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Systems Modifying the Acoustic Properties of Room Furnishings

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Abstract The article presents an idea how to increase the room acoustic absorption without significantly interfering with its appearance and architectural character. Based on scale model tests, analytical calculations and computer simulations, it has been shown that a noticeable reduction of room reverberation time and improvement of speech transmission index can be achieved by installing additional absorbing systems on selected furniture surfaces. By selecting the appropriate design and location of such systems, the functionality and appearance of the modified furniture can be maintained.

Keywords: acoustic adaptation; sound absorbing elements; room acoustic parameters.

1. Introduction

Nowadays, minimalist interior design is common and fashionable. This design style is characterised by a large number of hard, sound-reflecting surfaces. People staying in such arranged rooms are exposed to high levels of reverberant noise and poor speech intelligibility. Moreover, these rooms also do not meet the regulations [1-3] concerning protection against reverberation noise and the appropriate conditions for verbal communication. In order to improve the acoustic conditions in the existing interiors, it is necessary to perform their appropriate acoustic adaptation. Most often, the adaptation consists of a sound-absorbing ceiling and/or acoustic wall panels. Unfortunately, such interference in the interior architecture usually disturbs the appearance and character of the room or is technically impossible to perform in the furnished room. Sometimes it may also be insufficient to meet the legal requirements regarding interior acoustic parameters. We can find solutions build into furniture [4] or furniture can have special acoustic properties [5]. An alternative or supplementary solution is to replace the current interior equipment with elements of the same functionality, but with better acoustic properties. However, this is very costly and often economically unjustified. There are no products on the market that would modify the existing interior furniture, increasing their acoustic absorption.

The paper presents the results of research on systems modifying the acoustic properties of room furnishings, which can improve the acoustics of a room without unduly interfering with its appearance. First, the effectiveness of these systems was analysed assuming their different locations on unused surfaces of modified room furnishings. Then, such systems were designed. They were to achieve the highest absorbing properties. At the same time, they could not significantly affect the functionality and appearance of the modified interior furnishings.

2. Methodology

The research methodology included both scale measurements and computer calculations in the CATT-Acoustic and Sound Flow software. Model tests were performed on a specially designed measurement stand, i.e. a 1:7.73 scale model of the full-scale reverberation chamber placed at the AGH University of Science and Technology. However, the measurement samples and the range of measurement frequencies were scaled according to the 1:8 scale to meet the minimum chamber volume requirements, i.e. 200 m^3. The measuring system consisted of a Architected Sound Omni Blue omnidirectional sound source, 46BE 1/4" measuring microphone with preamplifier, G.R.A.S. 12AL microphone amplifier, the UMC204HD BEHRINGER U PHORIA sound card and a computer. During the tests, the weather conditions (temperature, humidity and pressure) were recorded on an ongoing basis [1]. Measurement samples, i.e. 1:8 scale models of various interior furnishings, were made of a rigid high pressure laminate (HPL) characterised by low acoustic absorption. A highly sound absorbing reference material was placed on various surfaces of tested samples. The increase of the equivalent sound absorption area of the samples was then examined. In order for the results to be comparable with each other, the surface of the reference absorbing material was the same in each measurement variant of a given sample. Acoustic absorption measurements were performed according to ISO 354 [2] and ISO 20189 [3] standard procedures.

In the next step of the research, the systems modifying the acoustic properties of room furnishings were designed and their acoustic parameters were calculated using theoretical Bies-Hansen model [6] implemented in the Sound Flow software. The absorption coefficient presented as a function of frequency was the main acoustic parameter that determined the designed structures.

The last stage of research included computer simulations of acoustic parameters (reverberation time RT and speech transmission index STI) of the reference interiors with or without the full-sized tested systems mounted on selected surfaces of rooms furnishings. Simulations were performed using CATT-Acoustic software. The algorithms implemented in this software are based on geometrical acoustics with various levels and combinations of actual and random diffuse ray/cone split-up. Three reference rooms were analysed: open-space, office room and corridor as waiting room. The finish of the walls and the ceilings in the reference rooms were set up as a painted plaster; the floor was covered with PVC. Due to the lack of essential sound absorbing elements, the rooms were highly reverberant. The simulation settings were as follows: Algorithm 1, Max split-order 1, Number of rays and Tracking time 10 257 and 2063 ms for open space model, 13 000 and 850 ms for office room model, 20 000 and 2500 ms for corridor model. The results of the computer simulations were used to determine the acoustic parameters of the reference rooms depending on the location and type of the systems modifying the acoustic properties of room furnishings.

