http://doi.org/10.24867/JPE-2023-02-001

Journal of Production Engineering
Vol. 26 No. 2

JPE (2023) Vol.26 (2) Original Scientific Paper

Adžić, S., Radičević, B., Bjelić, M., Šimunović, D., Marašević, M., Stojić, N.

MEASURING THE INSULATING POWER FROM THE SOUND IMPACT OF THE FLOOR COVERING OF PRESSED EXPANDED POLYSTYRENE

Received: 04 September 2023 / Accepted: 27 November 2023

Abstract: *The paper presents a study of the change in the sound of the impact for two in practice the most commonly used thickness of the floating floor from expanded pollistyrene. The standard SRPS ISO 717-2 defines Normalized values of the level of impact sound per Terce for the reference ceiling, and the procedure for obtaining an authoritative reduction of the sound level of impact of floor covers. The addition of expanded polystyrene panels to the reinforced concrete ceiling was evaluated for the improvement of sound insulation according to the SRPS EN ISO 717-2 standard. The results of the research showed that by increasing the thickness of the layer of pressed expanded polystyrene there is an improvement in the insulation from the sound of the impact.*
Keywords: *impact sound, floor covering, pressed expanded polystyrene*

Merenje izolacione moći od zvuka udara podnog prekrivača od presovanog ekspandiranog polistirena.
U radu je prikazano istraživanje promene zvuka udara za dve u praksi najčešće korišćene debljine plivajućeg poda od ekspandiranog pollistirena. Standardom SRPS ISO 717-2 definisane su normalizovane vrednosti nivoa udarnog zvuka po tercama za referentnu tavanicu, i postupak za dobijanje merodavnog smanjenja nivoa zvuka udara podnih prekrivača. Dodavanjem ploča od ekspandiranog polistirena na armirano betonsku tavanicu ocenjeno je poboljšanje izolacije od zvuka udara prema standardu SRPS EN ISO 717-2. Rezultati istraživanja su pokazali da povećanjem debljine sloja presovanog ekspandiranog polistirena dolazi do poboljšanja izolacije od zvuka udara.
Ključne reči: *zvuk udara, podni prekrivač, presovani ekspandirani polistiren*

1. INTRODUCTION

The introduction of the acoustic classification scheme in almost all European countries is a consequence of the development of regulations for sound protection in buildings. A division was made into sound insulation classes according to which buildings as a whole or individual apartments and business premises are classified, based on the way that was implemented in the current state of energy efficiency. Sound insulation requirements are regulated by national standards in all European countries. In Serbia, it is the standard SRPS U.J6.201, which specifies the minimum values of sound insulation of buildings and the maximum permitted normalized impact sound level, which must be met during the design, construction or reconstruction of buildings intended for human habitation. The standard covers distinct types of buildings (residential, commercial, etc.), and types of boundary walls and floors for rooms of different purposes in them. This standard was written long ago (in 1989), and today, in some elements, it is inconsistent with modern regulations in the field of acoustics in construction, which are defined by the national standards of most European countries. The existing standard in Serbia regulates sound protection by prescribing a value of 52 dB as the minimum for the relevant insulating power between apartments in both horizontal and vertical directions [1].

Also, this standard is not aligned with the regulations of ISO standards in this area. As the standard defines minimum acoustic requirements, the state of sound protection can be classified into two groups: satisfactory or unsatisfactory. In addition, if the acoustic parameters of the sound protection meet the requirements of the standard, it is not possible to give an assessment of how good the sound protection is. In many European countries, the problem of unambiguously defining the minimum requirements for sound insulation in buildings has long been recognized and activities have been undertaken to solve it. The classification of apartments and buildings according to the state of acoustic quality was introduced in a similar way as in the field of energy efficiency. Acoustic classification was introduced in the mid-nineties of the last century by the standards of European countries. There are differences in the number of classes and their threshold values, but essentially the divisions are made on the same principle. In many states, three classes A, B, C and class D have been created for old buildings that were built before the regulation was passed. There is also a proposal for a new ISO standard to unify the acoustic classification of buildings according to the sound insulation achieved in them in all countries. In this regard, six acoustic quality classes are provided, from A to F [2, 3].

