 0.6 W / (m2.K), Rw = 55 dB.
6 Doors	Lindner soundproof wooden doors with sound insulation up to 50 dB in wooden frame. From the acoustic and aesthetic point of view, there is an additional product installed called Alfacoustic.
7 Carpet	Carpet Roland TDM 1 put under drums with thicker fibers and high sound absorption. They are being produced exactly for this purpose. If necessary, the carpet can be placed also on the other surfaces of the rehearsal space or cover the whole room.
8 Offset walls	Sound barrier (air cavity barrier) is created all around the rehearsal space up to the ceiling, 150 – 180 mm thick. The air cavity barrier is created using offset walls Rigips with the Rigips Gyptone boards as a finish.
9, Internal acoustics Cladding	To the height of 1 meter from the floor Alfacoustic V profile 7 cm is used to capture frequencies of medium and high bands. The size of one board is 50*50 cm.
10, Internal acoustics Cladding	In the height from 1 m to 2 m from the floor Alfacoustic pins 7 cm are used. They are used to capture frequencies of medium and high bands
11, Internal acoustics Cladding	For the room corners from the floor to the ceiling so-called bass traps for catching bass frequencies are recommended.

Figure 8 shows the structural and material solution of the model rehearsal space. To ensure comprehensive acoustic properties of the rehearsal space, acoustic cladding materials from Alfacoustic are used for the absorption of bass, mid and high frequencies. These products are made out of acoustic foam with an open cell structure.

The principle of acoustic polyurethane foam lies in small air bubbles, in which the sound is dispersed and thus reduced. The acoustic foam is thus directly intended to eliminate undesired sound frequencies. For example 4-centimeters thick pyramids absorb around 45% of the incoming sound and the largest 10-centimeters thick up to 65% of mid and higher frequencies.

Up to the height of 1 meter from the floor V-profile cladding of 7 cm is used to capture frequencies of medium and high bands. The cladding is 2 cm thick at the base with 5 cm thick profile and arranged on 50*50 cm boards.

In the height from 1 m to 2 m from the floor are used pins 7 cm. They are used to absorb the frequencies of medium and high bands. In the remaining space between the upper edge of

International Journal of Scientific & Engineering Research, Volume 8, Issue 8, August-2017
ISSN 2229-5518

the cladding and the ceiling, Rigips Gyptone perforated boards are used.

On the corners of the room from the floor to the ceiling, so-called bass traps are placed to absorb the bass frequencies.

All these products have self-extinguishing properties. It is recommended to use the adhesive bonding by Den Braven called MULTI Kleber.

For the harder music styles, it is recommended to use also professional Plexiglas by Alfacoustic. They serve as protecting screens and are tuned to every detail. Placed in front of the drums, they prevent the sound distribution from the drums, especially the high-frequency sounds of cymbals. It is a very convenient solution for avoiding the sound of drums to be caught by the microphone of the singer.

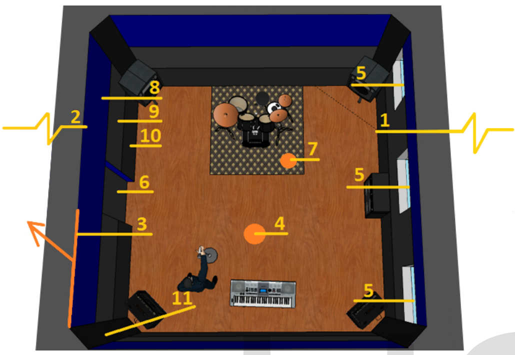

Fig.8. Structural and Material Solution
(1) Exterior wall, (2) Interior wall, (3) Ceiling structure (4) Floor, (5) Windows, (6) Doors, (7) Carpet, (8) Sandwich wall

Solution of the calculations of the room acoustics can be seen in Fig. 9 and Fig.10.

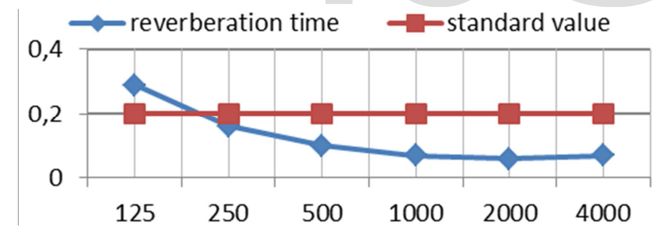

Fig.9. Reverberation time for different frequency

7 Discussion

7.1 Results

The results correspond with the expected reverberation time, which is a characteristic value for determining the acoustic quality of the space. The desired absorption can be achieved by the use of the (chosen by the authors) acoustical tiles. The proposed solution is overstated in terms of normative requirements because the music rehearsal space could also be used as a "home recording studio," where acoustic requirements are higher.

