

Sound Absorption Properties of the Patented Wood, Lightweight Stabilised Blockboard

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Abstract. It is well known that wood tends to shrink and swell as the relative humidity of the air changes. There have been, and still are, attempts to make dimensionally stable wood panels such as Dendrolight®. The physical-mechanical, operational, including acoustic, properties of this material have been significantly improved compared to traditional wood-based panels. However, the production of this material requires very specific processing equipment and a large energy investment. The developers of this material in Latvia invented and patented wood, Lightweight Stabilised Blockboard (LSB). In order for this material to be used in the production of various products, it is necessary to clarify its characteristic, technological, as well as operational properties. The study gathers information about the sound absorption properties of various natural and wood materials, characteristics, and the sound absorption of the studied material at different sound frequencies. The reviewed sources of information indicate that nowadays there are still problems in sound conduction and absorption and isolation issues are being addressed in building acoustics. The production of samples and the determination of sound absorption were carried out using a developed methodology developed in accordance with regulatory requirements. The data obtained in the practical study were compared with the relevant indicators of the Dendrolight® and wood-based panels used for building structures and to determine their compliance with the requirements set forth in the standards ISO 10534-2 and ISO 11654. Research data show that LSB corresponds to E sound absorption class in some of the investigated frequencies.

Key words: wood cellular material, sound absorption, high density fibreboard, building elements.

Introduction

In 2010, the invention and start of industrial production of wood cellular material – Dendrolight® – seemed promising. A wide range of uses was predicted for the mentioned material, starting from simple furniture boards and ending with complicated building elements. However, large-scale production volumes of these wood panel materials never materialised. Nevertheless, individual research institutions – Münster University of Applied Sciences and manufacturing companies such as Gisler Holzbau GmbH in Germany, ARB Pope Ltd. in Latvia – are still trying to develop materials of a similar technological solution, for creating potential “breathing” products and increasing the production efficiency of existing products. One such product is the Lightweight Stabilised Blockboard or LSB, patented in Latvia by the company ARB Pope Ltd. (Roziņš *et al.*, 2014a). This type of board is mainly made of pine (*Pinus*

sylvestris L.) profiled solid wood boards (Roziņš *et al.*, 2014b) in the inner layer and various board materials or solid wood lamellas in the outer layers. Similar to Dendrolight® type boards, their mass is reduced thanks to double-sided grooves embedded in the longitudinal direction of the boards. LSB is a new product whose characteristics and influencing factors have not been studied yet. The potential application of LSB is the production of large-sized cabinet furniture and sliding or hinged interior doors. LSB can be predicted to be widely used in the transport industries, as well as in certain construction segments, such as door production and partition walls. Compared to classic wood-based panels – plywood, high density fibreboard (HDF), particleboard *etc.* – LSB has significantly lower mass, lower density and higher form stability, as well as significantly higher specific gravity. Research has been carried out on the physical, mechanical, as well as technological and some operational properties of

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LSB (Roziņš *et al.*, 2020). However, no studies have been carried out on the acoustic properties of LSB until now.

Today, more and more people in the world want to live and work undisturbed, without hearing annoying and disturbing noises, and therefore noise protection or noise suppression methods are improved year by year, developing new and innovative wood materials and products, including various wood materials and products (Smardzewski *et al.*, 2015). Good room acoustics require both reflective and absorbing materials (Bies & Hansen, 2009, 2017).

Three main sub-sectors are distinguished in modern building acoustics (Veits, 2006):

- room acoustics or architectural acoustics, which deals with ensuring optimal audibility and good sound in rooms, auditoriums and open-air events;
- noise suppression of sound insulation and engineering equipment, or construction acoustics, which deals with ensuring the permissible noise level in rooms;
- building acoustics or urban construction acoustics, which deals with ensuring the permissible noise regime in the construction of cities and villages.