In the period from the beginning the acoustic classification of buildings in European countries began until today, there was a change in the SRPS ISO 717-2 standard. This brought about a change in the way of calculating the normative value of the normalized impact sound level, because the numerical values for the same ceilings, obtained according to the two variants of the standard, differ from each other [4].

There is much less variation in the materialization of ceilings and their geometry than in the case of boundary walls between apartments. As a rule, the ceilings are concrete with a thickness of 15 to 20 cm. The variability of the ceilings occurs only in the layers of the floating floor and in the ways of lateral conduction. In Serbia, the drafting of the Regulation on acoustic comfort in buildings is underway. The aspiration is to harmonize the sound protection requirements with the trends that exist in Europe. This raises the question of re-examining the minimum sound insulation requirements that residential buildings should meet.

If the practice of most European countries were to be followed, the limit value of sound protection of 52 dB should be increased. It is realistic that it can be between 53 dB and 55 dB [5].

2. MATERIALS AND METHODS

2.1 Material

Within this work, EPS - Expanded Polystyrene (Styrofoam) thickness of 10±10% mm in 500x1000mm panels and density ρ=20±10% kg/m3 was used as a material for floor insulation. Styrofoam (boards based on expanded polystyrene-EPS) is one of the most commonly used materials in construction for thermal and sound insulation, conforming to the European standard. It is used as sound insulation of floor and wall surfaces, and as floor sound insulation, they are placed under "floating screeds" or underfloor heating systems. Styrofoam as a material also has thermal insulation properties, it is characterized by high energy saving, shape stability, and simple installation. With panels of expanded polystyrene, as sound insulation against impact noise built into the floor structure, high-quality protection against impact noise, a certain reduction of air noise and an additional thermal insulation effect are achieved. The panels are placed on clean surfaces, from which the remnants of the plaster and protruding reinforcement parts are removed. If necessary, a layer of fine sand can be applied. The panels are placed starting from one corner. An edge strip that separates the screed (floor) from the walls along its entire width is mandatory and should be about 2 cm higher than the level of the finished concrete screed. The plates are laid densely next to each other, in order to prevent the formation of the so-called "sound bridges" and are connected to each other with the help of displaced connecting joints.

2.2 Methods

The SRPS EN ISO 16283-2:2016 standard is identical to the EN ISO 16283-2:2015 CEN/TC 126 standard. The standard establishes procedures for determining impact sound insulation by measuring the sound pressure when the sound source acts on the floor or staircase of a building. These procedures are applied to rooms with a volume of 10 m^3 to 250 m^3 for the frequency range from 50 Hz to 5000 Hz. Test results can be used to quantify, evaluate and compare impact sound insulation in furnished and unfurnished rooms where the sound field may or may not be diffuse. Two methods of producing a percussive sound are described: with a tap and with a percussive ball. These shock sources do not reflect all possible sources of sound shock on staircases and in buildings. The tapper can be used to assess various light, hard impacts such as steps in high-heeled shoes or falling objects. A rubber ball can be used to assess hard, soft impacts, such as walking with bare feet or children jumping [7].

To determine the authoritative normalized value of the impact sound level $L_{n,w}$, the SRPS ISO 717-2:2015 standard defines the standard curve of the normalized impact sound level, which at 500 Hz has a value of 60 dB. This curve is moved up or down by a whole number of decibels as long as the sum of the unfavorable deviations per terce in relation to the insulation power curve is less than 32 dB (given that the impact sound level should be as low as possible, the unfavorable deviations are in that part of the frequency characteristic where the standard curve has smaller values than the normalized impact sound level curve). The value of the shifted standard curve at 500 Hz represents the relevant normalized value of the impact sound level $L_{n,w}$.

