Research of Selected Acoustic Descriptors of Two-Layer Sandwich Absorbers

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KEY WORDS
Environmental Noise, Transportation, Noise Wall, Sound Absorption Coefficient, Sound Transmission Loss, Absorber, Sandwich Absorber
ABSTRACT
In spite of existing European and national legislation aimed at noise abatement, public interest and concern about noise are high. The EU Directive 70/157/EEC [13] for setting and controlling environmental noise is aimed at creating less noisy and more pleasant environment for European residents within "Sustainable Development in Europe". The authors are presenting a methodology for measuring selected acoustic descriptors (sound absorption coefficient and sound transmission loss) for acoustic materials, which are currently in process of development. Emphasis is put on sandwich structures of absorbers. Verification results of the proposed methodology are presented.

1. Introduction
In spite of existing European and national legislation, aimed at noise abatement, public interest and concern about noise are high. Directive of EU 70/157/EEC [13] for setting and controlling environmental noise is aimed at creating less noisy and more pleasant environment for European residents within “Sustainable Development in Europe”.

Harmful effects of environmental noise are various and they can be produced in various ways. They can be categorised into three main categories: effects influencing health, impacts on quality of life and financial implications on affected persons.

In the European Union, about 80 million persons are exposed to high noise levels, which are unacceptable or result in sleep disorders and other undesirable influences. There are approximately 170 million people living in the so-called ‘grey regions’, where noise is very annoying.

Transportation causes the main problem in the sphere of noise. In Europe, the first limits of protection against noise were specified for transportation. In this respect, the most important directive is 70/157/EEC [13], limiting noise for vehicles. The EU has only recently started to regulate noise emissions from railway transportation (2002). Limits for air transport are specified mainly at international levels ICAO (International Civil Aviation Organization).

Noise protection measures for reducing the effect of noise caused by transportation (road, railway and air transport) can be passive and active. Active measures try to prevent the origination of noise, while passive measures are adopted only then, when noise arises. Passive noise protection measures can be divided into two groups, namely: measures preventing acoustic noise propagation (noise barriers and/or walls, noise protection embankments and the like) [7].

Attention is paid to the design process and materials used for construction of noise walls and to their properties. The authors have focussed their attention on the research of new acoustic materials made on the basis of recycled raw materials and applicable for the structures of sandwich absorbers (two-layer and multiple-layer absorbers).

The paper presents a proposed methodology for measuring selected acoustic descriptors (the sound absorption coefficient α and the sound transmission loss TL) [1].

2. Proposal of Methodology for Measuring
Selected Acoustic Descriptors of Acoustic
Materials, which are Currently in Process of Development

Out of several possible acoustic descriptors, the authors have focused their attention on the two following descriptors:

- sound absorption coefficient (α),
- transmission loss (TL).

For measuring the sound absorption coefficient (α) and the transmission loss (TL) there are two theoretically available methods, namely: the method of standing wave ratio and the method of transfer function. The authors have used in their work the method of transfer function [9]. This method can be used for measuring the sound absorption coefficient, the reflection factor, the normal impedance and the normal admittance. Based on this method is the impedance tube (Fig. 1).

The proposed methodology of measurement in-
3. Verification of the Proposed Methodology for Measuring Acoustic Descriptors for Acoustic Materials, which are Currently in Process of Development

The proposed methodology of measurement was verified by measuring selected acoustic descriptors, namely: the sound absorption coefficient (\(\alpha\)) and the transmission loss (TL) for the materials, which are currently in process of development.

3.1 Instruments, Software and other Equipment

The system for measuring the sound absorption coefficient (\(\alpha\)) (for the frequency bands of 100 Hz to 800 Hz and 400 Hz to 2500 Hz, respectively) is shown in Fig. 6. It is comprised of a tube with inner diameter of 60 mm – SW060-L and of a holder of the tested sample with inner diameter of 60 mm – SW060-S.

The system for measuring the sound absorption coefficient (\(\alpha\)) (for the frequency bands of 800 Hz to 6300 Hz) is shown in Fig. 7. It is comprised of a tube with inner diameter of 60 mm – SW060-L, of a tube with inner diameter of 30 mm – SW030-L and of a holder of the tested sample with inner diameter of 30 mm – SW030-S.