For real sound sources, however, the wave-front usually differs from the theoretical one (Long, 2006). The sound field in a completely or partially closed room is fundamentally different from an open field, because without direct sound, the receiver also receives a certain amount of sound reflected from surfaces. These reflections can be divided into single-reflected sound and multiple-reflected sound. Accordingly, the higher the absorption capacity of the surfaces of the room, the closer the sound field is to the free one. Material vibrations also contribute to sound energy loss, but are often less important than absorption because sound propagates through the connected pores (Yang *et al.*, 2020). In the case of the studied object – LSB – these are wood cells. Room reverberation time strongly depends on frequency. At low frequencies, this time is longer, at high frequencies – shorter. Latvian Construction Standard LBN 016-15 “Building Acoustics” regulates the reverberation time of rooms in the frequency range from 500 to 2000 Hz. It is actually only three octaves, but the room acoustic parameter calculation programs require absorption data from 100 to 3150 Hz to determine the room acoustic parameters. Acoustic adsorbents (sound dampeners) are finishing materials and special constructions whose sound absorption coefficient is greater than 0.5 in at least one of the frequency bands (125, 250, 500, 1000, 2000 and/or 4000 Hz). Considering that wood is a porous material

and today super high-resolution technologies are used to explain its microstructure (Arzola-Villegas *et al.*, 2023), it seems that all wood materials must be ideal sound absorbers. However, history may show the use of wood in musical instruments differently (Yoshikawa & Waltham, 2014). When designing building system elements, one should consider the properties of sound conductivity depending on the direction of wood fibres, which is well known to everyone. Conductivity is significantly more stable with fibres in the longitudinal direction (Guiman *et al.*, 2023).

Important acoustic properties are sound absorption, noise level and sound insulation capabilities. The acoustics of rooms are significantly influenced by the acoustic properties of the materials used for their interior construction. For this reason, very low-density wood structural elements are not particularly suitable for obtaining sufficient room sound acoustic properties (Thomas, 2014). In order to reduce the impact of noise pollution and the absorption of sound wave energy, porous and fibrous materials and combinations of these materials, which are very good sound absorbers, should be used (Cao *et al.*, 2018). In addition, sound-absorbing materials can improve acoustic quality, such as sound clarity and speech intelligibility, by providing adequate reverberation time in a sound operating area, such as concert halls, including open air, opera houses and exhibition halls, etc. (Na *et al.*, 2007). Wood and wood materials are among the materials that have always been used in interior separation of residential, administrative, sports and public buildings. Various sound-emitting devices are increasingly placed in buildings, and solutions are being sought for buildings so that they can be built with thinner materials to save resources. Considering the above-mentioned, the aim of the research is to find out the sound absorption coefficients and calculated sound reverberation of LSB depending on the material thickness and the geometric parameters of the middle layer and to compare it with Dendrolight®, as well as with wood panel materials – particle boards, OSB and plywood.

Materials and Methods

Characterisation of the investigated materials

Pine (*Pinus Sylvestris* L.) timber with a moisture content of 12% was used to create the inner layers of the LSB, depending on the total thickness and width of the LSB boards being studied, 95 mm. Wood materials were selected without visible wood faults. The principle scheme of making LSB is shown in Fig. 1.

In general, the profile and geometric parameters of the LSB middle layer can be seen in Fig. 2A. The grooved lamellas of the middle layer are oriented at an

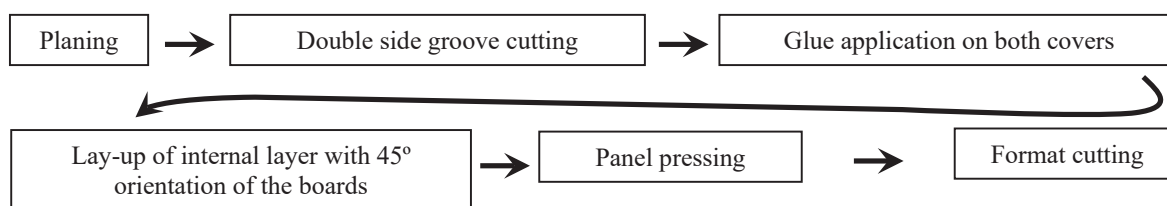


Figure 1. The principal scheme of producing LSB.

