BARTKO Ladislav, Ing., PhD.[1]
KONKOLY Tomáš, Ing.[2]
BADIDA Miroslav, Dr.h.c. prof. Ing., PhD.[3]
[1,3]Technical Univerzity in Košice, Faculty of Mechanical Engineering, Department of Process and Environmental Engineering, Park Komenského 5, 042 00 Košice, Slovak Republic
[2]MagnetiMarelli Slovakia, s.r.o., Industrial Park, 044 58 Kechnec, Slovak Republic

RESEARCH OF ACOUSTIC DESCRIPTORS OF SANDWICH ABSORBERS

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 [11] 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.
Keywords: *environmental noise, transportation, noise wall, sound absorption coefficient, sound transmission loss, absorber, sandwich absorber*

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 [11] 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 [11], 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) [12].

Attention is paid to the design process and materials used for construction of noise walls and to the irproperties. 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),

- transmissionloss (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. 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).

Fig. 1 The impedance tube

The proposed methodology of measurement includes the use of the impedance tube, two positions of positioning the microphones and the system of numerical frequency analysis for determining the sound absorption coefficient of sound absorbers for normal incidence of sound. It can also be applied for determining acoustic surface impedance or acoustic surface admittance for sound absorbing materials, due to the fact that the impedance ratios of sound absorbing materials are proportional to their physical properties, such as airflow resistance, porosity, elasticity and density.

This test method is similar to the test method specified in STN EN ISO 10534-1 [4] in terms of using an impedance tube with a sound source connected to one of its ends and a test specimen mounted into the tube at its other end. However, the actual test method is different. In this test method the plane waves are generated in the tube by the sound source and the decomposition of the interference field is achieved by measuring acoustic pressures in two fixed positions of microphones mounted on the wall of the tube or by a microphone shifted in the tube and the subsequent calculation of the complex acoustic transfer function, by absorption at normal incidence and by impedance ratios of the acoustic material. This test method is designated to provide an alternative method of measurement, in general much faster than that included in STN EN ISO 10534-1[4].

The proposal of methodology for measuring selected acoustic descriptors by using an impedance tube and by applying the method of transfer function is presented in Figs. 2, 3, 4 and 5.
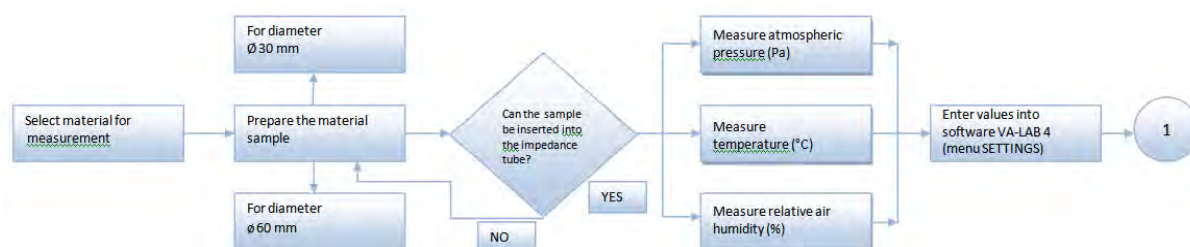

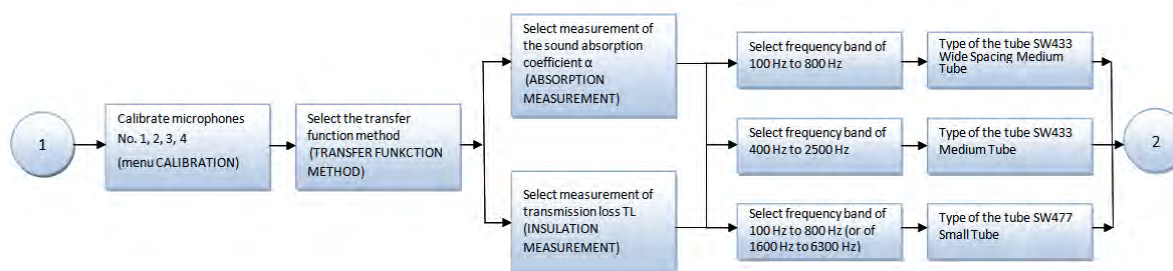*Fig. 2 Methodology for measuring select ed acoustic descriptors*