3. Results

3.1. Scale measurements of the equivalent sound absorption area of the samples with reference material located in different places

The following scaled samples of room furnishings were selected for the measurements: office desks, chairs and wardrobes (Fig. 1). The reference material was mounted singly on all surfaces of the samples; however, this article discusses only the measurement results for the two most functionally and visually favourable cases of the reference material location on each of the samples: for an office desk: under the table top (Variant D1) and on desk screens (Variant D2); for a wardrobe: on the front (Variant W1) and on the side walls (Variant W2); for a chair: under a seat (Variant C1) and on the back (Variant C2).

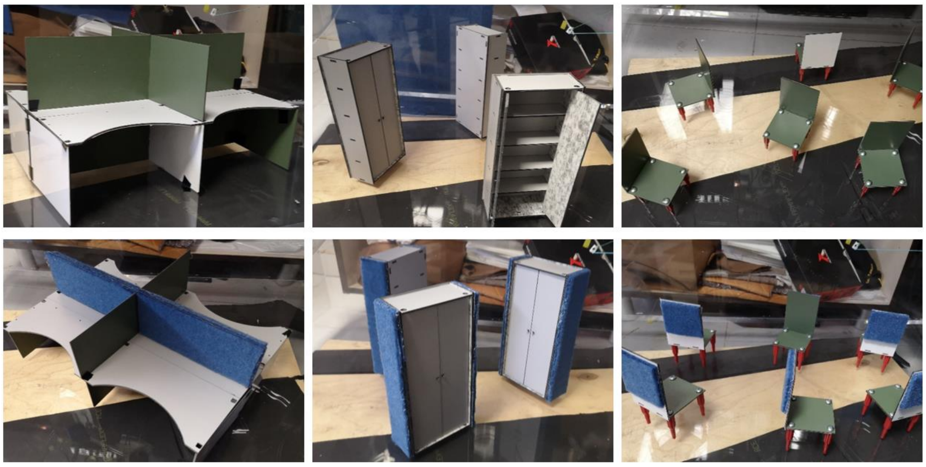

Figure 1. Scaled samples of room furnishings with (top) and without (bottom) the reference material on the selected surface: office desks, wardrobes, chairs, from top to bottom.

Figures 2-4 show the measured values of the equivalent sound absorption area divided by total surface area of the sample for all studied samples, both with (Variants no. 1-2) and without (Variant no. 0) the reference material. The presented diagrams show that even if the absorbing elements are placed under the furniture, the acoustic absorption of the element increases significantly. This is an interesting conclusion in the context of the possibility of concealing additional absorbing systems.