Addressing the room acoustics, the following is achieved:

- pleasant, relaxed atmosphere of the space,
- high speech intelligibility,
- balanced sound reproduction at low and high volumes,
- soothing sound image and fine details in sound resolution,
- bass contour in reproduction, without resonance,
- the natural color of sound without hardness,
- stabilization of the surround sound display, balanced stereo sound

7.2 Requirements of Building Acoustics for Music Centers

Building acoustics is an area of acoustics, examining the effects of the structural elements in the sound propagation between the different parts of the building. The sound has the property of finding the easiest transmission path from A to B. It is mostly a path of the least resistance. Therefore, while solving the building acoustics of music rehearsal spaces, an overall situation has to be taken into account. Otherwise, the success of the acoustic design optimization is exposed to some risk.

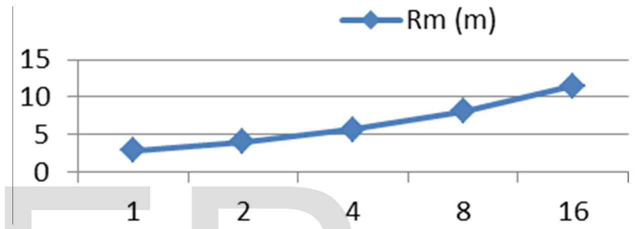

Fig.10. Reverberation distance Rm (m) for different directivity factor

Addressing the sound insulation properties of building structures and elements there are three most common manifestations of the sound propagation:

Airborne sound insulation: a sound that propagates through the air - the sound energy from a source in the broadcast room propagates through air, impinges on the structure and from that is radiated into the receiving room.

Impact sound insulation: a sound that occurs once - sound power is generated by the mechanical impact on the building's structure, usually the ceiling construction and floor.

Structural sound propagates through building construction, where the sound source doesn't have to be close.

In building acoustics, it is important to know the difference between the sound absorption and the airborne sound insulation. These parameters are often confused and the result is dissatisfaction with the proposed solution.

Sound absorption of material means that the material has the ability to prevent the sound from bouncing back while the airborne sound insulation of material means the ability to prevent the distribution of sound through the material.

Both of these properties are primarily used to reduce noise. The sound-absorbing materials applied in the space, reduce noise (room acoustics) and soundproof materials isolate the source of the noise. Each situation is specific and influences the way how to proceed and which method to choose when designing a music rehearsal space.

When evaluating the sound-insulating properties of struc-

International Journal of Scientific & Engineering Research, Volume 8, Issue 8, August-2017
ISSN 2229-5518

tures first, the highest acoustic quality of the structure must be ensured. It is represented by the airborne sound insulation, thus the ability of a structure to prevent sound transmission from one space to another. In the design phase, the structure has to be evaluated, so that the chosen system complies with the requirements for airborne sound.

Airborne sound is characterized by the level of airborne sound insulation R, which is measured in decibels:

Airborne sound insulation - Laboratory R (dB) (Sound reduction index) indicated in 1/3 or 1/1 octave band from 100 Hz to 3150 Hz (i.e. Soundproof area),

Structural airborne sound insulation - R' (dB) (Apparent sound reduction index) indicated in 1/3 or 1/1 octave band from 100 Hz to 3150 Hz (i.e. Soundproof area).

Determining parameters for evaluation of sound insulation properties are defined by:

The sound insulation index Rw (dB) (Weighted sound reduction index) - a single value in decibels intended for evaluation of airborne sound insulation of the building structure according to the results of measurements in the laboratory,

Building sound insulation index R'w (dB) (Weighted apparent sound reduction index) - a single value in decibels intended for evaluation of airborne sound insulation of the building structure according to the results of measurements in the building,

Index of standardized sound insulation for a complicated floor plan or building envelope with balconies and loggias - DnTw (dB) (Weighted standardized level difference),

Index of normalized impact noise level - Ln,w (dB) (Weighted normalized impact sound pressure level).

In the case of measurements in a particular building (room) the measured value of building sound insulation index is compared with the minimum requirements set out in the standard STN 73 0532: 2013-01. 8

These are the values measured on site, and thus reflect the negative impact of lateral sound propagation paths. Assessment under that standard applies to the ambient sound reduction, but must first be corrected by the index correction for the lateral sound propagation paths:

R'w = Rw - k (dB)

For partition structures surrounded by massive elements k = 2 dB, for hard partition structures in skeleton construction k = 2–5 dB, for light partition structures in skeleton construction k = 4–8 dB, for single homogeneous structure k = 2–3 dB, for lightweight prefabricated walls k = 5–7 dB.