Fig. 3 Methodology for measuring select ed acoustic descriptors (continued)
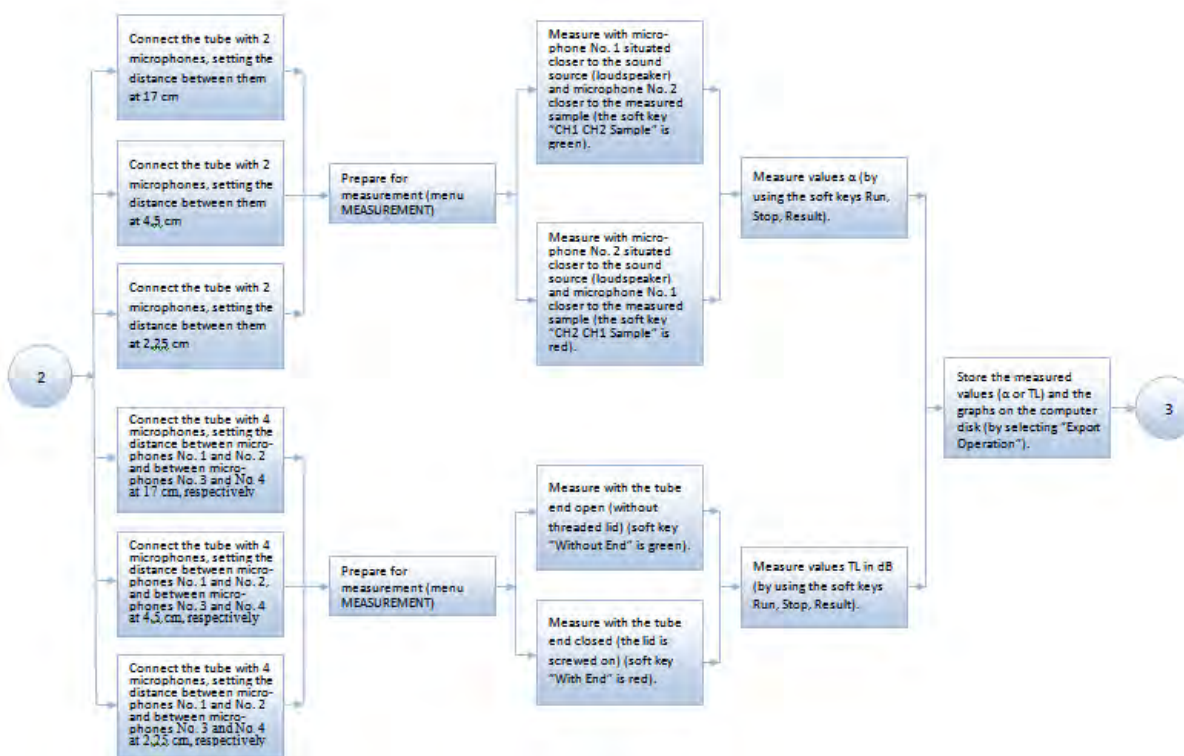

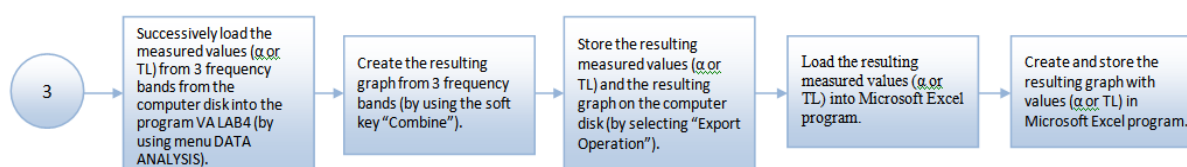*Fig. 4 Methodology for measuring select ed acoustic descriptors (continued)*

Fig. 5 Methodology for measuring select ed acoustic descriptors (continued)

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 (α) and the transmission loss (TL) for the materials, which are currently in process of development.