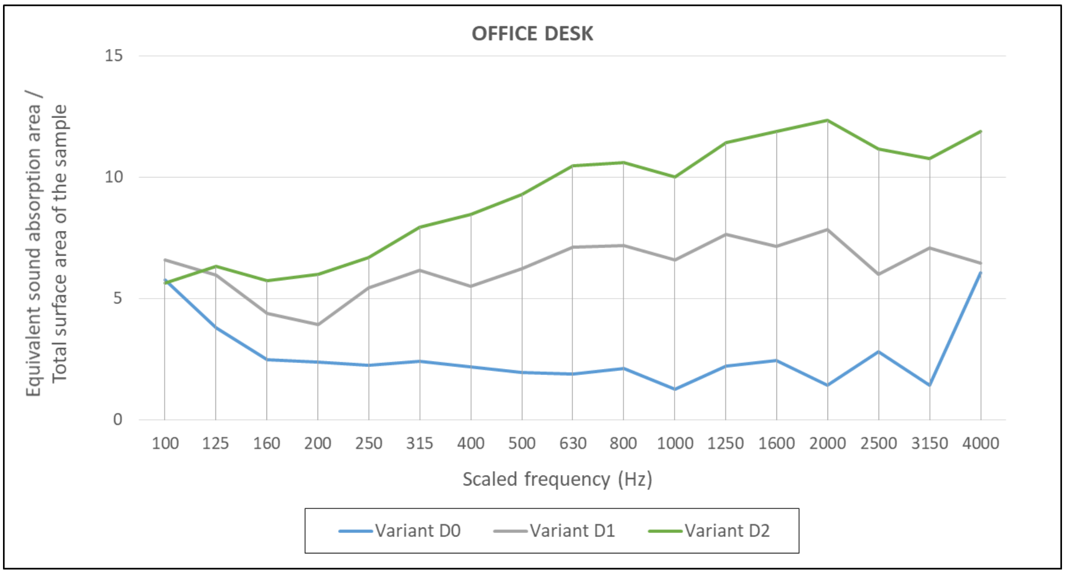

Figure 2. Measured values of the equivalent sound absorption area divided by total surface area of the sample for scaled office desk, both with (Variants D1-D2) and without (Variant D0) the reference material.

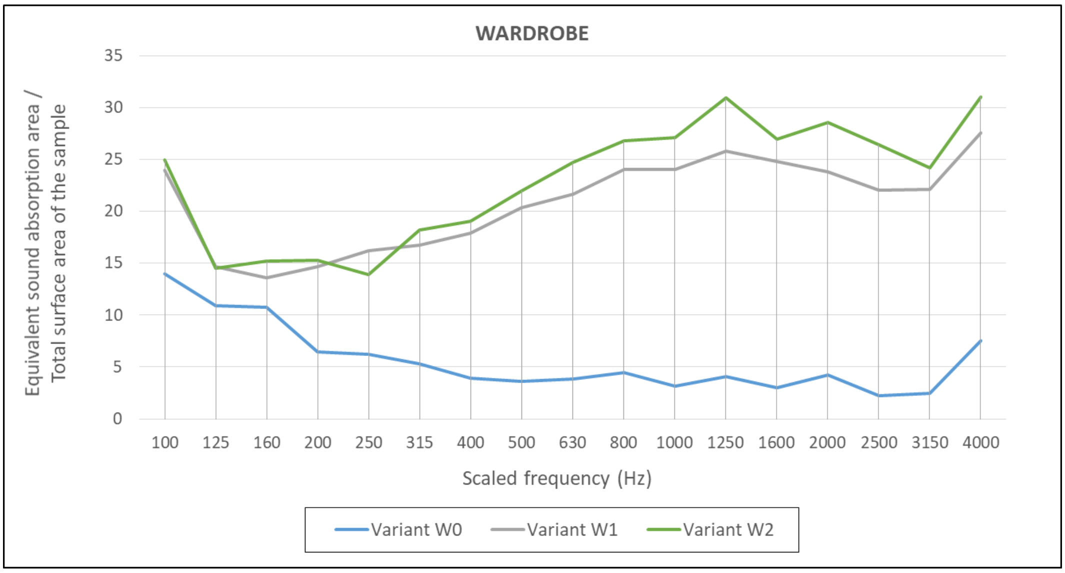

Figure 3. Measured values of the equivalent sound absorption area divided by total surface area of the sample for scaled wardrobe, both with (Variants W1-W2) and without (Variant W0) the reference material.

