PROCEEDINGS of the
International Symposium on Room Acoustics

15 to 17 September 2019 in Amsterdam, Netherlands

Acoustic adaptation of performance and lecture spaces in historical buildings

Zlatka MADZHAROVA[1]; Aleksandar KIRECHEV[2]

[1] University of Architecture, Civil Engineering and Geodesy, Bulgaria

[2] Technical University, Bulgaria

ABSTRACT

Historical buildings are an architectural form of heritage, where unique aesthetic spaces can be adapted to host new functions. This is a case study of a national heritage building in Sofia, Bulgaria, originally built as a private house and atelier for a famous sculptor. The building is currently adapted as a cultural center with a theatrical performance hall, an exhibition/lecture hall and a small music hall. The spaces need acoustic corrections in order to provide adequate performance. Due to aesthetic and historical reasons sound-absorbing panels should be designed and imported in the space in an appropriate manner. Room acoustic simulation software is used to locate the most effective positions of sound-absorbing panels, to reduce reverberation time and improve speech intelligibility.

Keywords: Adaptation, Heritage buildings, Acoustical performance

1. INTRODUCTION

Historical buildings are often a subject of adaptation due to their unique aesthetic spaces, as well as architectural and community values. Hosting a new function can result in the need of acoustic corrections of the venue in order to provide adequate performance. Aiming to preserve the integrity of the building's original interior, sound absorbing panels must be implied in an appropriate manner. Room acoustic simulation software is used to identify the type of material and the most effective positioning of the acoustic correction according to the specific geometrical characteristics of the spaces.

In this case study a national heritage building in Sofia, Bulgaria, was selected, namely the Red House Centre for Culture and Debate "Andrey Nikolov". The spaces are adapted to a theatrical performance hall and a music hall, each having certain specifics in the interior such as roof glazing, enlarged windows or joined spaces. The walls in the music hall have smooth plaster finish, but the ones in the performance hall have absorbing panels fixed to the wall structure, following a renovation in 2004. For each hall, measurements were taken on acoustic characteristics as the reverberation time T_{60},C50 and C80. With the aid of the software, the most appropriate location of the unobtrusive acoustic treatment is found in order to adjust the reverberation time, preserving the aesthetic integrity of the historical building. The results of the measurements of the two venues on site and the relative acoustic corrections of the varying positions of the interventions are demonstrated.

2. BUILDING HISTORY

The Red House, shown on figures 1 and 2, was initially build in 1928 as an atelier and home for the Bulgarian sculptor Andrey Nikolov, located in the city center of Sofia, Bulgaria. In 1959 the house was donated to the Ministry of Culture for the purpose of running and performing public and cultural activities. Today the building is a cultural monument of national importance. The site underwent exterior and interior architectural interventions in 2004, when a project for "Reconstruction and adaptation of the house-museum Andrey Nikolov" was completed. Since then the cultural center has served as the first space for public debate and the first independent space for

[1] z_madzharova@outlook.com
[2] sakata6371@gmail.com

art, culture, social practices and psychodrama in Bulgaria.

Figure 1 – The Red House Cultural Center (entrance of the building)

Figure 2 – The Red House Cultural Center

3. ARCHITECTURAL ANALYSIS

The architecture of the building has a complex character as it had to include different spaces for the occupants' needs. It consists of one large and one small studio for the sculptor and living areas for his family. The mixed character of the rooms - residential and workshops – atelier/studios, determines the varied nature of the scale. The largest volume in the building (the Large studio) has a clear height of 7.37 m, a volume of 677.10 m^3 and a clean plan without a support, which makes it suitable for its new function - a hall for performances (debates). The next largest volume (the small workshop) has a clear height of 6.33 m and a volume of 270.50 m^3, which also corresponds to its new function as a temporary exposition hall. The public character of the adapted function implies the large scale of the premises. Halls 21 and 22 are unified as a rehearsal and a small concert hall. The scale is comparatively smaller in height, but has a larger spread area divided into a stage and an audience. The housing areas are adapted for administrative purposes, offices, sanitary and storage rooms. For the purpose of this case study the Large studio and the Small concert hall were examined.

The Large studio, figures 3 and 4, has a clear rectangular plan, large window openings providing natural light and illuminating the former working area. The space also has roof glazing over the bearing metal structure. The combined rehearsal room represents two connected rectangular volumes with floors and ceilings at different levels, respectively. All the walls are solid brick-built, plastered both in interior and exterior. During the adaptation in 2004 most of the original structures of the walls had been preserved. Only the Large studio breaks the original wall structure in an attempt to acoustically interfere with placing acoustic perforated panels on the walls for sound absorption. During the reconstruction, the original double-glazed window frames have been preserved, either with wooden or metal structure. There are curtains in front of the windows in the Large studio.