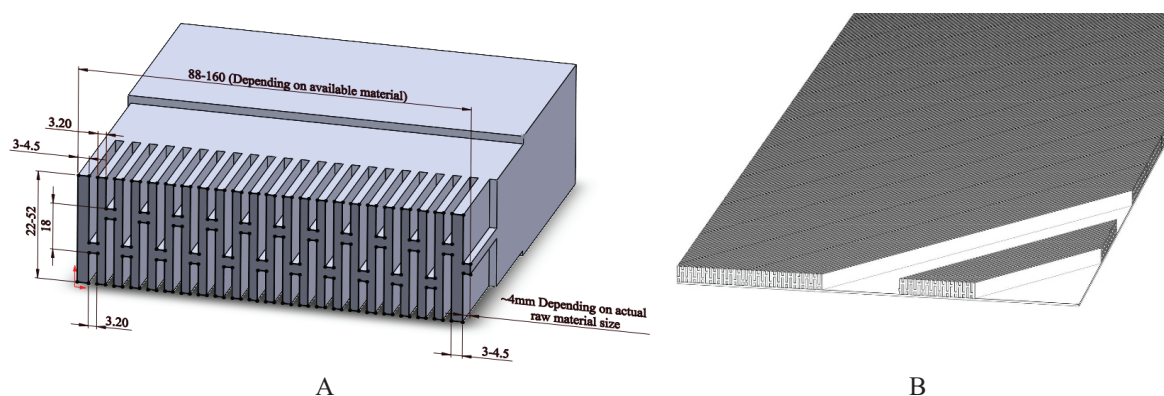


Figure 2. LSB core: A – single profiled board; B – orientation of the profiled boards in LSB.

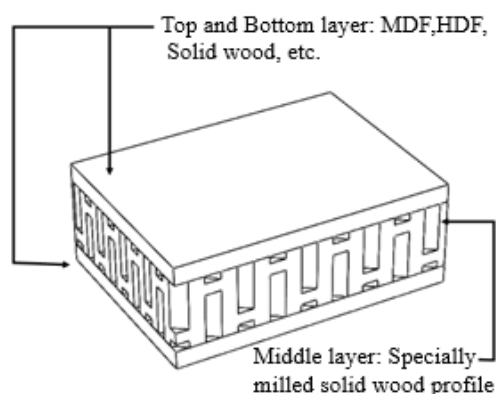


Figure 3. Schematic representation of LSB.

angle of 45° with relation to the longitudinal direction of the LSB panel (Fig. 2B).

LSB fully prepared can be seen in Figure 3.

PVA glue DANAFIX 447 was used for double-sided gluing of HDF and solid pine wood lamellas to the inner layer of profiled pine wood lamellas. The technological parameters of gluing are as follows: pressing pressure 0.2 MPa; glue application 180 g m⁻²; holding time under the pressure: 60 minutes, and gluing temperature: 20 °C. The profiled boards are glued at an angle of 45° in relation to the longitudinal direction of HDF or solid pine wood lamellas using a vacuum press.