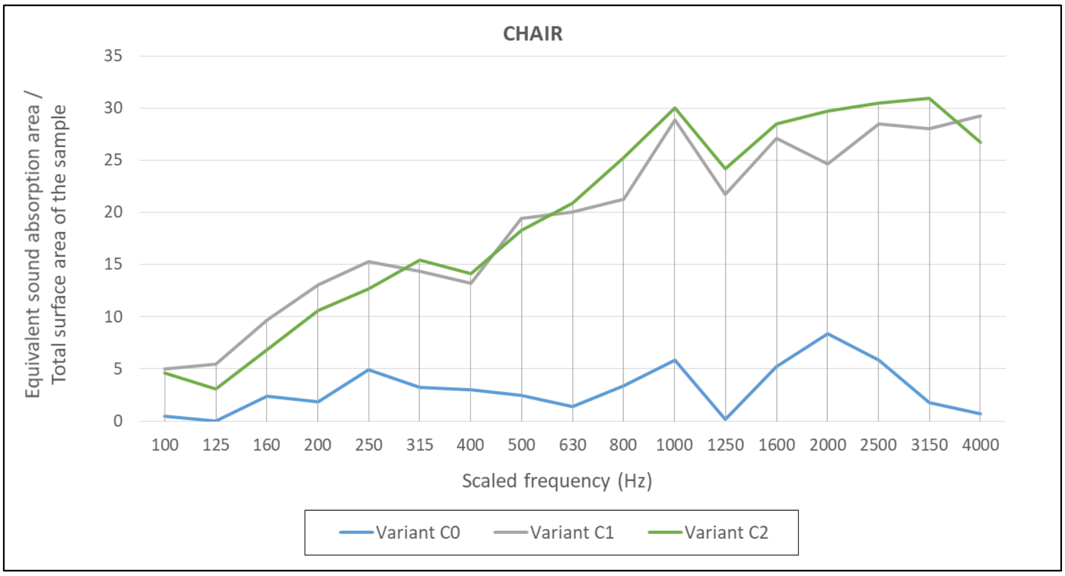

Figure 4. Measured values of the equivalent sound absorption area divided by total surface area of the sample for scaled chair, both with (Variants C1-C2) and without (Variant C0) the reference material.

3.2. The design of systems modifying the acoustic properties of room furnishings

For each variant measured at the stage of model tests, an acoustic design of the appropriate system was prepared. Table 1 lists all the designed systems dedicated to individual room furnishings taking into account their location on the appropriate furniture surface. The table also shows the calculated basic acoustic characteristics of these systems.

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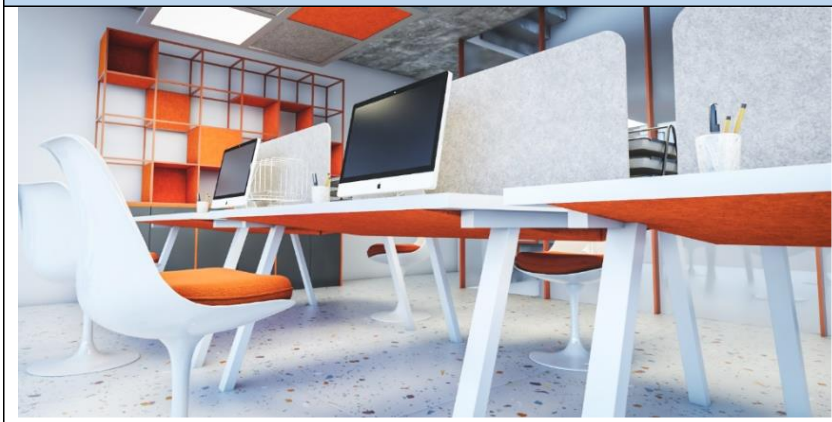
Table 1. The designed systems dedicated to individual room furnishings

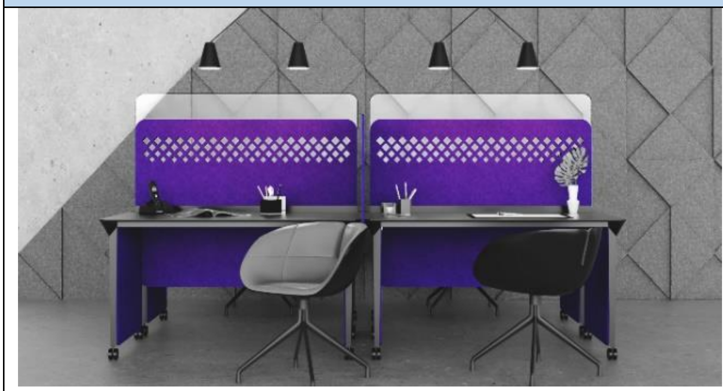
UNDER-FURNITURE SYSTEM: Variants D1, C1



Wedge-shaped structures made of PET sound-absorbing material 9 mm thick (1900 kg/m^2) filled with foam absorbing material 25-50 mm thick.

f (Hz)	125	250	500	1000	2000	4000
α **(–)**	**0.32**	**0.85**	**0.99**	**0.87**	**0.87**	**0.92**

