Development and Realization of Multilayered Thin Sound Reduction Panel for Existing Walls

Tsvetan Nedkov, Diana Tzonevska

Abstract— **This paper presents the research and development process of sound reduction panel for existing walls with the specific market needs. According to the contemporary urban way of life, many people in cities live in acoustically weak building constructions. Increased noise levels generated from the occupants provoke annoyance, and the need for efficient sound attenuation panels for existing partition elements is growing. Not only the sound reduction properties, but the thickness of the panel, simple application and visual properties are of significant meaning. According to those needs, a thin layered sound reduction panel with sound attenuation and sound absorption properties has been developed.**

Index Terms— **Sound reduction, thin multilayered panel, existing wall, absorption.**

I. INTRODUCTION

In the past century, the gypsum board systems were widely used to increase the sound insulation properties of existing walls. These systems usually consist of two layers of gypsum boards, metal frame construction and stone wool damper in the air cavity. Such a system can increase the overall sound reduction properties of existing wall built from aerated concrete blocks (20 cm thickness) with more than 12 dB in average.

There are many advantages of such a system – good sound insulation properties for mid and high frequencies, low weight, possibilities to control the transmission loss (TL) properties by changing the air gap thickness. On the other hand, there are several main disadvantages reported from residential users in the Balkan region (Bulgaria, Serbia and Macedonia). The overall thickness of the system is high, there are strong dips in the sound insulation properties, a huge amount of gypsum dust in the period of installation exists and the installation is not “do it yourself” (DIY). The feedback from the clients is obtained in the past 3 years through telephone calls, installed systems and inquires (more than 4600 from Bulgaria, Serbia and Macedonia).

According to the collected information, the initial design of the wall panel "Tiho" (the name of the panel means “silence” in Bulgarian language) is provided, see Fig. 1. Development of this sound reduction panel is characterized by a small thickness (48 mm), good transmission loss efficiency, DIY fast installation without dust, sound absorptive and sound insulation and unique finish design.

The sound reduction efficiency of the panel is achieved with two main techniques: insertion of thin heavy damped layer in the system “mass + spring + mass” and reduction of reverberation time in the receiver room. With this approach, average sound reduction of more than 7 dB for addition layer with weight of 5.6 kg. per square meter is achieved. Regarding to the finish absorption layer (placed at the front side) when the panel is installed on the wall, in the area distant about 80 cm from the panel, the reduction of the sound pressure level (SPL) is in average 3 – 4 dB.

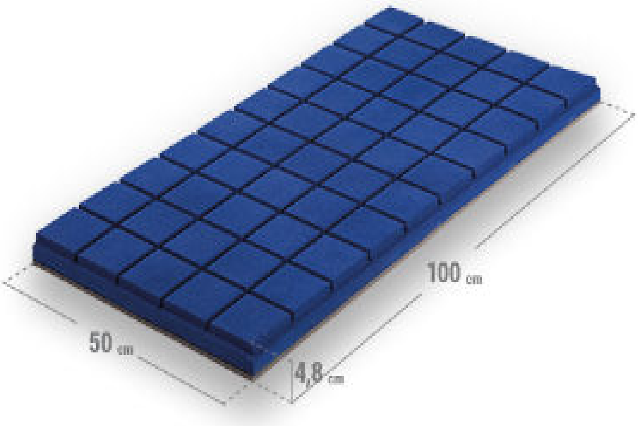

Fig. 1. Front side of sound reduction and absorption panel Tiho with finish blue layer from flock fibers.

The panel consists of four different layers, two of them made from acoustic foam, one thick membrane with high density and finish layer from flock fibers. The layers are glued to each other and the panel is mounted on the wall with PU glue.

II. GUIDELINES FOR PANEL DESIGN

After 6 years of research and collecting information from customers looking for soundproofing solution, some trends in their answers can be noticed. The issue either with newly bought or old renovated homes is similar. The residents have already done the renovation, and when they are ready to start living in their homes, they realize that there is a problem with the noise coming from the near homes. This means they need to continue with the reconstructions in order to deal with this issue. This also implies another period of disturbed living, installation noise, dust and interior amendments. Most of them ask for a solution that could be dust free, thin and would not

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require drilling and noise. They have often refer to such solution as “soundproofing wallpaper”, and most of them have been willing to install the solution themselves.