Calculation of the relevant impact sound reduction ΔL_w is determined according to the expression:

$$\Delta L_W = L_{n,r,o,w} - L_{n,r,w} \ [dB] \quad (1)$$

where is:

- ΔL_W - impact sound level reduction measured and expressed according to SRPS EN ISO 10140-1, Annex H
- $L_{n,r,o,w}$ - calculated normalized authoritative impact sound level of the reference ceiling
- $L_{n,r,w}$ - calculated normalized authoritative sound level of the impact of the ceiling with the floor covering

In order to take into account, the peaks of the impact sound level curve at certain low frequencies in wooden or bare concrete ceilings, a term for spectral correction C_I, was introduced, which is calculated according to the formula:

$$C_I = L_{n,sum} - 15 - L_{n,w} \ [dB] \quad (2)$$

where is:

- $L_{n,sum}$ - energy-normalized sound levels per terce from 100 Hz to 3150 Hz
- $L_{n,w}$ - the relevant normalized impact sound level

The standard SRPS ISO 717-2:2015 defines the normalized values of the impact sound level by thirds for the reference ceiling (homogeneous concrete slab, according to SRPS EN ISO 10140-5:2015) and the procedure for obtaining the authoritative reduction of the impact sound level of floor coverings. Namely, this standard value is obtained as the difference between the standard impact sound level of the reference ceiling and the standard impact sound level of the reference ceiling with the tested floor covering. When it comes to the value related to the normalized authoritative sound level determined on the basis of field measurements, then it is labeled $L'_{n,w}$.

3. RESULTS AND DISCUSSION

The measurement was made in industrial conditions in a room with dimensions: length 6 m, width 3.81 m and height 2.71 m. Its volume is V_1=62 m^3. The reception room is dug into the ground and is located below the delivery room. The dimensions of this room are: length 6m, width 3.72 m and height 2.22 m, and its total volume is V_2'=49.5 m^3. Since, during the measurement, there was a refrigerator with a volume of 9.5m3 in the reception room, then the total volume was reduced by that value and the volume V_2=40 m^3 was obtained.

The volumes and corresponding measurements of the examination rooms should not be equal. It is recommended that the difference in the volumes of the rooms and/or in their length measures be at least 10%. The volume of the examination rooms must be at least 50 m^3. The dimensions of the rooms should be chosen so that the natural frequencies in the low-frequency areas are uniformly distributed as much as possible. Theoretical calculations, as well as some experiments indicate that when testing walls or mezzanine structures, it can be recommended that the sample occupies the entire partition wall or ceiling of the test room, i.e. that the test hole should be extended from wall to wall, i.e. from ceiling to floor. In this case, a volume of 50 m^3 to 60 m^3 is suitable from the point of view of the recommended size of the test hole. The rooms in which the test was conducted dimensionally correspond to the requirements of the SRPS EN ISO 10140-5:2015 standard, which is why the results of the impact sound level measurement were evaluated both as field measurements according to the SRPS 16283-2:2016 standard and as laboratory measurements according to the SRPS EN ISO 10140 standard -1, Annex H.

It is necessary to carry out a field measurement of the improvement of the insulation against sound impact for the insulation material - Styrofoam, and to find the dependence on the thickness of the material. The measurement was made for two different thicknesses of insulating material (styrofoam) of 10 mm and 20 mm. The measurement is performed together with a floating floor made of cement screed d=40 mm, under which layers of material are inserted, whose improvement in sound insulation is measured. To measure the impact sound improvement, it is necessary to measure the normalized impact sound level of an RC (reinforced concrete) ceiling and the normalized impact sound level of an Rc (reinforced concrete) ceiling with a cement screed floating floor with a thickness of d=40 mm.

The measurement was performed with equipment consisting of a receiving and transmitting measuring chain. The transmission measuring chain consists of: Taping machine, model 3207, Brüel & Kjaer with five cylindrical hammers with an axial distance of 100 mm and a cylinder diameter of 30 mm and three circular metal supporting legs covered with hard rubber with a diameter of 30 mm. The receiving measuring chain consists of: Hand-held portable analyzer type 2270 Brüel & Kjaer, with a microphone from the company Bruel & Kjaer, type 4189. The calibration of the measuring system was performed before and after the measurement with a calibrator from the company Bruel & Kjaer, type 4231.

Description and identification of the building structure and method of measurement:

The paper presents research on the impact sound reduction of a 250 mm thick reinforced concrete ceiling to which floating floor layers were added. First, a 40 mm thick cement screed was added, followed by two plates of pressed polystyrene, each 10 mm thick.