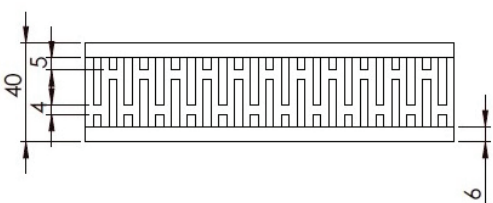
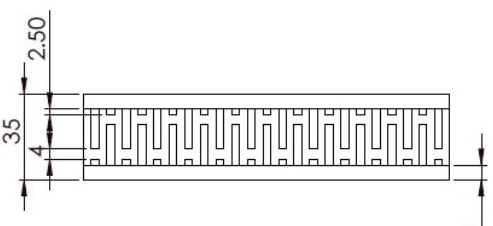
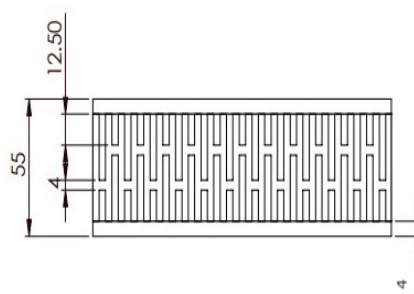
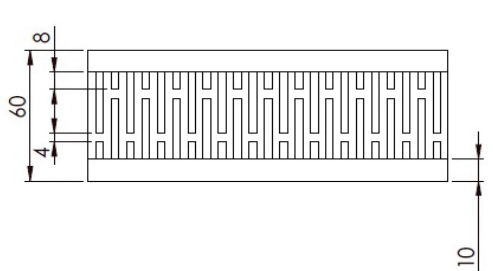
For sound absorption studies, four LSBs of different constructions were selected (Tab. 1), which

are potentially planned to be used for the creation of structural elements – doors, thin partitions or wall panels. The thickness of the samples according to the thickness of the LSB indicated in Table 1. The diameter of the samples were 39 mm. The results of the study are compared with previous studies of the sound absorption properties of Dendrolight®, as well as with the relevant values of wood-based panels widely used in construction – plywood, OSB and particle boards.

Before and after preparing the samples, the materials were aged for moisture equalisation in the conditioning chamber, to their constant mass, at an air temperature of 20±3 °C and a relative air humidity of 65±5%.

Table 1

Characterisation and description of the studied samples

Description of the samples	Number of samples	Geometric parameters – cross cut of the investigated samples	Visualisation of the samples
LSB2 (total thickness 40 mm, glued on both sides with 6 mm thick HDF)	5		
LSB3 (total thickness 35 mm, glued on both sides with 6 mm thick HDF)	5		
LSB4 (total thickness 55 mm, glued on both sides with 4 mm thick HDF)	5		
LSB5 (total thickness 60 mm, glued on both sides with 10 mm thick solid pine wood)	5		

Characterisation of the test methods and equipment

An industrially manufactured impedance tube (AFD 1000 – Sound Absorption Tube Set) (Fig. 4) was used to measure the absorption coefficient for determining sound absorption coefficients in the range from 100 Hz to 4000 Hz.

For the investigation of the sound absorption the impedance tube with additional equipment for sound measurement and computer program SINUS AFD-1000 were used. For each sample, in addition to the determination of sound absorption coefficients, in

different frequency ranges, humidity was determined for them in accordance with the requirements of standard EN 322 (1993). A Memmert ULE 500 drying chamber was used to dry the samples to their constant weight. The KERN EW600 electronic scale was used to weigh the samples. As an additional indicator, density is also determined for each sample in accordance with the requirements of standard EN 323 (1993). The dimensions of the density sample were determined using a Mitutoyo 550.5 caliper. Samples were prepared for each type of sample. The sound absorption coefficient



Figure 4. Impedance tube for measuring sound absorption.

at each sound frequency was determined for each sample two times, measuring it from two sides of the sample. This was done with the purpose of detecting or measuring the sound absorption coefficient on one side, and on the other side of the sample – the constructive effect of the sample. From a sample group of five, two average values were obtained – one for each of the two sides of the sample, for example, for sample group LSB2, they are LSB2-1 and LSB2-2.

The computer program Ramsete 3.0 was used to evaluate the effect of sound absorption, where a 3D model of a standardised room was created, with the sound absorption properties of LSB materials, and an analogue of the room where wooden panels from the material library of the computer program were used. Geometric dimensions of the room: width 4, length 6 and height 3 meters. Acoustic properties from the computer program library were used: wooden finishing panels for walls and ceilings, linoleum for floor covering.

