Research of Transmission Loss Properties of Thin Layered Sound Reduction Systems for Building Partition Elements

Tsvetan Nedkov[1], Snejana Pleshkova-Bekjarska[2]

Abstract – **In this document are studied the properties of different combinations of thin layered materials for increasing the index of sound insulation of separating walls built from bricks with holes that are most commonly used in the contemporary building constructions. In the research are combined thin porous elastic elements laminated with thin plates with medium and high density.**

Keywords – **sound reduction systems, transmission loss properties, building partition elements.**

I. Introduction

In the contemporary building constructions the need of thin layered noise reduction system for airborne sound becomes more common to use for application on partition walls, floors and ceilings. The "classical" systems are built from metal or wood frame, porous absorbers and gypsum boards, but they take away from the useful space of the room at least 70 to 150 mm from every surface. Moreover to be high efficient the systems must be suspended on expensive rubber hangers. For this reason in this document are studied the properties of different combinations of thin layered systems, directly laminated to the existing brick wall, combining elastic polyurethane absorbing layer with solid plates with different properties.

II. Instructions for the Authors

For this research Sharp's prediction model [1] will be used to calculate the sound reduction curve , describing the lost of energy when sound transmits trough double partition wall. The sound reduction curve owns a few characteristic points [2,3] (Fig. 1). Point A from the graphic (Fig.1) defines the resonant, frequency of the system f_0 and its value of sound pressure TL_A:

$$f_0 = 80\sqrt{(m_1+m_2)/dm_1m_2} \ \text{(Hz)} \tag{1}$$

$$TL_A = 20\log_{10}(m_1+m_2) + 20\log_{10} f_0 - 48 \ \text{(dB)} \tag{2}$$

[1]Tsvetan Nedkov is with the Faculty of Telecommunications at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria, E-mail: tsvetan_nedkov@abv.bg.

[2]Snejana Pleshkova-Bekjarska is with the Faculty of Telecommunications at Technical University of Sofia, Kl. Ohridski 8, Sofia 1000, Bulgaria, E-mail: snegpl@tu-sofia.bg.

m_1 and m_2 – masses of the first and second partition,

d – distance between the partitions.

Point B defines the beginning of the coincidence region closed between the values of the critical frequencies of the partitions $0.5\,f_{c1}$ and f_{c2} :

$$f_{c1} = 0.55c^2/c_{L1}h_1 \ \text{(Hz)} \tag{3}$$

$$c_{L1} = \frac{\sqrt{12}}{h}\sqrt{\frac{B}{m}} \tag{4}$$

c_{L1} – speed of sound propagation in the first partition,

h_1 – thickness of the first partition,

c – speed of sound in the air 332 m/s,

B – bending stiffness of the first partition.

The type of connection between the partitions defines the value (dB) of point B and is line-line [1] [2] [3] described with the following equation:

$$TL_{B2} = 20\log_{10} m_1 + 10\log_{10} b + 20\log_{10} f_{c1} + 10\log_{10} f_{c2} + 20\log_{10}\left[1+\frac{m_2 f_{c1}^{1/2}}{m_1 f_{c2}^{1/2}}\right] - 78 \ \text{(dB)} \tag{5}$$

where f_{c2} is the critical frequency of the second partition; b is the spacing between line supports.

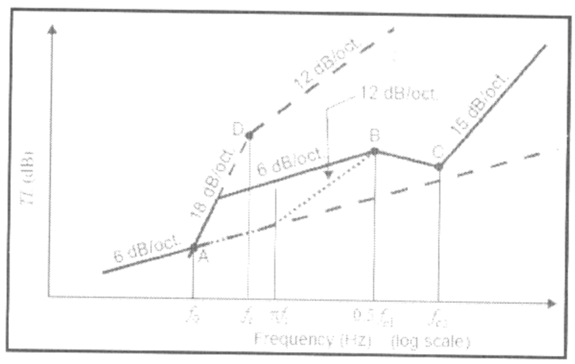

Fig. 1. A design chart for estimating the transmission loss of a double panel wall, based on Sharp`s analysis

Defining point C: this point marks the end of the well expressed region of coincidence , after that the curve mounts with 15 dB/octave [5]. When the partitions have a different density and thickness this means that f_{c2} is not equal to f_{c1} and the equation that describes the value (dB) of point C is:

$$TL_C = TL_{p0} + 6 + 10\log_{10}\eta_2 + 20\log_{10}\frac{fc_2}{fc_1} \text{ (dB)}. \quad (6)$$

Coefficient η_2 defines the internal loss of the second partition.