Floor structures are tested for the air, but especially for the step sound insulation characterized by normalized impact noise level Ln (dB) and index of normalized impact noise level Ln,w (dB). Ceiling structures, mostly meet the criteria of airborne sound insulation, which stems from the fact that the airborne sound insulation depends mainly on the mass per unit area (kg / m^2).

In practice, there are considerable differences between the measured values and the construction of airborne sound insulation values measured in a laboratory, reaching 3–10 dB, and in some cases more. The cause of negative subjective assessment of the structure is in many cases neglecting the impact of lateral sound propagation paths, which was subsequently confirmed many times by acoustic measurements.

In design practice, there are number of simple or moderately complex methods that can determine the correction for the lateral sound transmission paths and propose the partition structures in a way, that after the installation they meet the requirements of standard EN 73 0532: 2013-01. A more detailed calculation method is specified by the standard STN EN 12354-1: Building acoustics - Estimation of acoustic performance of buildings from the performance of elements - Part 1: Airborne sound insulation between rooms.

7.3 Proposals to Improve the Acoustic Conditions of Music Rehearsal Spaces

Proposed methods for improving the acoustic conditions in the rehearsal space depend on the input requirements:

The complete loss of all reflections, an acoustically "closed" rehearsal room - non-profiled sound-insulating panels for cladding.

Acoustically designed (enhanced) rehearsal room, taking into account the price (price / performance ratio) - a combination of acoustic foam profiles (ripples, sinuses, pins, V - profiles).

A complex acoustic solution of rehearsal space (absorbed bass, mid and high frequencies) - a combination of acoustic foam profiles (ripples, sinuses, pins, V - profiles) in corners the use of the bass trap.

Music rehearsal spaces within the building can be placed above each other and side by side. It is, therefore, important to eliminate the interference caused by the penetration of sound through the structures. To achieve an acoustic comfort it is necessary to ensure that the interfering noise is on the sound intensity level LA = 35 dB. This value may be achieved as follows:

The level of airborne sound insulation of the partition walls is at least at the level of 56 dB; proposed is the construction of the sandwich assembly.

Ceiling grid, double insulated ceiling.

An entrance door into the rehearsal space need to be soundproof, sound insulation index Rw = 50 dB; acoustic foam applied to the doors; entry into the rehearsal room is doubled; an additional space is created, called Silent chamber.

Windows with soundproof index Rw = 47 dB.

During the installation of acoustic tiles, it is necessary to follow quality principles for assembly according to the manufacturer in order to prevent acoustic bridges.

8 Conclusion

Existing buildings of music centers confirm their importance and need. Spaces that can be found here - concert hall and rehearsal rooms, along with music shops, exhibition spaces, and living room - offer a modern cultural space with a great potential. The architectural design of a music center building should correspond with the surrounding buildings and activate the site intended for its construction. There must be also an architectural and urban connection to existing buildings and their equipment.

International Journal of Scientific & Engineering Research, Volume 8, Issue 8, August-2017
ISSN 2229-5518

The layout of music center buildings, music studios as well as their structural design must meet the essential requirements of the relevant regulations and standards. Music centers must be designed in accordance with the needed functions and with the special requirements of people who will use them (bands, singers, audience, etc.). The operation of these buildings must not interfere with the surroundings, with neighboring buildings, facilities, on the contrary, it should be an architectural and functional asset.

We are meeting with the action of the sound everywhere and our well-being requires that specific conditions are met depending on the intended use. This means that the duration of the sound and its aftermath should have the right length for us to enjoy it.

The presented study of the acoustics of a model rehearsal room determines the scope of acoustic adjustments that are necessary to ensure the room and building acoustics of this example (test) model. The necessary building modifications influence positively the productivity of those who use the space (bands, singers). Currently, there is a range of materials on the market, using which not only a great structural design and acoustics can be achieved, but, at the same time they meet relatively high aesthetic criteria. Designers and investors should pay adequate attention to the field of acoustics. By less demanding acoustic space it is sufficient to consult the experts. In the case of more complex spaces, including the music rehearsals, it is necessary to carry out acoustic design calculations (acoustic project).

Acknowledgment

The authors wish to thank for financial support of the research projects VEGA 1/0835/14 of Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences.

References

[1] N. W. Adelman-Larsen, E. R. Thompson, and A. Ch. Gade. 2010. "Suitable Reverberation Times for Halls for Rock and Pop Music." The Journal of the Acoustical Society of America 127 (1): 247–255.