The system for measuring the transmission loss (TL) (for the frequency bands of 100 Hz to 800 Hz and 400 Hz to 2500 Hz, respectively) is shown in Fig. 8. It is comprised of a tube with inner diameter of 60 mm – SW060-L and of an extension piece of the tube with inner diameter of 60 mm – SW060-E.

The system for measuring the transmission loss (TL) (for the frequency bands of 1600 Hz to 6300 Hz) is shown in Fig. 9. It is comprised of a tube with inner diameter of 60 mm – SW060-L and of a holder of the tested sample with inner diameter of 60 mm – SW060-S.
Fig. 2: Methodology for measuring selected acoustic descriptors [1].

Fig. 3: Methodology for measuring selected acoustic descriptors (continued) [1].

Fig. 4: Methodology for measuring selected acoustic descriptors (continued) [1].

Fig. 5: Methodology for measuring selected acoustic descriptors (continued) [1].
inner diameter of 60 mm – SW060-L, of a tube with inner diameter of 30 mm – SW030-L and of an extension piece of the tube with inner diameter of 30 mm – SW030-E.

3.2 Selection of Materials for the Experimental Part
The selected acoustic descriptors (the sound absorption coefficient $\alpha$, the transmission loss $TL$) were measured for the following acoustic materials, which are currently in process of development:
- **Ekomolitan (Fig. 10)** [2,3,5]
- **Recycled rubber (Fig. 11)** [2,3,6]
Measurement were also carried out, for comparison, for the material Nobasil (Fig. 12), which is a component part of various sandwich structures of noise walls (barriers).

3.3 Preparation of Test Samples
The test samples of the two-layer sandwich absorbers were prepared in various combinations of materials, such as Ekomolitan, Nobasil and recycled rubber (Figs. 13. a 14.). Dimensions of the test sample:

3.4 The Measured Values of the Sound Absorption Coefficient and of the Transmission Loss
This part of the paper presents outputs from the measurement of the sound absorption coefficient carried out for a two-layer sandwich test sample composed of 2 cm thick recycled rubber positioned closer to the sound source and of 2 cm thick Ekomolitan positioned at the end (Fig. 15.) [1], as well as outputs from the measurement of transmission loss for a two-layer sandwich having the same material composition (Fig. 16.) [1].
Fig. 15: Display of the sound absorption coefficient for a two-layer material, composed of 2 cm thick recycled rubber positioned closer to the sound source and of 2 cm thick Ekomolitan positioned at the end.

Fig. 16: Display of the transmission loss for a two-layer material, composed of 2 cm thick recycled rubber positioned closer to the sound source and of 2 cm thick Ekomolitan positioned at the end.
4. Conclusion - Evaluation of Measured Values

The sound absorption coefficient ($\alpha$) is a dimensionless number varying from 0 to 1. The closer is the measured value to 1 or is equal to 1, the sample of the measured absorber, and thus the absorber itself, will have a better (higher) sound absorption [4,10,14].

We have also measured the transmission loss (TL). It is a value in dB, based on the ratio of the sound wave incident at the front side of the acoustically absorbing material to the sound waves transmitted from the rear side. TL represents the sound damping properties of the material, i.e. the higher that value is, the more efficient is the damping of the sound.

The authors have measured the coefficient of sound absorption ($\alpha$) and the transmission loss (TL) for various combinations of two-layer sandwich absorbers composed of materials such as Ekomolitan, recycled rubber and Nobasil. Table 1 includes the measured values of descriptors.

The frequency spectrum of noise caused by transportation reaches its maximum in the frequency range of 500 Hz to 1500 Hz, and the most intensive noise is caused at the frequency of 1000 Hz [10,11,12].

Noise walls (barriers) are often constructed as noise panels with a supporting frame using sandwich absorbers. For the purpose of the thesis, samples representing a sandwich composed of materials such as recycled rubber, Nobasil and Ekomolitan were made. The arrangement of individual layers of the sandwich was different. Measurements have been carried out for two-layer sandwiches. (Fig.17 and Fig. 18).