Point [5,6] describes the increase of the noise reduction curve when there is absorption material in the cavity, defining the specific frequency f_l :

$$f_l = \frac{55}{d} \text{ (Hz)}. \quad (7)$$

III. Experimental part

The source room is a soundproofed reverberation chamber with dimensions 332 x 200 x 150 cm and with an opening for the tested specimens of 182 x 135 cm. The receiver room is 1220 x 680 x 320 cm. The testing chamber did not match ISO standart 140 – 1 and 140 – 3 but it's parameters are satisfying the needs of the experiment [4]. In the testing opening is built a partition wall from a ceramic brick with holes, thickness of 120 mm, plastered from one side with cement based mortar 15 mm thick. This type of wall is one of the commonly used in the contemporary building process. Tested specimens are separated from the other elements with a 10 mm rubber pad. In the source chamber is placed a dodecahedron sound source connected with a generator of "pink noise". One microphone is placed in the source chamber, connected with a sound level meter and frequency analyzer. In the source room at distance 40 cm from the specimen is placed a condenser microphone, connected with a sound level meter and a frequency Pulsar Instruments 106. The generated sound pressure in the source room is SPL – 94 dB.

The first part of the experiment is the measurement of sound reduction index of the brick wall without insulation. This sound reduction curve exists in all of the figures in order to facilitate the comparison of all applied systems.

TABLE I
PARAMETERS OF TESTED MATERIALS

Type of material	Density	E Modulus	Coeff. of Poisson	Coeff. of internal loss
---	kg./m³	GPa	ν	η
Ceramic brick with holes	655	6.85	0.12	0.013
Gypsum fiber board (GF)	1130	3.9	0.3	0.012
Gypsum board (GB)	680	2.1	0.24	0.01
PU elastic absorber (Ab)	150	0.7	0.35	0.15

In the second part are prepared 4 different combinations with 3 sub combinations of each one:

Set I. The absorbing elastic layer with thickness of 10 mm is laminated to gypsum fiber board (the elastic layer is glued to the wall and to the fiber board with polyurethane glue) and is measured. After that are added 6 point connections (PVC nails) and the measurement is done again. In the third combination is added second mass to the fiber board with 12.5 mm thick gypsum board by screws (linear connection) and it is measured as well (Fig. 3).

Set II. The absorbing elastic layer is doubled (20 mm) and the other elements are the same as in Set I. (Fig. 4).

Set III. Here, again the elastic layer is 20 mm, but the thickness of the fiber board (GF) is increased to 15 mm. The other elements are the same as Set I (Fig. 5).

Set IV. Successively are connected 10 mm elastic layer with 10 mm fiber board plus 10 mm elastic layer and 10 mm fiber board – combination of two elastic and two solid plates with final layer of gypsum board (Fig. 6).

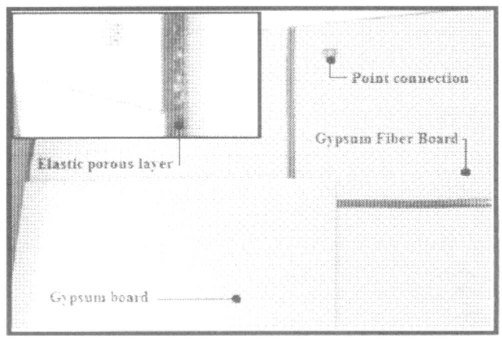

Fig. 2. Thin layered noise reduction system (Set II, measurement 5)