Instruments, software and other equipment

The system for measuring the sound absorption coefficient (α) (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
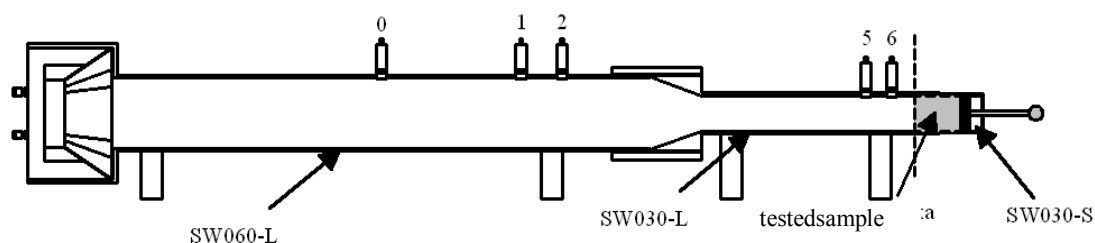
a tube with inner diameter of 60 mm – SW060-L and of a holder of the tested sample with inner diameter of 60 mm – SW060-S.
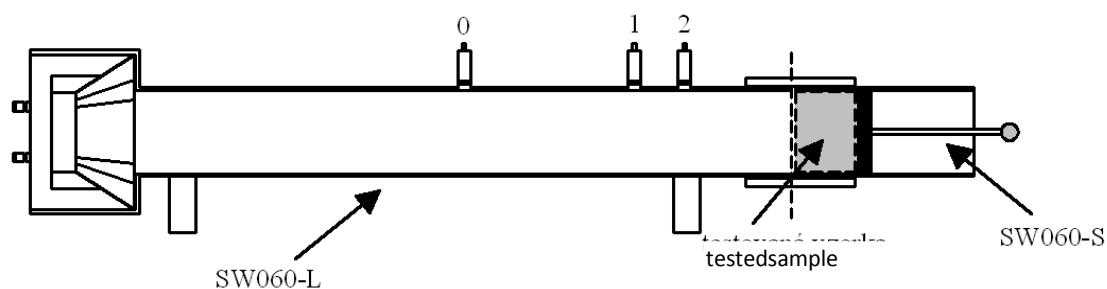
Legend: 0, 1, 2 – mounting sockets for microphones
Fig. 6 The system for measuring the sound absorption coefficient
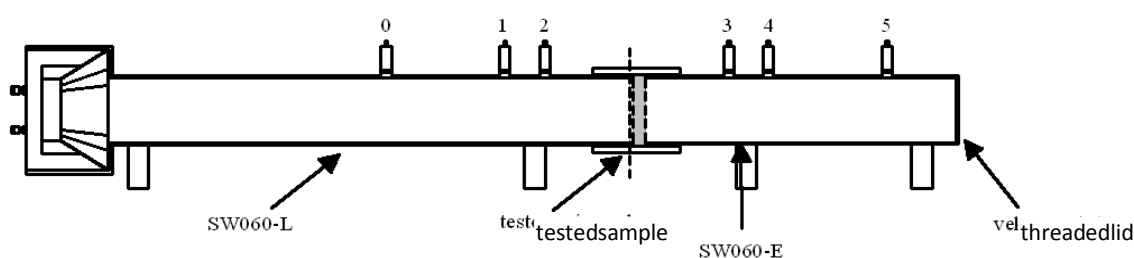*(100 Hz to 800 Hz and 400 Hz to 2500 Hz, respectively)*

The system for measuring the sound absorption coefficient (α) (for the frequent cybands 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.

Legend: 0, 1, 2, 5, 6 – mounting sockets for microphones
Fig. 7 The system for measuring the sound absorption coefficient (800 Hz to 6300 Hz)
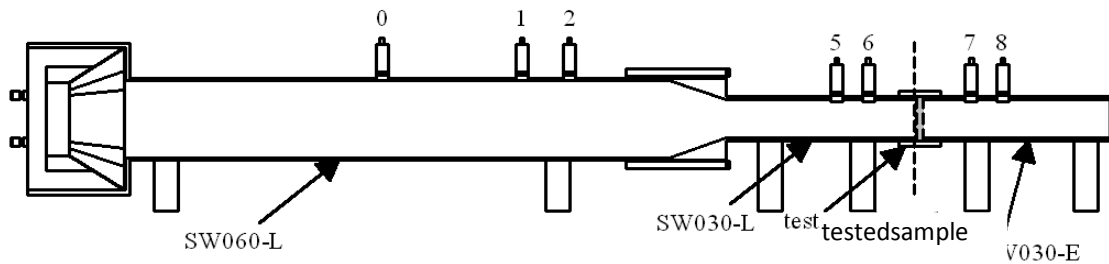
The system for measuring the transmission loss (TL) (for the frequent cybands of 100 Hz to 800 Hz and 400 Hz to 2500 Hz, respectively) is shown in Fig. 8. It is comprised of a tube with inner diameter of 60 mm – SW060-L and of an extension piece of the tube with inner diameter of 60 mm – SW060-E.