Therefore, the main effort is to find an easy way to install and cut the solution that should be lightweight and at the same time heavy enough, which does not require finishing layers and could be easy to carry. However, the major property of this product has to be high soundproofing. Having collected all information about what the product should be, the starting point is its thickness that should not exceed 5 cm. Reasons for such thickness come from the characteristics of the residential buildings in the Balkan area, where living rooms and bedrooms are not more than 12-20 square meters, and the residents are not willing to loose their space. Another important reference point for the development of the soundproofing solution is the need for an easy to buy-carry-apply yourself solution. Therefore, the panel has to be light enough to be carried and hold during the installation. It is also preferable that the panel has such a size to be easily stored, carried and mounted. The size of 100 x 50 cm is handy enough to be applied by a single person, and also to be stored and transported in boxes, which are loadable in a car or in a small van. The weigh of approximatelly 3 kg per panel is convenient to hold during the installation. When shipped/carried in boxes of 6 panels, total weight is 15,8 kg per box, which is again a relatively convenient weight to be carried with special equipment.

III. Calculation of Sound Transmission Loss

In the stage of the panel design, a predictive calculation of the sound transmission loss with two different methods were provided: transfer matrix method (TMM) and Sharp’s method for double partitions.

A transfer matrix method [1] is used to calculate the sound transmission loss regarding to the propagation through different layers of the partition. For modeling the porous absorber layers, JCA model [2] is used. The multilayered partition with incident and transmitted sound wave [3] is shown in Fig. 2. The sound wave propagation in the layer *i* can be presented with the transfer matrix [T⁽ⁱ⁾][4],[5]:

$$V(M_{2i-1}) = \left[T^{(i)}\right]\vec{V}(M_{2i}) \tag{1}$$

where the components of vector $\vec{V}(M)$ are variables that describe the acoustic field in the point M from the solid, fluid or porous media.

The position of resonance frequency f_0 and the coincidence region between points f_{c1} and f_{c2} are calculated. The points A, B, C and D give the values of TL for the first natural resonance, existence or absence of absorption in the air cavity between two masses and region of coincidence. The resonance frequency f_0 can be calculated with the following equation:

$$f_0 = 80\sqrt{(m_1+m_2)/dm_1m_2} \tag{2}$$

where m_1 and m_2 are the masses of both solids, d is the distance between them. Then, the transmission loss value of the specific point A can be calculated as

$$TL_A = 20\log_{10}(m_1+m_2) + 20\log_{10} f_0 - 48 \tag{3}$$

The critical frequency region is calculated as separate critical frequency for the first f_{c1} and the second partition f_{c2}:

$$f_{c1,2} = \frac{0.55c^2}{c_{L1,2}h_{1,2}} \tag{4}$$

where c is the speed of sound in fluid (air), c_{L1} and c_{L2} is the speed of sound in the partitions, h_1 and h_2 is the thickness of the partitions.

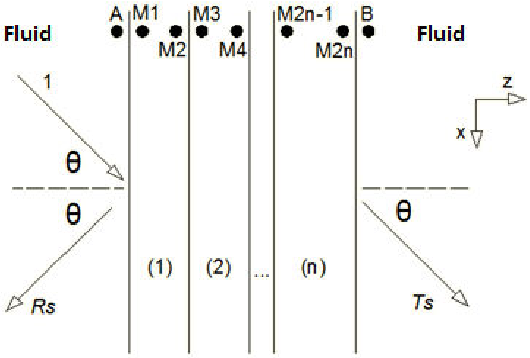

Fig. 2. Model of partition wall section with different impedance layers used for transmission loss calculations of transfer matrix method.

In the Sharp’s TL prediction model for double partitions [6], specific points from the transmission loss curve, shown in Fig. 3, are calculated.

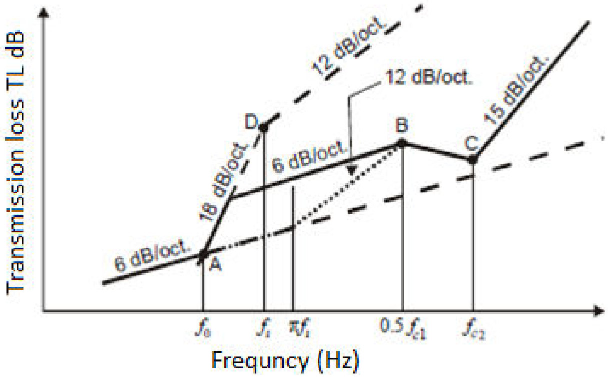

Fig. 3. Transmission loss curve with its specific points according to the Sharp’s model

The TL of the panel is calculated in this way. The panel is glued to the partition wall of thickness of 200 mm, made from aerated concrete blocks, density 700 kg./m^3, E modulus of 3.9 GPa and internal loss coefficient η = 0.01. On both sides, there is a gypsum plaster with thickness of 10 mm, density 720 kg./m^3, E modulus 2.1 GPa, η = 0.01.