The data processing program Analyse-it for MS Excel, a computer package, was used for the mutual comparison of the data of the sample groups of empirical data of the study and for checking the significance of the difference. ANOVA, the t-test method of comparing the data of two unrelated sample groups, was used to test the significance of the difference between individual sample groups. The sample groups are significantly different if the two-sided alternative significance value of $p \leq 0.05$ is compared. On the other hand, if the p value is > 0.05 , then the average values of the compared sample groups differ insignificantly.

Results and Discussion

Obtained average values of sound absorption coefficient of 40 mm thick LSB2 (average wood moisture content $W=11.2 \pm 0.41\%$ and density $\rho=455 \pm 19.6 \text{ kg m}^{-3}$) covered with 6 mm thick HDF (Fig. 5). Compared to the values given in ISO 11654, it corresponds to class E.

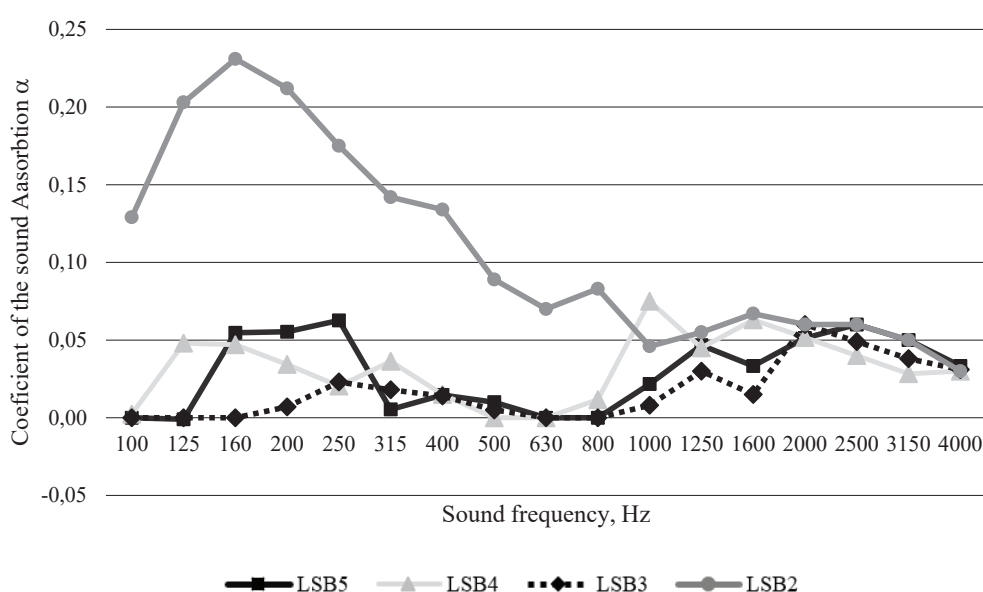


Figure 5. LSB sound absorption coefficients at sound frequencies from 100 to 4000 Hz.

Compared to the data of previous studies on sound absorption coefficients of Dendrolight®, LSB2 shows similar coefficient values at all sound frequencies (Smardzewski *et al.*, 2015; Strazdiņš, 2011), and values up to 3 times lower than unglued Dedrolight® middle layer in 22.5 mm thickness (Smardzewski *et al.*, 2015). A similar difference was obtained in a study (Strazdiņš, 2011) using 25 and 50 mm thickness. Obtained average sound absorption coefficients of the 35 mm thick LSB3 (average wood moisture content $W=11.1\pm0.51\%$ and density $\rho=450\pm20.9 \text{ kgm}^{-3}$) covered with 6 mm thick HDF (Fig. 5). Compared to the values given in the ISO 11654 standard, it corresponds to class F.