Legend: 0, 1, 2, 3, 4, 5 – mounting sockets for microphones
Fig. 8 The system for measuring the transmission loss TL
(100 Hz to 800 Hz and 400 Hz to 2500 Hz, respectively)

The system for measuring the transmission loss (TL) (for the frequen cybands 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, of a tube with inner diameter of 30 mm – SW030-L and of anextension piece of the tube with inner diameter of 30 mm – SW030-E.

Legend: 0, 1, 2, 5, 6, 7, 8 – mounting sockets for microphones

Fig. 9 The system for measuring the transmission loss TL (1600 Hz to 6300 Hz)

Selection of materials for the experimental part

The selected acoustic descriptors (the sound absorption coefficient α, the transmission loss TL) were measured for the following acoustic materials, which are currently in process of development:

- Ekomolitan (Fig. 10)
- Recycled rubber (Fig. 11)[2]

Fig. 10 Ekomolitan   *Fig. 11 Recycled rubber*

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).

Fig. 12 Nobasil

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.).
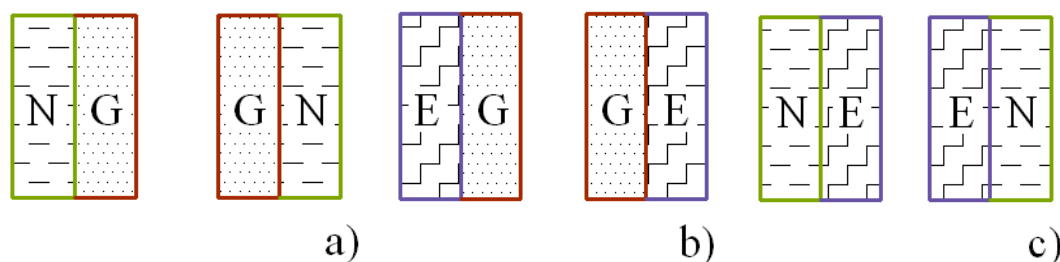
Legend: N – Nobasil, G – recycled rubber,   E – Ekomolitan

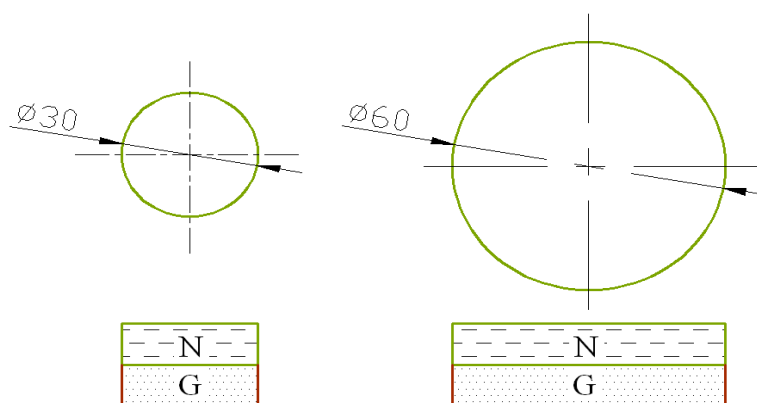*Fig.13 Two-layer sandwich samples*

Dimensions of the test sample:

Fig.14 Dimensions of the two-layer test sample

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 co-efficient 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.), as well as outputs from the measurement of transmission loss for a two-layer sandwich having the same material composition (Fig. 16.) [1].

4 CONCLUSION – EVALUATION OF MEASURED VALUES

The sound absorption coefficient (α) 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.

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 (α) 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.