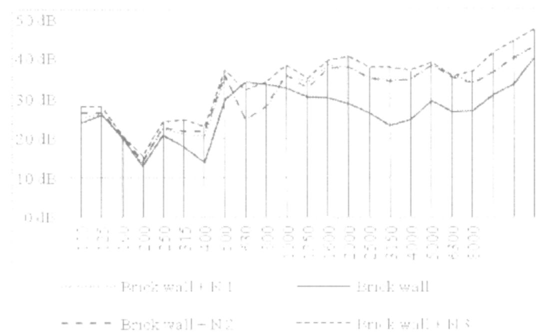

Fig. 3. Experimental results of noise reduction to Set I, measurement 1, 2 and 3

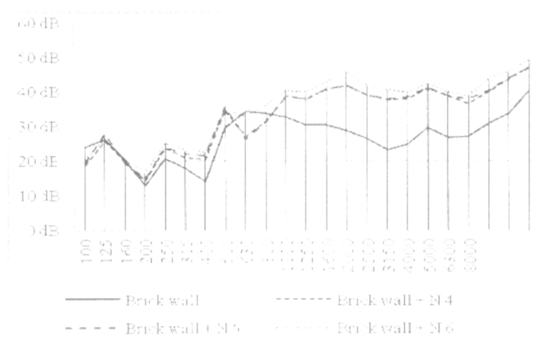

Fig. 4. Experimental results of noise reduction to Set II, measurements 4, 5 and 6

TABLE II
COMBINATIONS WITH EXAMINED MATERIAL

Set	N Measurment	Elastic porous layer	Point connect.	1-st added mass	Elastic porous layer	2-nd added mass	3-rd added mass
I	1	10 mm + Ab	-	10 mm GF	-	-	-
	2	10 mm + Ab	6 pcs.	10 mm GF	-	-	-
	3	10 мм + ЗП	6 pcs.	10 mm GF	-	12.5 mm GB	-
II	4	20 mm + Ab	-	10 mm GF	-	-	-
	5	20 mm + Ab	6 pcs.	10 mm GF	-	-	-
	6	20 mm + Ab	6 pcs.	10 mm GF	-	12.5 mm GB	-
III	7	20 mm + Ab	-	15 мм ГФ	-	-	-
	8	20 mm + Ab	6 pcs.	15 мм ГФ	-	-	-
	9	20 mm + Ab	6 pcs.	15 мм ГФ	-	12.5 mm GB	-
IV	10	10 mm + Ab	-	10 mm GF	10 mm + Ab	10 mm GF	-
	11	10 mm + Ab	6 pcs.	10 mm GF	10 mm + Ab	10 mm GF	-
	12	10 mm + Ab	6 pcs.	10 mm GF	10 mm + Ab	10 mm GF	12.5 mm GB

Ab – elastic absorbing material from polyurethane foam
GF – gypsum fiber board;

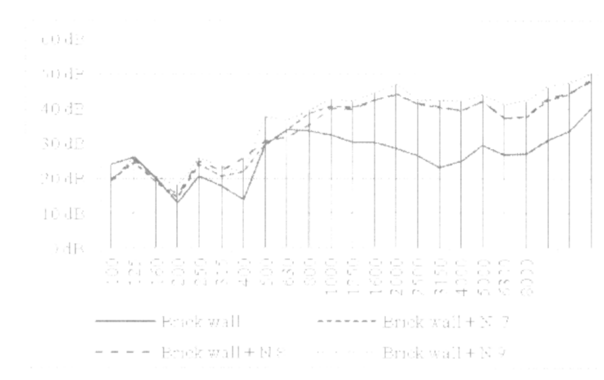

Fig. 5. Experimental results of noise reduction to Set III, measurements 7, 8 and 9

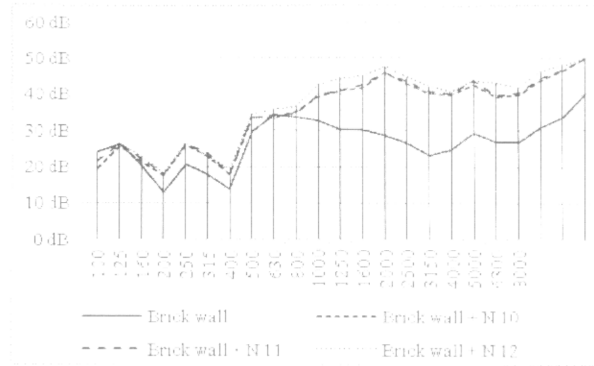

Fig. 6. Experimental results of noise reduction to Set IV, measurements 10, 11 and 12

GB – gypsum board;
Point connection – realised from 6 peaces of PVC nails

IV. ANALYSIS OF RESULTS

In Set I the increase of sound insulation is mainly in the high frequency region. The resonance frequency is observed at 200 Hz and there is insignificant decrease at 630 Hz. Differences between the calculated and measured results (Fig. 7) are caused from that Sharp's model [1] which does not give satisfactory results for cavities below 25 mm and the second reason is the flanking transmission between the chambers. In Set II the thickness of the porous elastic layer is doubled to 20 mm. The result is increasing sound insulation in frequency region from 630 to 1250 Hz with an average of 5 dB. Again there is an insignificant decrease at 630 Hz.