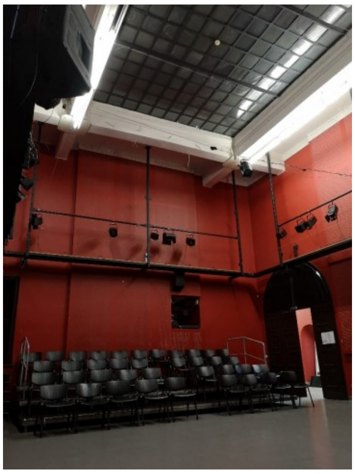

Figure 3 – The Large studio

4. ACOUSTIC MEASUREMENTS

For each of the two examined spaces the acoustic measurements were carried out using an omnidirectional spherical source fed with a SWEEP signal. The impulse responses were detected and analyzed for the specific use of the room. The sound source was placed in each room , corresponding to the performance position and the microphones measurements were in different points in the audience area at a typical ear height (1.2m) to obtain the average value of the received sound. The acoustic parameters were measured in according to BREEAM Standards.

For the Large studio and the Small concert hall the room dimensions are presented in table 1. Figure 4 shows the Large studio during acoustic measurement recording, with the sound source and the microphone. The measurements were taken in the morning during weekends in order to minimize the impact acoustic disturbance from the surrounding area. During the recordings the background noise varied around LeqA=40 dBA.

Table 1 – Room dimensions

Room	Volume, m^3	Average height, m	Base area, m^2
Large studio	677	7.37	91.86
Small concert hall /stage/	120	4.40	25.00
Small concert hall /audience/	130	3.20	36.68

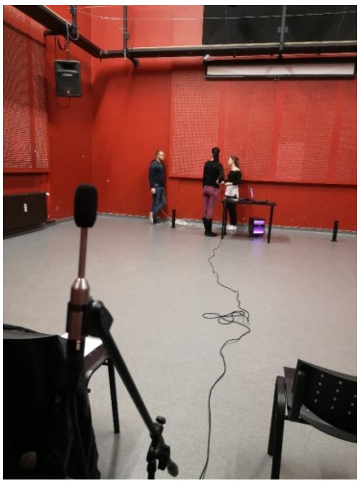

Figure 4 – The Large studio-measurements

5. VIRTUAL MODEL

CAD software was used to create a virtual model of the performance spaces, necessary for the acoustic simulation. Materials with absorption and scattering coefficients were assigned to each surface. The rooms virtual models were calibrated on the reverberation time measured values. We observed the effects of the insertion of absorbent materials in the spaces on reverberation time and speech understanding, according to the new hosted function of each one. For each room we have a different value of area of absorbent material placed on the vertical walls or inserted below the ceiling.

5.1 Large studio

The acoustic characteristics of the Large studio had to comply with the new function of a theatrical performance space. Table 2 shows the BREEAM standards for reverberation time in performance halls for speech and music according to volume. For speech intelligibility we analyzed the relative noise indicators: C50 and the articulation loss of consonants %Alcons assimilated to STI.

Table 2 – BREEAM standards for reverberation time, T, at 500 Hz in unoccupied rooms

Room volume, m³	Reverberation time T, s	
	speech	music
200	0.6	1.2
500	0.7	1.3
1000	0.9	1.5

The average measured reverberation time T_{60} for the Large studio is 1.15s and the insertion of the absorbent materials decreases it to approximately 0.8s, corresponding to the volume of the space and the new function. Figure 5 shows the values of T_{60} measured on site, the calculated T_{60} from the calibrated virtual model, the calculated T_{60} value after inserting a surface of a transparent microperforated folio as an acoustic correction on the vertical walls, or when the same equivalent area of the material is placed below the ceiling. The type of the absorbent material was chosen for its acoustic characteristics and impact in space as a transparent and unobtrusive object, revealing the original interior of the architectural monument.

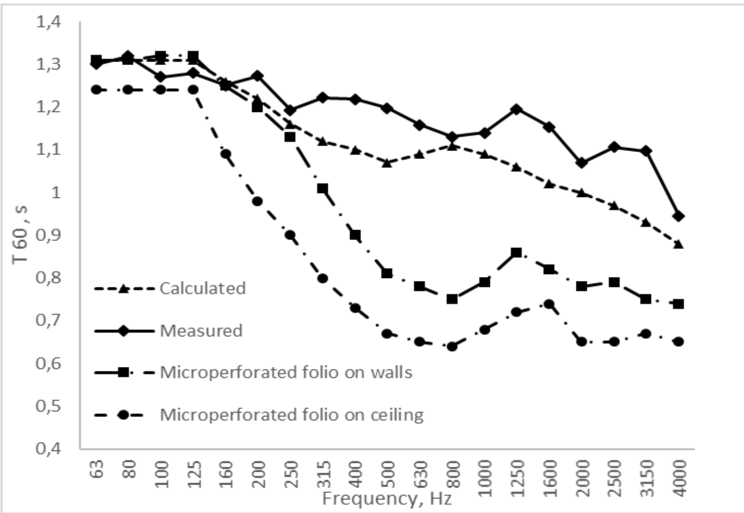

Figure 5 – Large studio, values of T_{60} (measured, calculated, with 36 m^2 microperforated folio on walls, with 36 m^2 microperforated folio below ceiling)

Table 3 shows the %Alcons measurements compared to the STI values in numerical range ranking from bad to excellent. Table 4 shows the %Alcons values: measured, virtually modelled, with 36 m^2 microperforated folio on walls, with 36 m^2 microperforated folio below ceiling.