The results are compared with the measured results, shown in Fig. 4. It is obvious that there are differences in the predictions obtained by both models in the whole frequency range, predictions for the resonance frequencies and coincidence region. Neither of these methods is accurate for calculation of the TL when small air gaps (less than 10 mm) filled with the sound absorption material are present.

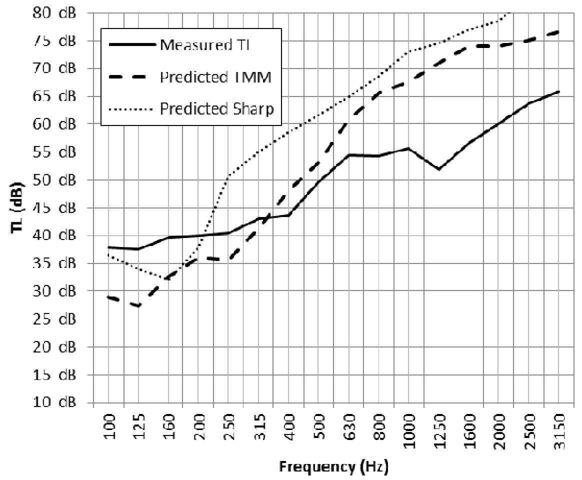

Fig. 4. Comparison of the TL results predicted by the TMM, Sharp's model and measured results.

The measurements of TL were carried out in the laboratory according to the standard EN ISO 10140 – 2:2010 [7] for airborne sound insulation and rated according to the standard EN 717-1 [8]. The samples were placed on the wall at the side to the receiver room, as shown in Fig. 5. The effect of the absorption to the overall sound reduction was also observed. First, the TL of a single wall (without the panel) was measured and afterwards the TL of the wall with added panel. The results of these measurements (TLs) are given in Fig. 6.

Fig. 5. Measurement of TL in laboratory with installed panels on the wall at the side of the receiver room.

The absorption coefficient α was measured in the reverberation chamber according to the standard ISO 354:2003 [9] and the results are shown in Fig.7.

The overall sound reduction caused by the "Tiho" panel in the frequency range from 125 to 400 Hz is between 2 to 4 dB, which is quite insufficient to achieve unintelligibility of the speech with partition wall built from aerated concrete blocks. Applying heavy weight membrane with high internal losses and low modulus of elasticity but not tunable properties for high transmission loss of low frequency region, those values can be the maximum possible TL.

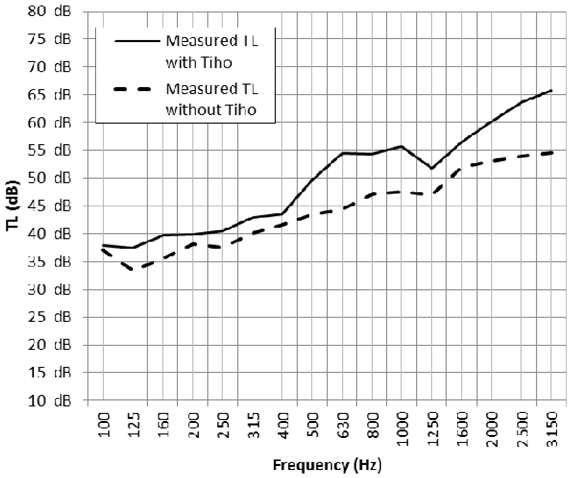

Fig. 6. Comparison of the TL results of single partition wall with and without additional layer of Tiho panel.

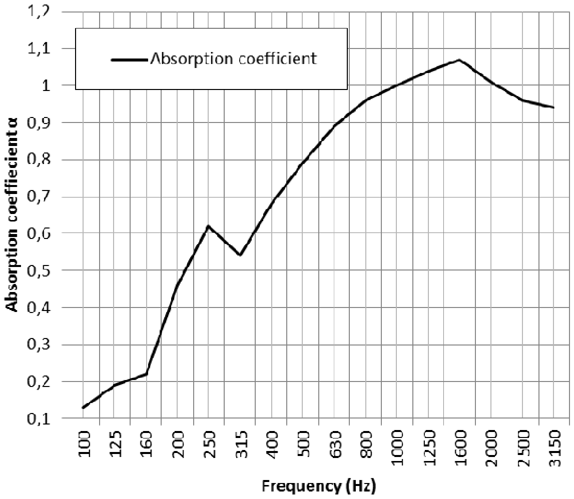

Fig. 7. Measured sound absorption coefficient α of panel Tiho according to standard ISO 354.

For middle and high frequency region, the overall sound reduction generated by the "Tiho" panel is between 5 and 10 dB. There is a dip in the transmission loss curve at 1250 Hz related to the "mass + spring + mass" resonance frequency. Taking into account that this resonance is below the most sensitive region of human hearing (around 3150 Hz), this dip compromises the overall sound insulation characteristic of the panel.