The relevant normalized impact sound level $L'_{n,w}$ of the reinforced concrete ceiling was 54 dB. With the addition of a cement liner, the impact sound is reduced to the level of 44 dB, which according to the SRPS EN ISO 717-2 standard, is an improvement in impact sound insulation (ΔL_w) by 8 dB. The basic emphasis of the research is placed on the elements of the structure of the floating floor, which belong to the sound insulators of impact, which in this case are plates of expanded polystyrene. For them, complete results of measurements of the relevant normalized sound of impact ($L'_{n,w}$) and improvements from the sound of impact (ΔL_w) are presented.

Measurement 1:

On the reinforced concrete ceiling, area P=22.9m2, thickness d=250mm, a floating floor consisting of a layer of cement screed, thickness d=40mm and one layer of styrofoam, unit thickness d=10mm, was installed without gluing, as shown in the picture.

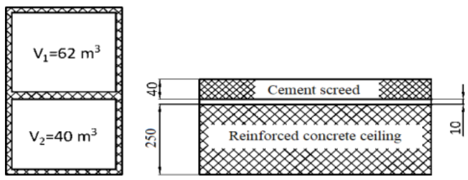

Fig. 1. Concrete-reinforced construction with cement screed and 10 mm thick Styrofoam

Normalized impact sound level L'_n according to SRPS EN ISO 16283 - 2: 2016 and improvement of impact sound insulation according to SRPS EN ISO 10140-1:2017 Annex H for measurement 1 are presented in Table 1.

Frequency f Hz	L'_n dB	ΔL dB
50		
63		
80		
100	35.1	5.4
125	38.7	6.8
160	41.3	9.8
200	37.1	8.9
250	33.1	7.1
315	32.3	9.7
400	36.7	7.3
500	36.3	8.1
630	34.4	11.4
800	34.0	11.8
1000	32.9	14.6
1250	30.4	18.6
1600	28.4	21.4
2000	26.8	22.9
2500	23.0	24.4
3150	18.1	27.2
4000	12.8	29.8
5000	8.6	28.9

Table 1. Normalized impact sound level and improvement of impact sound insulation for measurement 1

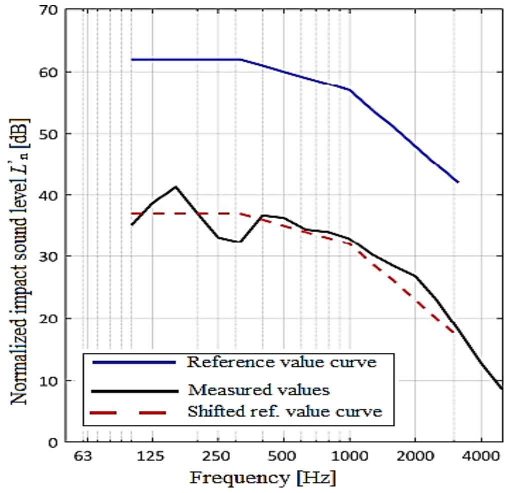

Fig. 2. Normalized impact sound level for measurement 1

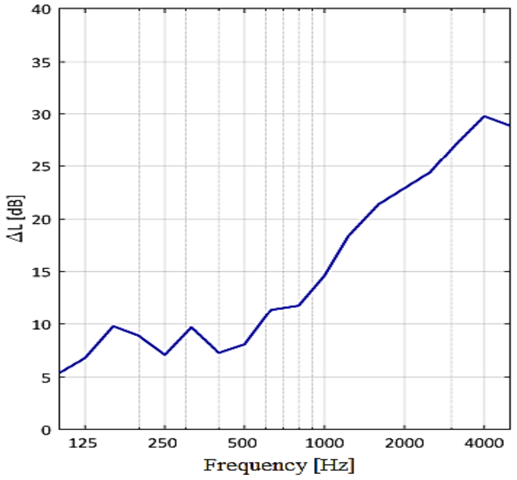

Fig. 3. Improvement from impact sound using isolation for measurement 1

Rating according to SRPS EN ISO 717 – 2 : 2015 ΔL_w = 19 dB, $C_{I,\Delta}$= -3 dB and $C_{I,r}$= -3 dB.

Measurement 2:

On the reinforced concrete ceiling, area P=22.9m2, thickness d=250mm, a floating floor consisting of a layer of cement screed, thickness d=40mm and two layers of styrofoam, unit thickness d=10mm, was installed without gluing, as shown in the picture.