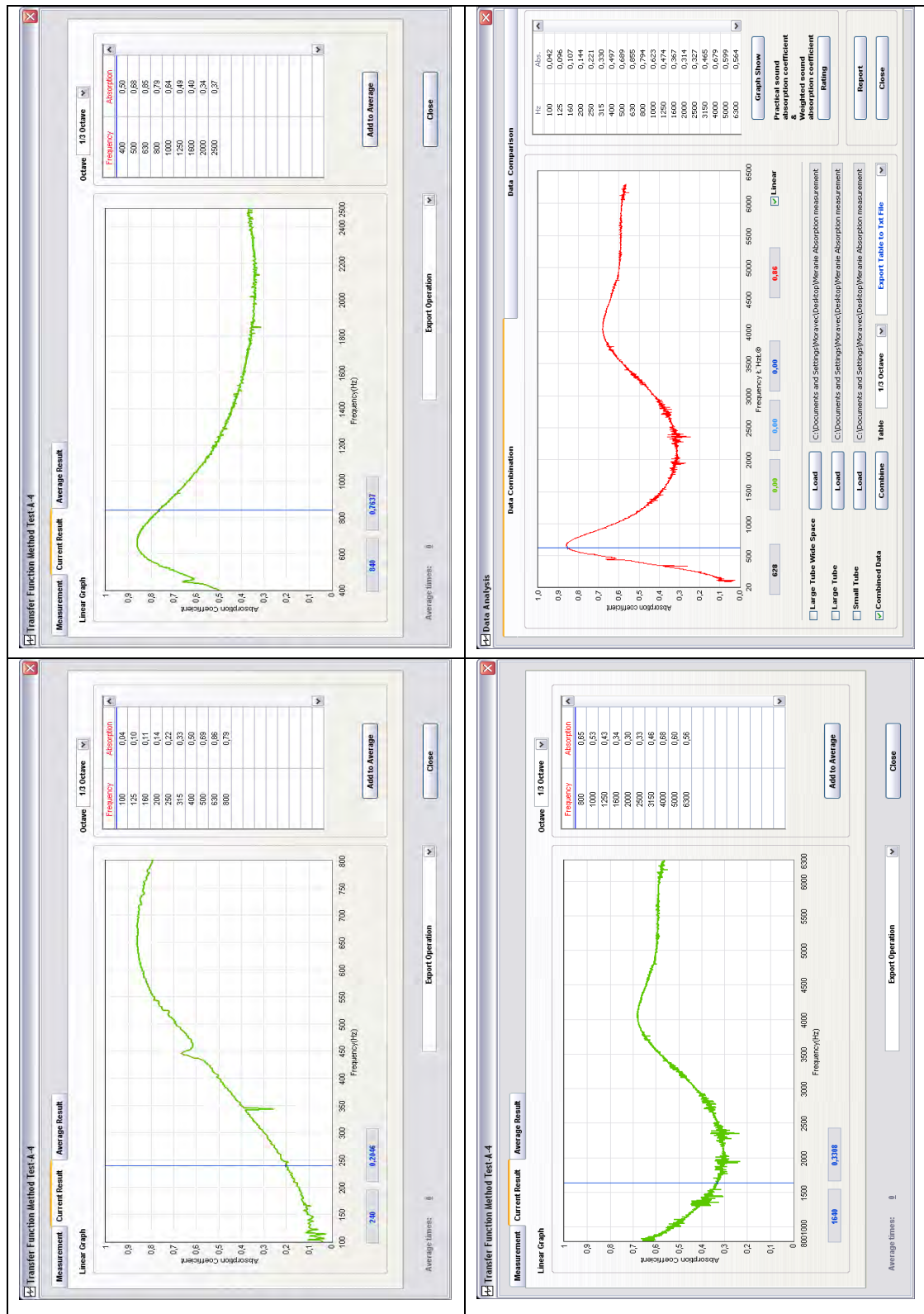*Fig. 15 Display of the sound absorption coefficient for a two-layer material, composed of 2 cm thick recycled rubber positioned closer to the sound Source and of 2 cm thick Ekomolitan positioned at the end*