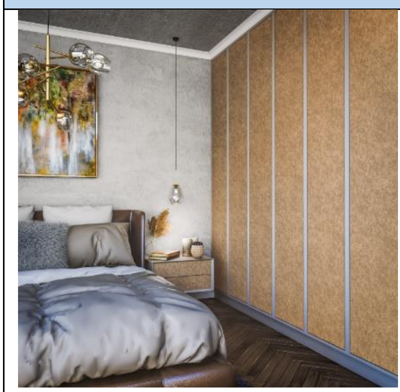
ON-FURNITURE SYSTEM: Variants D2, C2, W2



Structures made of PET sound-absorbing material 2 × 9 mm thick (2 × 1900 kg/m^2) mounted directly on the surface of the furniture.

f (Hz)	125	250	500	1000	2000	4000
α **(–)**	**0.02**	**0.08**	**0.25**	**0.55**	**0.84**	**0.94**

STEAD-FURNITURE SYSTEM: Variant W1



Structures made of PET sound-absorbing material 2 × 9 mm thick (2 × 1900 kg/m^2) instead of the wardrobe front.

f (Hz)	125	250	500	1000	2000	4000
α **(–)**	**0.81**	**0.72**	**0.68**	**0.73**	**0.82**	**0.91**

3.3. Computer simulations of the rooms acoustic parameters depending on the location and type of the systems modifying the acoustic properties of room furnishings

Computer simulations were performed for three representative rooms: open-space, office room and corridor as waiting room (Fig. 5). In open-space the desks were tested, in corridor – chairs and in office room – wardrobes. Figures 6-8 show the main results of the simulations, i.e. the values of reverberation time and speech transmission index for reference rooms before and after acoustic adaptation.

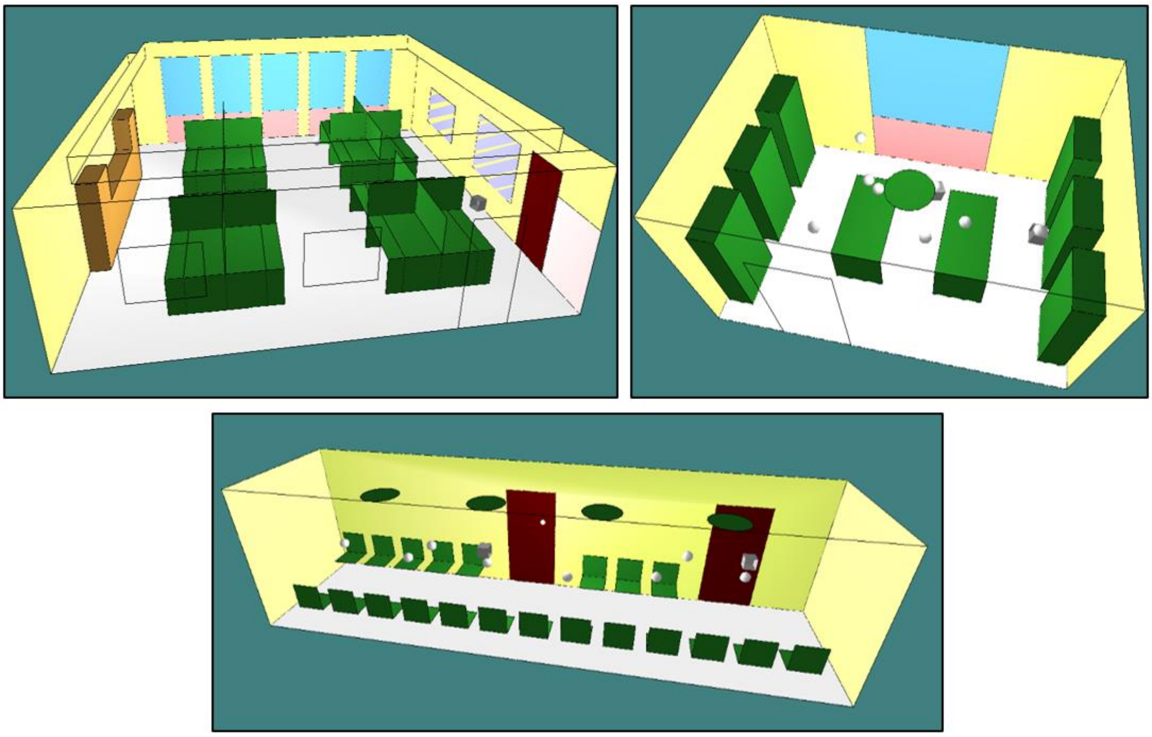


Figure 5. Computer models of reference furnished rooms: open-space, office room, corridor, respectively.