In Set III the thickness of the first mass is increased from 10 to 15 mm and the elastic layer is 20 mm. The sound insulation in the mid frequency region is increased with an average of 6 dB.

In Set IV the resonance frequency is moved to 400 Hz and

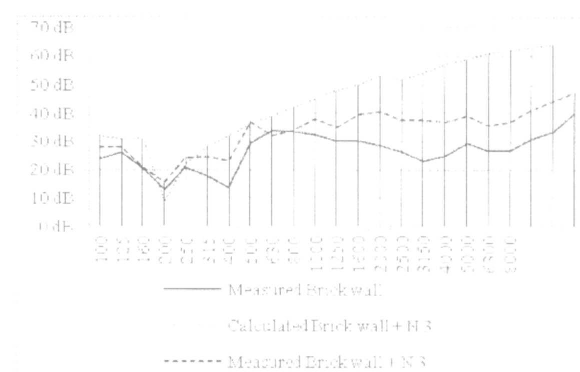

Fig. 7. Comparison between measured and calculated results of sound reduction index of Set I, N3:brick wall + 10mm elastic layer (Ab) + 10 mm fiber board (GF) + 6 point connections

the average sound insulation in mid frequencies is 4 dB (Fig. 8).

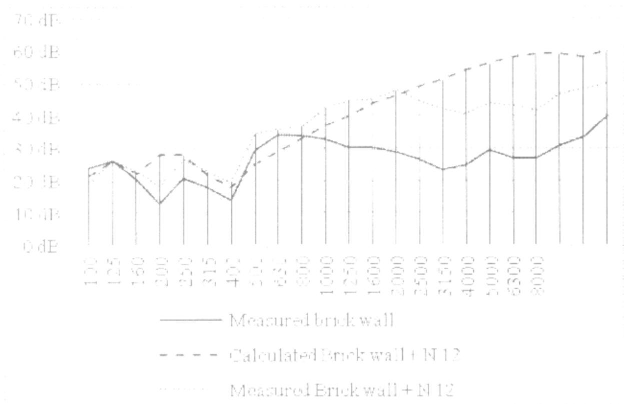

Fig. 8. Comparison between measured and calculated results of sound reduction index of Set IV, N12: brick wall + 10 mm elastic payer (Ab) + 10 mm fiber board (GF) + 6 point connections + 12.5 mm gypsum board (GB)

In all the sets the increase of sound insulation for the range of 125 to 250 Hz is an average of 3 dB compared with the brick wall. The resonance frequency is well predicted from the theoretical model, but there is a big differences for the coincidence region. The influence of point connections is measured - it is beneficial for sound insulation with 1 to 2 dB for low frequencies and declines it with 1 to 2 dB for mid frequencies. For high frequencies there is no change in the behavior. Point connections are necessary for the mechanical strong connection for the added layers because only with glue equal strength cannot be guaranteed. The addition of second mass (gypsum board) gives results up to 500 Hz.

V. Conclusion

From the measured combinations the optimal balance between noise reduction properties and low price can be appointed the system with 20 mm elastic layer plus fiber board 15 mm and final layer of gypsum board (Set III, Measurement 9).

With total thickness of 47.5 mm is achieved increase of natural sound insulation of the brick wall with 12 dB. In contrary of the expectations the use of two added masses with two elastic layers by 10 mm (Set IV, Measurement 12) does not show significantly improved results than Set III - the natural sound insulation index is again 12 dB, but the thicknes is increased to 52.5 mm and the cost increases with almost 30 %.In Set I the achieved natural sound insulation index is 7 dB and the total thickness is 32.5 mm. In Set II the total thickness is 42.5 mm and that natural sound insulation index is 9 dB. All the systems are highly efficient for high frequencies and poorly efficient for mid and low frequencies. On other hand they are various methods of mountage and have a wide range of application in a building constructions.

Acknowledgment

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