[2] N. W. Adelman-Larsen, E. R. Thompson, and J. J. Dammerud. 2011. "On a Variable Broadband Absorption Product and Acceptable Tolerances of Reverberation Times in Halls for Amplified Music." Proceedings of Meetings on Acoustics 14 (1): 1–8. doi: 10.1121/1.3670733.

[3] M. Aretz and R. Orlowski. 2009. "Sound Strength and Reverberation Time in Small Concert Halls." Applied Acoustics 70 (8): 1099–1110.

[4] L. L. Beranek and N. Nishihara. 2014. "Mean-free-paths in Concert and Chamber Music Halls and the Correct Method for Calibrating Dodecahedral Sound Sources." The Journal of the Acoustical Society of America 135 (1): 223–230.

[5] C. Brausch and D. Katunský. 2015. "Changing Social Structure in Europe, Calls for Tailor-Made, Barrier-Free Living and Interior Design." Selected Scientific Papers - Journal of Civil Engineering 10 (1): 73–85.

[6] R. Germánus, 2014. Music Centre Building, Master Thesis. Košice: Technical University of Košice.

[7] J. Jablonska, E. Trocka-Leszczynska and R. Tarczewski. 2015. "Sound and Architecture – Mutual Influence." Energy Procedia 78: 31–36.

[8] K. Kalinová and J. Vaverka. 2009. "Resonant Effect of Nanofibrous Sound Absorptive Material in Room Acoustics." Building Research Journal 57 (1): 55–76.

[9] K.. Kato, K. Ueno and K. Kawai. 2015. "Effect of Room Acoustics on Musicians' Performance. Part II: Audio Analysis of the Variations in Performed Sound Signals." Acta Acustica united with Acustica 101 (4): 743–759.

[10] D. Katunský, M. Nemec, and M. Kamenský. 2013. "Airtightness of Buildings in Slovakia." Advanced Materials Research 649: 3–6.

[11] D. Katunský, J. Katunská and R. Germánus. 2016. "Protecting the Internal Environment of Music Rehearsal." Proceedings of the 16th International Multidisciplinary Scientific GeoConference 2016: 635–642.

[12] H. Kuttruff, 2009. Room Acoustics, Fifth Edition. Florida: CRC Press.

[13] Lopušniak, Martin, and Dušan Katunský. 2006. "Interaction of Selected Parameters within Design of Suitable Working Environment." Healthy Buildings: 147–152.

[14] L. Nijs and M. Rychtáriková. 2011. "Calculating the Optimum Reverberation Time and Absorption Coefficient for Good Speech Intelligibility in Classroom Designs Using U50." Acta Acustica united with Acustica 97 (1): 93–102.

[15] E. Neufert, 2000. Design of Buildings 2. Praha: Consultivenst International.

[16] D. Neumann, et al. 2005. Building Constructions I. Bratislava: Jaga Group.

[17] D. Neumann, et al. 2005. Building Constructions II. Bratislava: Jaga Group.

[18] R. Orlowski, 2014. "Sound Strength and Reverberation Time in Performance and Rehearsal Spaces for Music." Proceedings of the 2014 Forum Acusticum.

[19] A.G. Sotiropoulou, A. Savvopoulou, G. Karagiannis and G. Tzouvadakis. 2011. "Subjective Evaluation of Acoustics in Jazz Clubs." Acoustics Bulletin 36: 24–31.

[20] J. Van Dorp Schuitman, D. De Vries and A. Lindau. 2013. "Deriving content-specific measures of room acoustic perception using a binaural, nonlinear auditory model." The Journal of the Acoustical Society of America 133: 1572–1585.

Standards

[21] STN EN 73 0532: Acoustics. Rating of sound insulation in buildings and of building elements. Requirements.

[22] STN 73 0525: Design of room acoustics. General principles.

[23] STN 73 0527: Design of room acoustics. Rooms for cultural and school purposes. Rooms for public purposes. Administrative rooms.

[24] DIN 18041 "Hörsamkeit in Räumen - Hörsamkeit in kleinen bis mittelgroßen Räumen"

Internet sources:

[25] http://www.asb.sk/stavebnictvo/konstrukcie-a-prvky/akusticke-podhlady-a-obklady-priestorova-akustika

[26] http://www.magips.sk/admin/data/docs/12_.pdf

[27] http://www.obifon.sk/web/predpisy/teoria/domkino-a-basy

[28] www.arena.co.at

[29] www.budovaymca.sk

[30] www.alfacoustic.sk

[31] www.tzb-info.cz

[32] www.ravago.sk

[33] www.sebastienjansen.nl