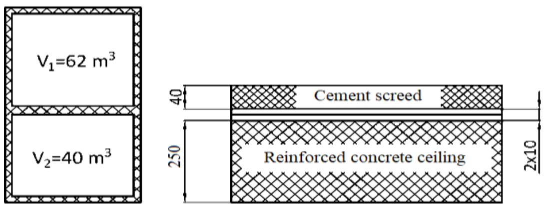

Fig. 4. Concrete-reinforced construction with cement screed and 2x10 mm thick Styrofoam

Normalized impact sound level L'_n according to SRPS EN ISO 16283 - 2: 2016 and improvement of impact sound insulation according to SRPS EN ISO 10140-1:2017 Annex H for measurement 2 are presented in Table 2.

Frequency *f* Hz	L'_n dB	ΔL dB
50		
63		
80		
100	36.3	4.2
125	38.5	7.0
160	40.1	11.0
200	34.8	11.2
250	31.5	8.7
315	31.4	10.6
400	34.6	9.4
500	33.9	10.5
630	32.7	13.1
800	32.3	13.5
1000	31.0	16.5
1250	29.0	20.0
1600	27.1	22.7
2000	25.6	24.1
2500	23.3	24.1
3150	18.3	27.0
4000	11.5	31.1
5000	8.6	28.9

Table 2. Normalized impact sound level and improvement of impact sound insulation for measurement 2

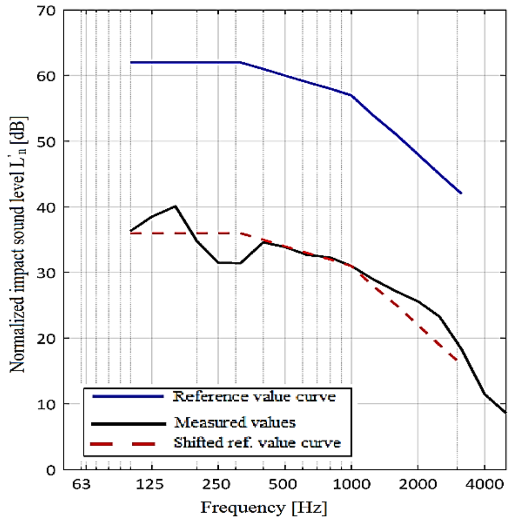

Fig. 5. Normalized impact sound level for measurement 2

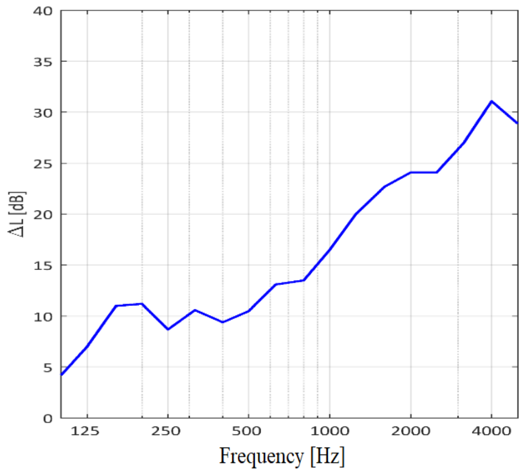

Fig. 6. Improvement from impact sound using isolation for measurement 2

Rating according to SRPS EN ISO 717 – 2 : 2015 ΔL_w = 20 dB, $C_{I,\Delta}$= -3 dB and $C_{I,r}$= -3 dB.