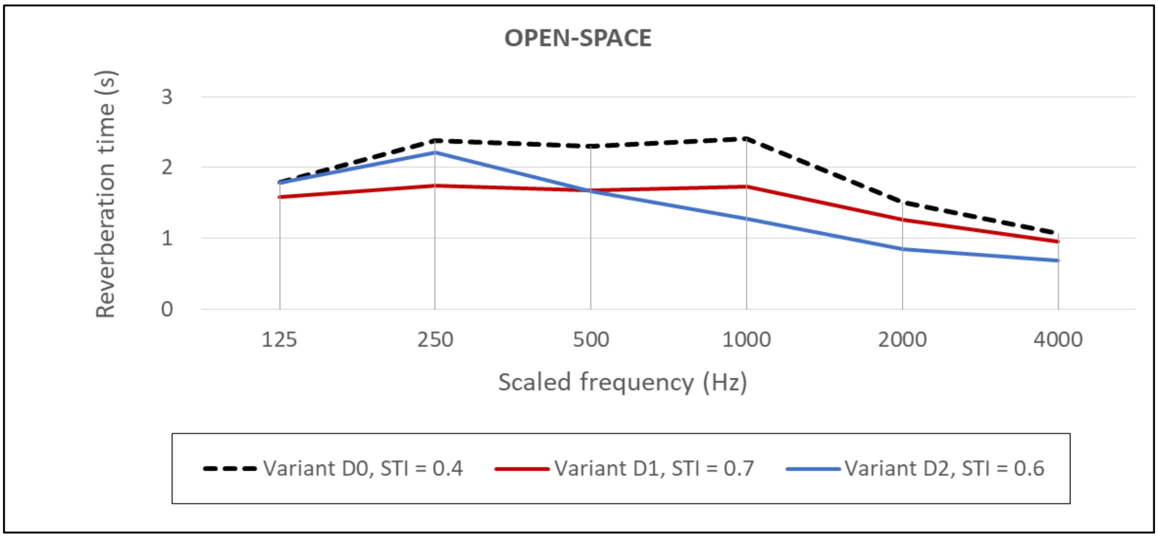


Figure 6. The values of reverberation time and speech transmission index for open-space before and after acoustic adaptation of office desks.