According to the described disadvantages and the main need for thinner and lighter sound insulation material, the next step for improving the TL properties in the defined frequency range is to insert a metamaterial layer in the panel.

The research for appropriate acoustic metamaterial layer with high sound insulation properties [10] [11] for low frequency range, high stiffness and thickness below 30 mm leads to the work of Sui [12]. He studied a lightweight soundproof honeycomb acoustic metamaterial, which has a good performance for the low frequencies sound proof and his works was enlighten in the research of Lu [13]. The proposed metamaterial with honeycomb structure (Fig. 8) achieves very high values of soundproofing in the region below the natural resonance. With thickness of 20.25 mm, it is measured that the sound transmission loss is greater than 36 dB at 100 Hz, see Fig. 9.

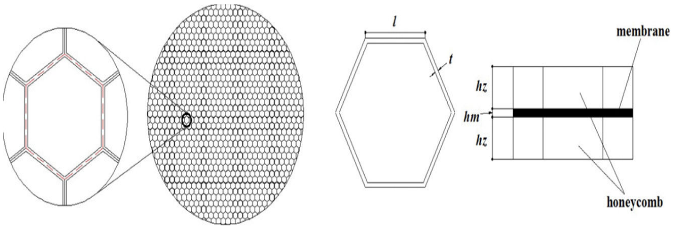

Fig. 8. Soundproofing metamaterial with honeycomb structure and middle positioned visco-elastic layer. The dimensions are: h_z = 10 mm, h_m = 0,25 mm, l = 3,84 mm and t = 0,8 mm.

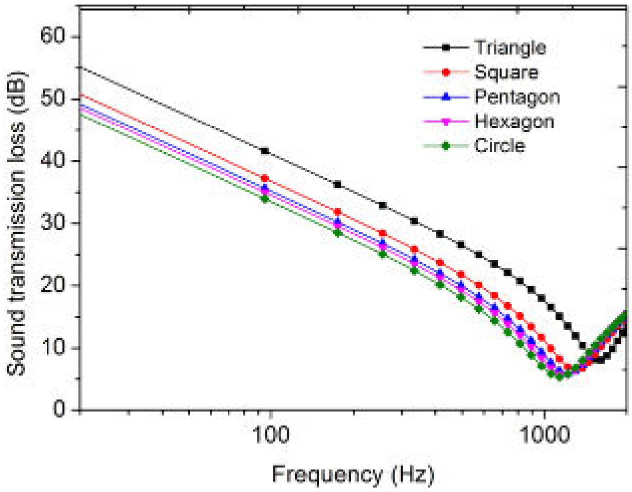

Fig. 9. Comparison of the TL results for different shapes in the research of Lu [13].

According to this research, the measurements of different combination of inner visco-elastic layer and different dimensions of the honeycomb structure will be provided in order to achieve optimal soundproofing parameters. For the first experiment, a honeycomb structure with thickness of the wall of 1.00 mm was produced with 3D printing technology, see Fig. 10. The measurements will be performed using the transmission loss tube based on the impedance tube, realized at the Faculty of Electrical Engineering, University of Niš, Serbia.

IV. CONCLUSION

The first edition of Tiho panel achieves good results in most of the needs of the customers – small thickness, easy application, interesting design, good sound absorption properties and good thermal insulation properties. According to the sound insulation – it is not enough in the low frequency region, significant for speech and intelligibility. Regarding this needs, the idea is to provide the improvement of the low frequency TL with incorporation of thin metamaterial layer.

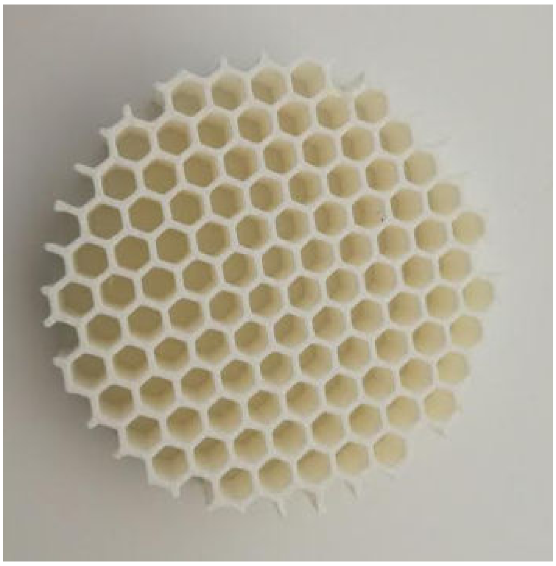

Fig. 10. Honeycomb structure of thickness of the wall of 1.00 mm produced with 3D printing technology.

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