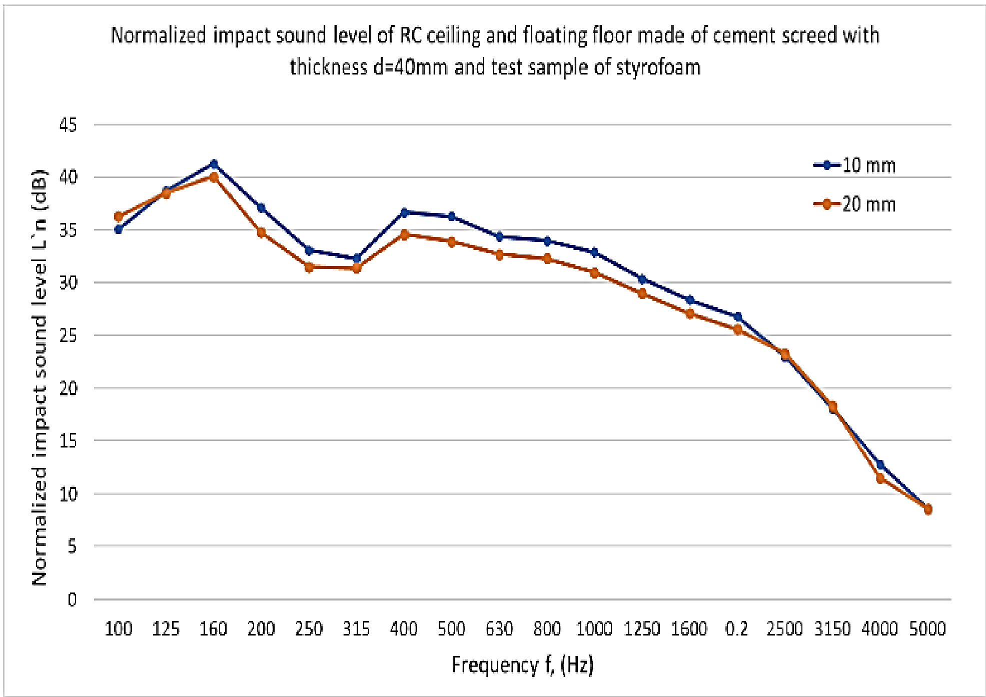

Fig. 7. Normalized impact sound level of RC ceiling and floating floor made of cement screed with thickness d=40mm and test sample of styrofoam

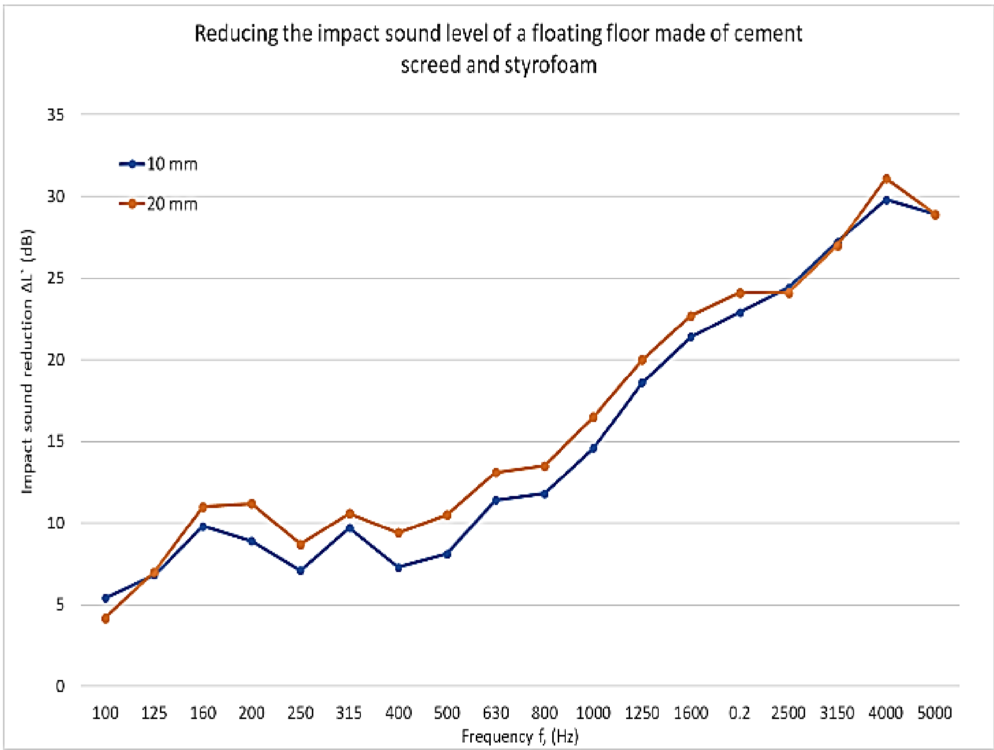

Fig. 8. Reducing the impact sound level of a floating floor made of cement screed and styrofoam

With the addition of a 10 mm thick pressed polystyrene panel, the relevant ceiling impact sound level was reduced to 35 dB, with a total improvement in impact sound insulation by 19 dB. If it is taken into account that the impact sound insulation improvement for the cement screed was 8 dB, it can be concluded that the individual contribution to the impact sound insulation improvement coming from the pressed expanded polystyrene board is 11 dB.