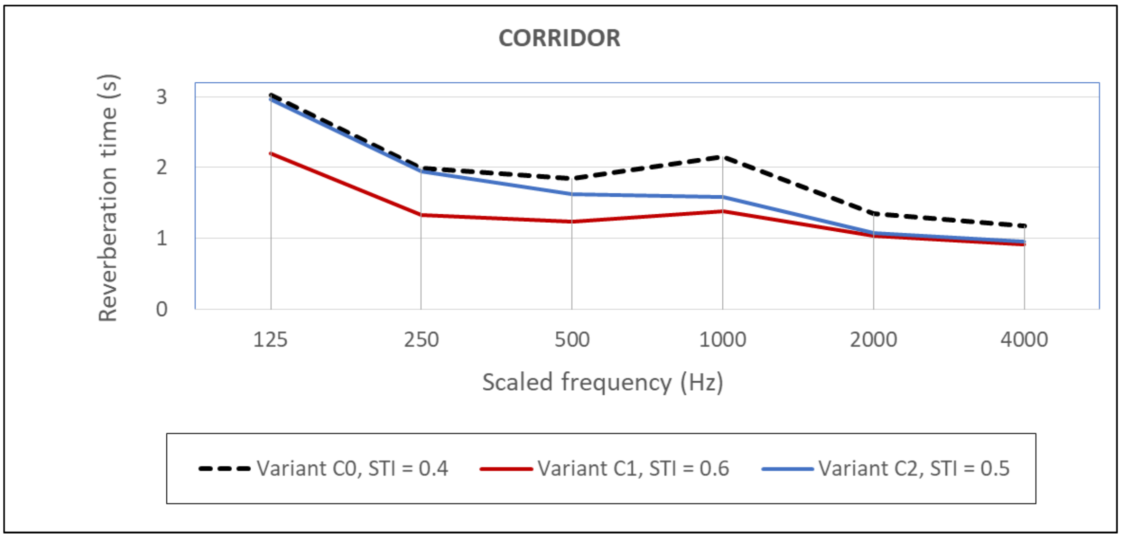


Figure 7. The values of reverberation time and speech transmission index for corridor before and after acoustic adaptation of chairs.

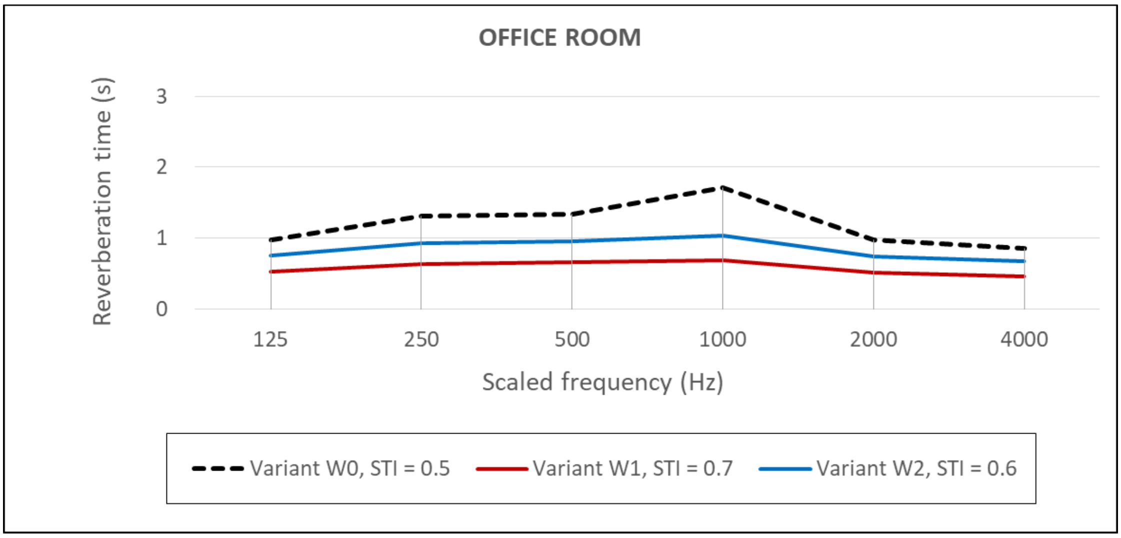


Figure 8. The values of reverberation time and speech transmission index for office room before and after acoustic adaptation of wardrobes.

The reverberation time characteristics and the values of the speech transmission index obtained in the simulations show that the designed systems significantly improved the acoustic parameters of the reference rooms even though a relatively small number of absorbing elements were used. The under-furniture system prove to be effective in reducing reverberation in the low frequency range; the stead-furniture system is effective over a wide frequency range; and the on-furniture system works best in the medium and high frequency bands. Moreover, as a result of the introduced acoustic adaptation, the speech transmission index also improved.

4. Summary

The paper shows that it is possible to noticeably reduce the room acoustic absorption and improve the speech intelligibility without significantly affecting its appearance and architectural character. This can be done by installing the appropriate systems modifying the acoustic properties of room furnishings. What is important, such elements can be mounted on less visible surfaces (under the desk top, under the chair seat). This location does not significantly affect their effectiveness in reducing reverberation. Another interesting solution is to replace the existing furniture parts with new ones with better absorbing properties (e.g. absorbing wardrobe fronts) or install the additional systems on furniture surfaces that are not functionally relevant (the sides of the wardrobe, the back of the chair). In such cases, however, the structure and colour of additional systems should be properly selected in order to minimise their impact on the interior design.

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Additional information

The authors declare: no competing financial interests and that all material taken from other sources (including their own published works) is clearly cited and that appropriate permits are obtained.

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