Obtained average sound absorption coefficients of the 55 mm thick LSB4 (average wood moisture content $W=11.1\pm0.55\%$ and density $\rho=458\pm20.7 \text{ kgm}^{-3}$) covered with 4 mm thick HDF (Fig. 5). Compared to the values given in the ISO 11654 standard, it corresponds to class F.

Compared to the sound absorption characteristics of Dendrolight® and also board materials of different thicknesses – HDF, particleboard, OSB and birch plywood – performed previously, LSB at low frequencies of up to 500 Hz shows similar indicators. However, when the sound frequency increases above 1000 Hz, or in the high sound frequencies, LSB shows approximately 3 to 5 times lower sound absorption coefficients. This is explained by the embedded grooves in the middle layer of the LSB, which significantly reduce the mass of the material and, consequently, the density of the LSB.

Obtained average sound absorption coefficients of the 60 mm thick LSB5 (average wood moisture content $W=11.2\pm0.43$ and density $\rho=400\pm35.2 \text{ kgm}^{-3}$) covered with 10 mm thick pine wood lamellas (Fig. 5). Compared to the values given in the ISO 11654 standard, it corresponds to class F.

However, the dispersion of the obtained data, which is smaller, including for the density of the LSB middle layer and glued materials, shows that a more homogeneous material shows more uniform properties. However, in general, sound absorption coefficients are lower than in previous studies. By analysing the sound absorption coefficient of different thicknesses of LSB coated by high density fibre boards, in general, it could be concluded that the difference in the thickness of the LSB based material does not significantly affect the sound absorption. Rather, it is the depth of the grooves of the middle layer, or the geometric characteristics of the middle layer. The density between LSB boards glued on both sides with HDF is slightly different; their thickness of 35 to 55 mm and, accordingly, the thickness of HDF boards from 4 to 6 mm does not significantly

affect the sound absorption properties of these boards. Therefore, it can be concluded that the thickness of the created LSB profile, which is respectively 23 mm in the case of a 35 mm thick LSB, 28 mm in the case of a 40 mm thick LSB, 43 mm in the case of a 55 mm thick LSB, except for the low frequencies from 100 to 630 Hz, has no direct effect on the sound absorption properties of LSB. LSB with a thickness of 60 millimetres, glued on both sides with 10 mm thick pine lamellas, shows relatively low values at all frequencies and, according to the requirements of the standard ISO 11654, belongs to class F.

Therefore, it can be concluded that the LSB pasting material can affect the sound absorption properties. If a lower density material is used for LSB middle layer covering the sound absorption properties deteriorate. A similar conclusion was also reached in the studies of the Smardzewski research group on wood panel materials (Smardzewski *et al.*, 2015). Using the ANOVA t-test, a comparison of two or more unstruck sample group was made and it was found that in all cases, except for LSB2 at low frequencies from 100 to 800 Hz, the p value is >0.05 , which indicates that the average values of the compared sample groups differ insignificantly. There are several ways to improve the sound absorption properties of LSB boards. One of them is to combine these LSB boards with other materials, such as natural fibres (Yang *et al.*, 2020), which show very good sound absorption properties applicable to humans in room conditions (500 to 2048 Hz). LSBs can improve sound absorption properties by connecting LSBs together, combining them with other wood board materials, such as low-density fibreboards, to form building system elements or sandwiches (Zhang *et al.*, 2018). However, other methods are also available in the literature, such as microwave exposure on wood materials (Wang *et al.*, 2014), which makes wood materials more homogeneous, or by filling the formed LSB grooves with flexible materials such as saw dust and polyurethane foam (Tiuc *et al.*, 2020; Dukarska *et al.*, 2022). Likewise, by creating the conditions for the structure of the panels with cavities, holes (<https://troja.lv/en/products/wall-and-ceiling-panels>), or by combining these panels with sound-absorbing materials, it is possible to achieve the desired result. It is possible that in the near or distant future, using structural elements of wood materials – wood substance – it will be possible to create LSB board elements in a 3D system, similar to what is currently the case with other natural fibres (Zaharia, 2023).