It follows from the measured values of the sound absorption coefficient of the sandwich absorbers that the sequence of individual layers (of utilized

Table 1: The values of the materials with thickness of 4 cm.

| Frequency [Hz] | Koeficient zvukovej pohľadivosti $\alpha$ [-] | Prenosový útlm TL [dB] |
|---------------|-----------------------------------|------------------|
|               | Recykl. guma + Nobasil | Nobasil + Recykl. guma | Recykl. guma + Ekomolitan | Nobasil + Ekomolitan | Recykl. guma + Nobasil | Nobasil + Recykl. guma | Recykl. guma + Ekomolitan | Nobasil + Ekomolitan |
| 100           | 0.022 0.100 0.042 0.060 0.044 0.121 | 13.822 13.911 6.391 6.442 13.144 13.170 |
| 125           | 0.095 0.109 0.096 0.065 0.109 0.153 | 13.685 13.902 6.588 6.586 13.137 13.277 |
| 160           | 0.135 0.136 0.107 0.078 0.130 0.232 | 13.703 13.881 6.806 6.806 13.200 13.289 |
| 200           | 0.206 0.193 0.144 0.097 0.180 0.290 | 13.733 13.922 6.604 7.091 13.259 13.371 |
| 250           | 0.295 0.246 0.221 0.120 0.247 0.345 | 13.782 14.000 7.170 7.384 13.402 13.171 |
| 315           | 0.425 0.311 0.330 0.159 0.318 0.404 | 13.858 14.106 7.680 7.264 13.143 13.300 |
| 400           | 0.571 0.382 0.497 0.216 0.457 0.461 | 14.035 14.261 8.184 8.057 13.413 13.600 |
| 500           | 0.675 0.451 0.689 0.294 0.582 0.503 | 14.202 14.323 8.375 8.387 13.660 13.789 |
| 630           | 0.747 0.507 0.855 0.412 0.689 0.542 | 14.239 14.559 8.869 8.831 14.095 14.137 |
| 800           | 0.709 0.562 0.794 0.574 0.789 0.565 | 15.101 14.882 9.497 9.412 14.751 14.659 |
| 1000          | 0.622 0.596 0.623 0.762 0.699 0.579 | 16.557 16.126 10.057 10.069 15.410 15.726 |
| 1250          | 0.540 0.603 0.474 0.905 0.900 0.677 | 18.928 18.146 10.599 10.616 13.146 12.540 |
| 1600          | 0.460 0.655 0.367 0.924 0.932 0.709 | 17.095 16.483 11.146 11.260 16.576 16.346 |
| 2000          | 0.406 0.718 0.314 0.870 0.944 0.685 | 20.952 20.038 11.840 11.957 18.131 17.675 |
| 2500          | 0.381 0.722 0.327 0.933 0.969 0.709 | 27.005 23.036 12.547 12.838 20.360 20.291 |
| 3150          | 0.456 0.747 0.465 0.999 0.958 0.779 | 19.843 23.555 12.794 12.676 23.451 23.243 |
| 4000          | 0.598 0.792 0.679 0.949 0.935 0.810 | 23.324 26.717 12.936 13.143 26.127 26.120 |
| 5000          | 0.650 0.827 0.599 0.906 0.929 0.838 | 28.611 29.171 15.241 15.374 28.525 28.062 |
| 6300          | 0.632 0.858 0.564 0.940 0.955 0.862 | 28.947 30.473 17.970 17.585 30.782 32.385 |
materials) is of crucial importance. The sequence of the sandwich layers of the measured materials, starting from the noise source (for the frequency of 1000 Hz), is recommended as follows:

- **Ekomolitan + Nobasil**,  
- **Ekomolitan + recycled rubber**,  
- **Recycled rubber + Nobasil**.

It can be stated on the basis of the measured values of transmission loss of the sandwich absorbers (Fig. 18.) that the sequence of individual layers of materials utilized in the sandwich is also of crucial importance.

The sequence of the sandwich layers of the measured materials utilized for two-layer sandwiches, starting from the noise source, is recommended as follows:

- **Recycled rubber + Nobasil**,  
- **Recycled rubber + Ekomolitan**,  
- **Nobasil + Ekomolitan**.

![Fig. 17: Sound absorption coefficient of two-layer sandwiches (total thickness of the sandwiches: 4 cm) [1].](image1)

![Fig. 18: Transmission loss of two-layer sandwich absorbers (total thickness of the sandwiches: 4 cm) [1].](image2)

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