By adding another panel of 10 mm thick extruded polystyrene to the floating floor structure, the relevant ceiling impact sound level was reduced to 34 dB, with an overall improvement in impact sound insulation by 20 dB. In this way, a reduction in the level of the relevant normalized impact sound by 1 dB was achieved and a contribution to the improvement of isolation from the impact sound by 1 dB was achieved, compared to the variant with one plate of pressed polystyrene.

Based on the results of the measurements, it can be seen that the expanded polystyrene panels represent a good sound insulator against impact sound, and as such they should find a place in the structure of floating floors.

4. CONCLUSION

The paper presents the results of measuring the impact sound level for panels made of expanded polystyrene (styrofoam) for two characteristic thicknesses from the aspect of practical application, which are used in sound insulation of floors.

Research results have shown that pressed expanded polystyrene is a good impact sound insulator, as it gives a far greater improvement in impact sound insulation with significantly less thickness compared to reinforced concrete slabs and cement screed. Because of this, it can be concluded that insulating materials such as expanded polystyrene and a group of related materials, must be used in floor structures to reduce the impact sound. This type of research provides knowledge about the possibilities of replacing building materials and structures with cheaper, and in acoustic terms often better. The continuation of the research will include other board thicknesses as well as a combination with other materials that can contribute to reducing the impact sound level of floors in residential buildings.

5. REFERENCES

[1] SRPS U.J6.201:1990 - Akustika u građevinarstvu - Tehnički uslovi za projektovanje i građenje zgrada

[2] ISO/TC 43/SC 2: 1984 - Building acoustics.

[3] COST Action TU0901: Integrating and Harmonizing Sound Insulation Aspects in Sustainable Urban Housing Constructions. Building acoustics throughout Europe. Volume 1: Towards a common framework in building acoustics throughout Europe.

[4] ISO 717-2:2013 - Acoustics - Rating of sound insulation in buildings and of building elements - Part 2: Impact sound insulation

[5] Miomir Mijić, Aleksandar Milenković, Danica Boljević, Dragana Šumarac Pavlović: Akustička klasifikacija stanova i njene posledice na tehnologiju gradnje, ETRAN 2017, Kladovo, 05. do 08. juna 2017, str. AK1.5.1-6, ISBN 978-86-7466-692-0.

[6] URSA Akustika SRPS 1.0 - Uputstvo za upotrebu programa. Elektrotehnički fakultet, Beograd. http://mail.ipb.ac.rs/~isalom/URSA/SIP_Prirucnik.doc

[7] SRPS EN ISO 16283-2:2016 - Akustika – Terensko merenje zvučne izolacije u zgradama i zvučne izolacije građevinskih elemenata – Deo 2: Izolacija od zvuka udara

ACKNOWLEDGEMENTS

This research is co-financed by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia on the base of the contract whose record number is 451-03-47/2023-01/200108. The authors express their gratitude to the Ministry of Science, Technological Development and Innovation of the Republic of Serbia for supporting this research.

***Authors:* PhD Student Stefan Adžić, Assoc. Prof. Branko Radičević, Assoc. Prof. Mišo Bjelić, PhD Student Dragiša Šimunović, Assist. Prof. Miljan Marašević, Assist. Prof. Nenad Stojić.** University of Kragujevac, Faculty of Mechanical and Civil Engineering in Kraljevo, Dositejeva 19, 36000 Kraljevo, Serbia, Phone.: +381 36 383-269, Fax: +381 36 383-269.

E-mail: stefan_adzic@yahoo.com
radicevic.b@ mfkv.kg.ac.rs
bjelic.m@ mfkv.kg.ac.rs
dsmasinac@gmail.com
marasevic.m@mfkv.kg.ac.rs
stojic.n@mfkv.kg.ac.rs