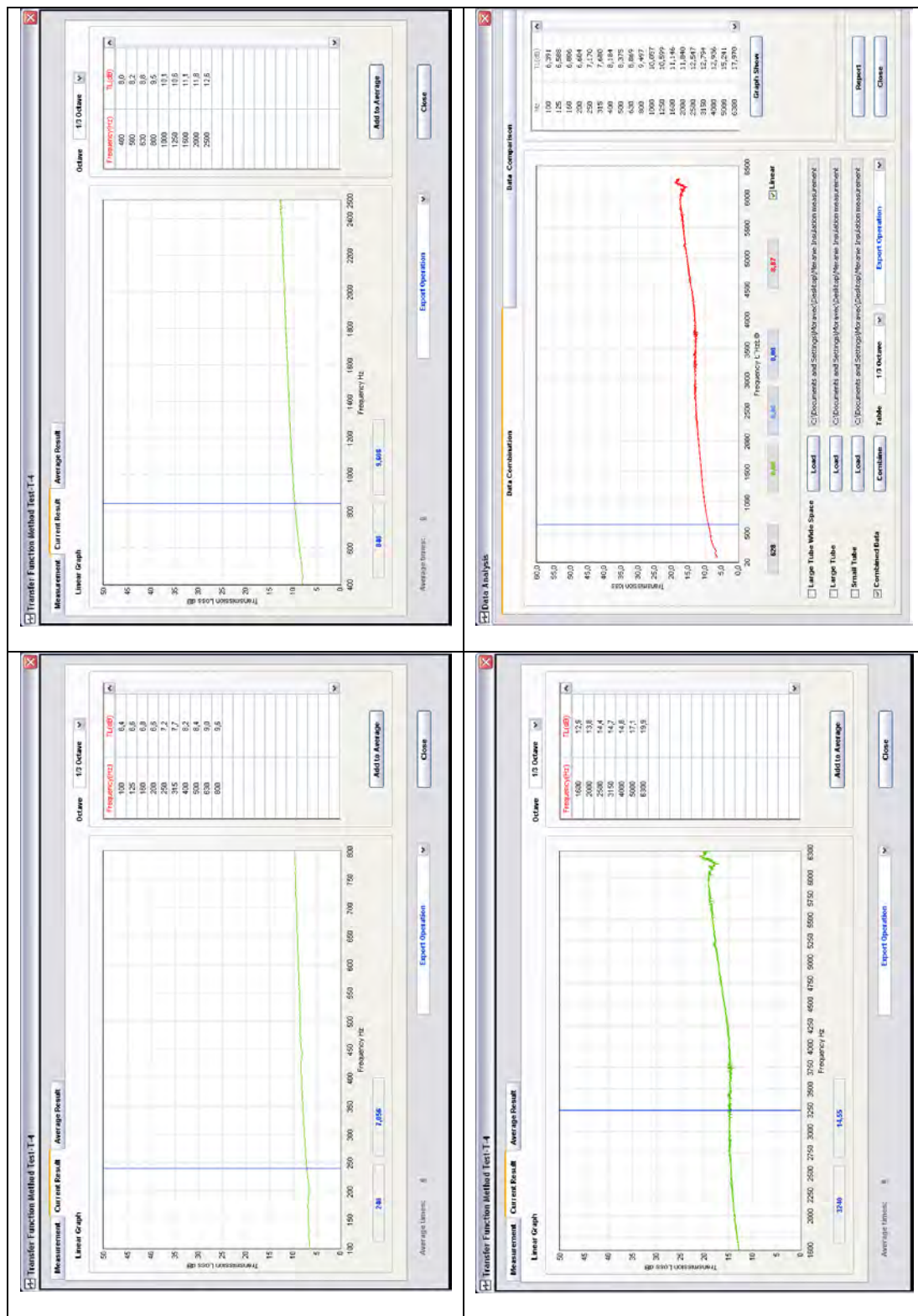
Fig. 16 Display of the transmission loss for a two-layer material, composed of 2 cm thick recycled rubber positioned closer to the sound source and of 2 cm thick Ekomolitan positioned at the end