Table 3 – %Alcons to STI

% Alcons	100%	57.7%	33.6%	19.5%	11.4%	6.6%	3.8%	2.2%	1.3%	0.0%
STI	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
				poor	fair	Good				

Table 4 – %Alcons measured values

%Alcons

stage	%
measured	11.6
Calculated	10.5
After treatment of walls	9.8
After treatment of ceiling	6.5

5.2 Small concert hall

For the acoustic correction of the Small music hall the same approach was applied. The average measured reverberation time T_{60} is 1.67s and the intervention decreases it to approximately 1.2s, corresponding to the volume of the space and the newly assigned function according to the BREEAM standards. The selected material for the wall treatment was wooden panels based on their performance as an absorber in the lower frequencies compared to the microperforated foil. For the ceiling intervention the wooden panels were not appropriate in reference to the interior of the space and therefore the microperforated foil was chosen.

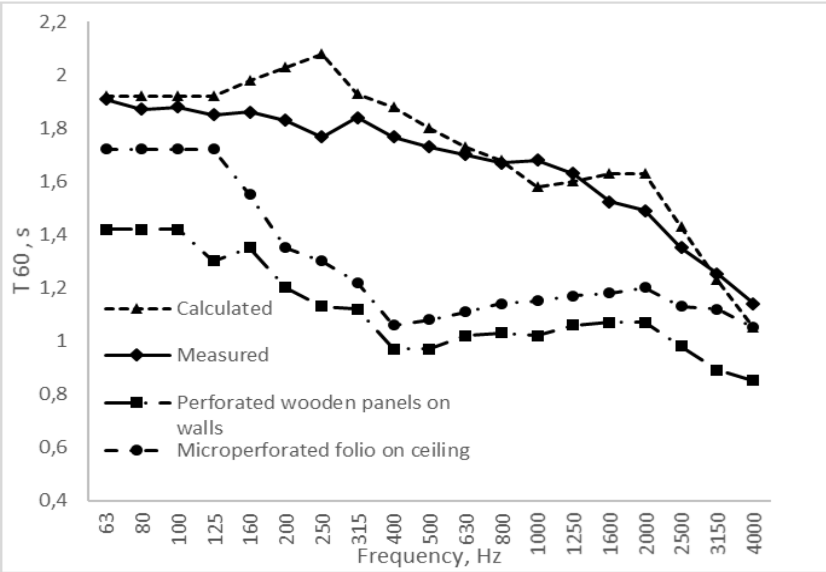

Figure 6 – Small concert hall, values of T_{60} (measured, calculated, with 16 m^2 perforated wooden panels on walls, with 16 m^2 microperforated folio below ceiling)

6. CONCLUSIONS

The analysis of the acoustic measurements of the performance spaces shows that an acoustic intervention can be implemented to improve the acoustic characteristics of the space, in order to adapt to their new functions. The interior specifics of each place should be taken into consideration when choosing the appropriate positioning and type of the absorbing material. The results show that the best correction doesn't exist only in one geometrical position and an individual approach should be applied in each case.

ACKNOWLEDGEMENTS

We have to express our appreciation to the Research, Consultancy and Design Centre (RCDC) in UACEG, Sofia, Bulgaria, for their financial support during the course of this research.

We are also thankful to our colleagues Assoc. Prof. Dr. Arch. Aleksandrina Nenkova and Assoc. Prof. Dr. Phys. Svetlana Dzhambova who provided guidance and expertise that greatly assisted the research.

Last but not least, the cooperation with the Red House Centre for Culture and Debate "Andrey Nikolov" and Gulliver Clearing House Foundation was essential for conducting the case study.

REFERENCES

1. William J. Cavanaugh, Joseph A. Wilkes- Architectural Acoustics: Principles and Practice 1st ed. New York, USA: Wiley; 1998.
2. Eckard Mommertz- Acoustics and Sound Insulation (Detail Practice) 1st ed. Regensburg, Germany: Aumuller Druck; 2009.
3. Michael Barron- Auditorium Acoustics and Architectural Design 2nd ed. New York, USA: Routledge; 2010.
4. Iannace G, Trematerra P, Qandil A. The acoustic correction of classrooms in historical buildings with numerical simulation, AIA-DAGA 2013 Conference on Acoustics (EAA), 18-21 March, Merano, Italy, 2013
5. BREEAM International NC 2016 Technical Manual, SD233 – Issue: 1.0 – Issue Date: 21/03/2016