To evaluate the effect of sound absorption, using the computer program Ramsete 3.0, creating a standardised 3D model of the room, with the inclusion of LSB materials in a 4 m wide, 6 m long and 3 m high room, the following results were obtained (Fig. 6).

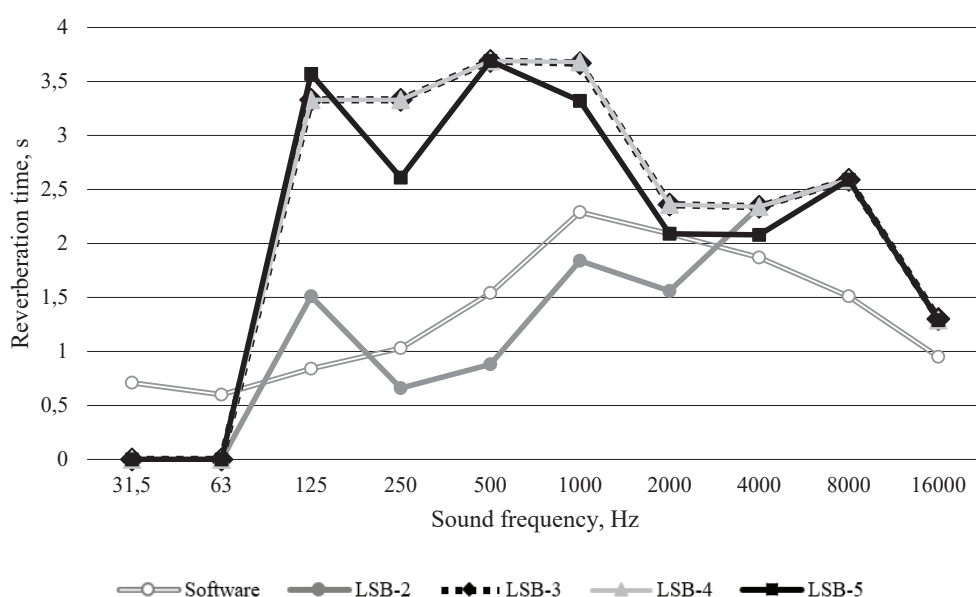


Figure 6. Reverberation time of LSB sound.

From the obtained data on sound reverberation time (Fig. 6), it can be seen that LSB2 shows slightly lower values compared to those calculated in the Ramsete program. On the other hand, in the case of LSB3, LSB4 and LSB5, the reverberation time is higher than the corresponding indicators calculated in the Ramsete program, which suggests that the geometric characteristics of the middle layer of LSB might play a role and LSB slabs should be combined with other sound absorbing materials or elements to obtain higher absorption coefficients.

The results of the research can be used for the characterisation and selection of LSB sound absorption coefficients as separate elements in the creation of constructions – building walls and covering panels. In order to determine the possibilities of using LSB material in the creation of various building structures and to determine its diffusivity coefficient, large-scale tests in a reverberation chamber should be performed.

Conclusions

The total thickness of the LSB board does not significantly affect its sound absorption properties – no differences were found at any of the determined sound frequencies from 100 to 4000 Hz.

The highest result of 0.26 was achieved at a sound frequency of 160 Hz LSB2. Therefore, LSB2 can be classified as class E according to standard ISO 11654 at that frequency. LSB3, LSB4 and LSB5 can be classified as F class according to ISO 11654.

The reverberation time LSB2 calculated in the Ramsete computer program is similar – slightly lower than the values calculated by the program. On the

other hand, in the case of LSB3, LSB4 and LSB5, the reverberation time is higher than the corresponding indicators calculated in the Ramsete program, which suggests that the geometric characteristics of the LSB slabs could have an effect on sound absorption.

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