Table 1

The values of the materials with thickness of 4 cm

Frequency f [Hz]	Sound absorption coefficient α [-]						Transmission loss TL [dB]					
	Recycled rubber + Nobasil	Nobasil + Recycled rubber	Recycled rubber + Ekomolitan	Ekomolitan + Recycled rubber	Ekomolitan + Nobasil	Nobasil + Ekomolitan	Recycled rubber + Nobasil	Nobasil + Recycled rubber	Recycled rubber + Ekomolitan	Ekomolitan + Recycled rubber	Ekomolitan + Nobasil	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	0,855	0,592	16,537	16,126	10,057	10,044	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

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.

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 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,
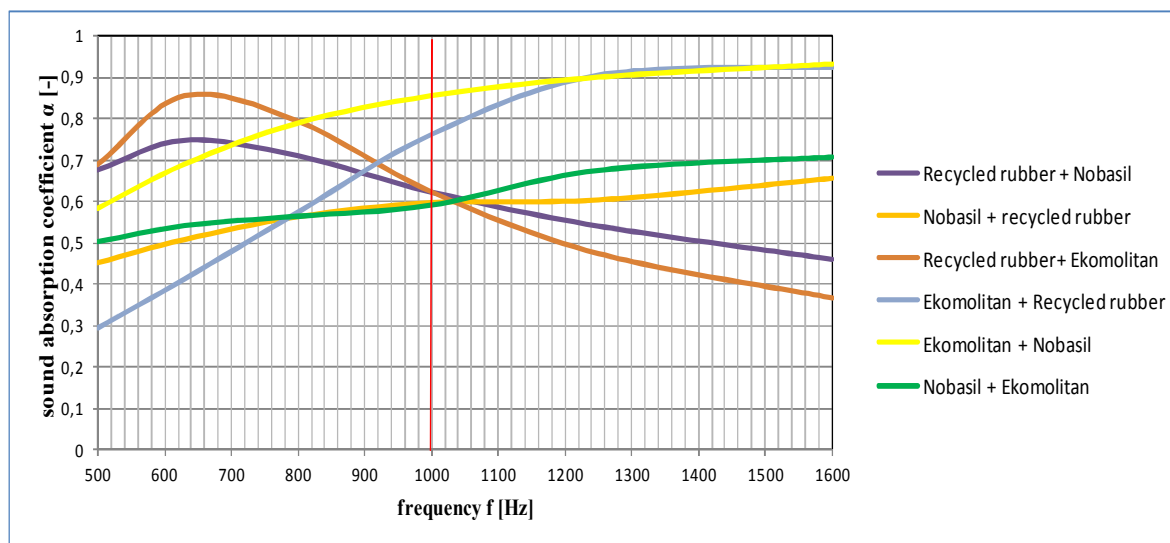- Recycled rubber + Nobasil.

Fig. 17Sound absorption coefficient of two-layer sandwiches (total thickness of the sandwiches: 4 cm)

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.
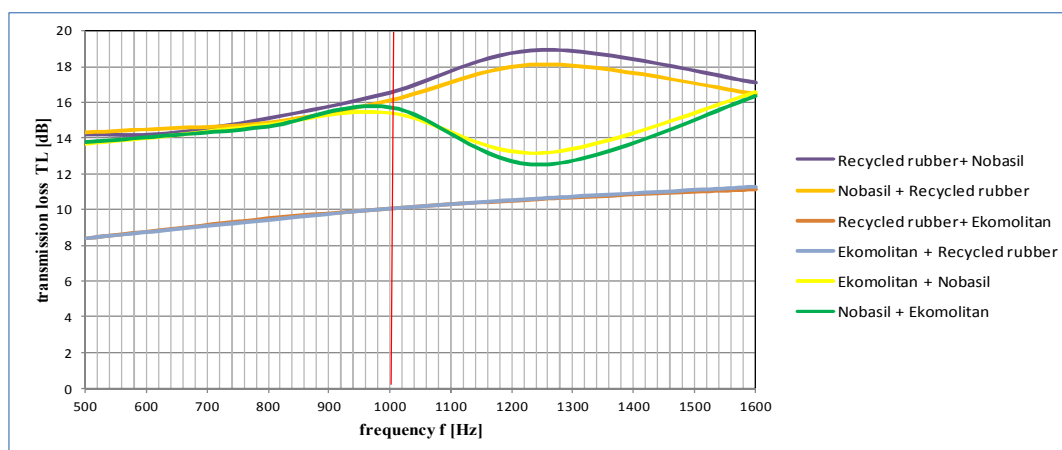

Fig. 18Transmission loss of two-layer sandwich absorbers
(total thickness of the sandwiches: 4 cm)

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.

References

[1]   BADIDA, M. – LUMNITZER, E. – BARTKO, L.: Možnosti znižovania dopravného hluku. Košice: Elfa, 2011. 303 s. ISBN 978-80-8086-181-0.

[2]   MATEL, F. – OCHOCOVÁ, R. – BADIDA, M. – LUMNITZER, E.: Kompaktné prvky z gumárenského recyklátu vyrobené technológiou mikrovlnného ohrevu. Úrad Priemyselného Vlastníctva SR, Banská Bystrica, 2003.

[3]   STN EN ISO 10534-1: 1996, Akustika. Určovanie koeficienta zvukovej pohltivosti a akustickej impedancie v impedančných trubiciach. Časť 1: Metóda použitia stojatej vlny.

[4]   STN EN ISO 10534-2: 1998, Akustika. Určovanie koeficienta zvukovej pohltivosti a akustickej impedancie v impedančných trubiciach. Časť 2: Metóda transformačnej funkcie.

[5]   STN ISO 10847: 2000, Akustika. Stanovenie vložného útlmu vonkajších protihlukových bariér všetkých typov na mieste trvalého uloženia (in situ).

[6]   STN EN 1793-1: 1997, Zariadenia na zníženie hluku z cestnej dopravy. Skúšobné metódy určovania akustických vlastností. Časť 1: Určenie zvukovej pohltivosti.

[7]   STN EN 1793-2: 1997, Zariadenia na zníženie hluku z cestnej dopravy. Skúšobné metódy určovania akustických vlastností. Časť 2: Určenie vzduchovej nepriezvučnosti.

[8]   STN EN 1793-3: 1997, Zariadenia na zníženie hluku z cestnej dopravy. Skúšobné metódy určovania akustických vlastností. Časť 3: Normalizované spektrum dopravného hluku.

[9]   Nariadenie vlády SR č. 115/2006 Z. z., o minimálnych zdravotných a bezpečnostných požiadavkách na ochranu zamestnancov pred rizikami súvisiacimi s expozíciou hluku.

[10]   Nariadenie vlády SR č. 339/2006 Z. z., ktorým sa ustanovujú podrobnosti o prípustných hodnotách hluku, infrazvuku a vibrácií a o požiadavkách na objektivizáciu hluku, infrazvuku a vibrácií.

[11]   Smernica Rady EÚ zo 6. februára 1970 o aproximácii právnych predpisov členských štátov o prípustnej hladine hluku a o výfukových systémoch motorových vozidiel. [online] [cit 2014-11-21]. Dostupné na internete:
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31970L0157:sk:NOT

[12]   Ministerstvo dopravy, pôšt a telekomunikácií SR. Použitie, kvalita a systém hodnotenia protihlukových stien. Účinnosť od: 01-12-2006. [online] [cit 2014-02-01]. Dostupné na internete:
http://www.telecom.gov.sk/files/doprava/dopinfra/cesinfra/tech_predpisy/2006/tp_08_2006_.pdf

[13]   BARTKO, Ladislav – VARGOVÁ, Jana: Zásady navrhovania a materiály vhodné pre konštrukciu protihlukových stien. In: Ekológia a environmentalistika : zborník príspevkov doktorandov zo 7. Študentskej vedeckej konferencie : 24. mája 2010, Zvolen. Zvolen : TU, 2010. s. 21-27. ISBN 978-80-228-2111-7.

[14]   BARTKO, Ladislav – VARGOVÁ, Jana: Analýza prístupov ku konštrukčnému a materiálovému riešeniu protihlukových stien. In: Ochrana životného prostredia pred hlukom : zborník z odborného seminára: Hodnotenie kvality prostredia 2010 : zborník z konferencie : 1. ročník odborného seminára a konferencie s medzinárodnou účasťou : zborník príspevkov : 22.-23. september 2010, Košice. Košice : TU, SjF, 2010. s. 138-143. ISBN 978-80-553-0489-2.