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EXPERIMENTAL ANALYSES OF NOISE MITIGATION CHARACTERISTICS FOR LOW DENSITY CELLULOSE COMPOSITES

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Abstract: *The paper presents a set of experimental analyses regarding acoustics characteristics of the low density cellulose (LDC) composites in order to evaluate the availability of these materials for using within noise control applications (sound absorption or barrier applications). Four types of LDC were considered, and two type of reference polymeric material as expanded/extruded polystyrene (EPS/XEPS) was supposed in order to facilitate comparative analysis of the final results. The experimental tests were developed based on laboratory setup containing two types of conventional impedance tubes, with four-microphone configuration and anechoic termination. The evaluations of normal incidence transmission and reflection coefficients, and a variety of other acoustical characteristics, fill the objective of this study. The experimental results denote comparable performances between proposed LDC composites and reference polystyrene-based specimens.*
Keywords: *sound transmission loss, sound absorption, low density cellulose composites, noise control, experimental analysis.*

1. INTRODUCTION

This study deals with the area of new materials intended for enabling higher levels of noise control within the sound absorption and barrier applications. Composites based on recycled materials, or from renewable sources, gain much concerning in actual research within various science and engineering fields. As a direct consequence of this trend, the nowadays research regarding the noise insulation serviceable solutions based on recycled materials acquires leading positions.

Hereby, a few actual investigations regarding the researches within the area of recycled materials utilization for acoustics insulation applications will be mentioned as follows. In works [1] the sound absorption properties of different materials developed from ground polyurethane foam waste are studied. Examination of the acoustical characteristics of a range of natural fibres has confirmed their effectiveness as porous sound absorbers [2]. In the study [3], hemp concretes made of different binders and different kinds of particles were characterized. The papers [4,5] presents an updated survey of the acoustical properties of sustainable materials for noise control, either natural or recycled. The study [6] was performed to introduce new sound absorbing materials and discuss their acoustical characteristics, looking also at the efficiency of sound absorber natural (green materials) as an alternative to commercial materials. Stanciu et al. [7] investigate the variation curves for acoustic properties of new materials made from mixture of wood particles and textile waste with different types of binders. Iannace and Berardi [8] shown that plant fibers provide a valid raw material for making sound absorbing panels at a reduced cost. The paper [9] presents research on developing new types of composite materials, in order to improve the acoustic comfort of an enclosure, using several wastes (fir sawdust, beech sawdust and particles of recycled rubber) and polyurethane binder as a matrix. In the work [10] was presented an evaluation of the sustainability of certain traditional insulating materials that are largely used in building acoustics, and presents the acoustic performances of alternative materials recommended for their "sustainable" properties.

In particular, the cellulose fibres take hold of an important segment in acoustics insulation and noise control theoretical and experimental research. Arenas et al. [11] used different samples of a single layer of loose-fill cellulose insulation with different thicknesses and measured their sound absorption properties, the airflow resistivity and porosity for both dry and moist samples, and shown that sound absorption properties are similar to those of the mineral fiber-based materials. In the works [12], a manufacturing procedure, originally devoted to porous ceramic, is reused in order to obtain a hybrid acoustic absorber with both cellulose and silica aerogel. Nguyen et al. [13] carried out investigations on green aerogels synthesized from recycled cellulose fibers. In their study, Jahangiri et al. [14] analyzed freeze-dried foam-formed products using nanofibrillated fibres in terms of sound absorption coefficient, and the results show that the acoustic properties of foam-formed materials using nanofibrillated fires are much greater than the standard NBSK foam-papers.

Besides the actual studies regarding new solutions based on green and recycled materials, intended for noise insulation, the applicable research within this area also acquire significant level. Hereby, theoretical and experimental investigations regarding the composites from recycled materials utilization in order to control sound insulation of noise pollutant technological places and equipments cabins was particularly presented in the works [15,16,17,18].

This study presents a set of assessments based on experimental analyses regarding the transmission and absorption coefficients of *low density cellulose* (LDC) composites, based on various percentage mixtures between pure cellulose and recycled paper fibres. Four types of LDC were considered in order to produce the basic composites, and two types of reference polymeric material as *expanded/extruded polystyrene* (EPS/XEPS) was supposed, enabling the comparison within the final results.

2. EXPERIMENTAL ANALYSIS

For this experimental analysis, the authors had proposed some composites based on LDC, produced in foam laid media, air dried freely at the room temperature for a time period between 24 and 48 hours [19]. No pressing procedure was used. According with the notations within Figure 1, the probe codes have the meanings as follows: (1) denotes the *air dried foam fibre* (ADFF) composite from 100% *cellulose fibres* with high purity, (4) denotes ADFF composite with 50% *cellulose fibres* and 50% *fibres from recycled paper*, (3S) means the ADFF composite based on 100% *fibres from recycled paper*. The fourth proposed composite LDC-based, coded (2C) – see Fig.1(a) – is a cellulose composite produced by *traditional papermaking process* – formation and dewatering – based on 100% *fibres from recycled paper*. The reference samples codes means EPS polymer (2) and XEPS polymer (4) respectively – see Fig.1(b). In this study, for reference specimens will be used (EPS) and (XEPS) codes respectively, in order to avoid confusions.

(a)

(b)

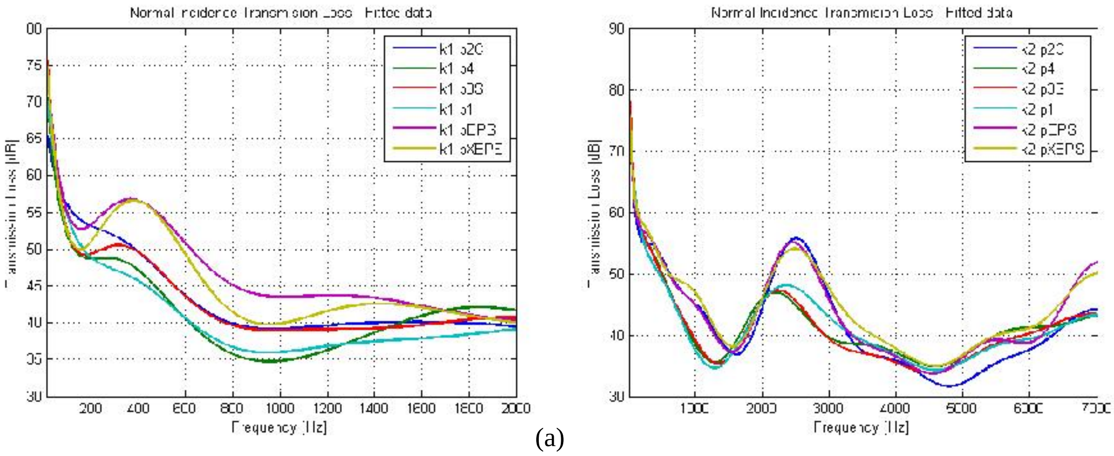
Figure 1: Samples of LDC composites (a) and
reference samples based on EPS/XEPS (b) – see text for coding details

The experimental tests was developed using a laboratory setup based on two types of conventional impedance tubes (see Fig. 2.a). Both tubes, with 100 and 28.5 mm diameter respectively, have *four-microphone* setup configuration and floating anechoic termination. It was used the "*two-load*" method, based on two different tube load, such as "*nearly–anechoic*" and *free terminations* respectively. Taking into account that the experimental setups provide only four acquisition channels, the first microphone – the closed of noise source within upstream tube – was considered as the reference. The procedure of experimental evaluation for both the normal incidence transmission loss (STL) of the sample, and the other characteristic parameters was basically derived from the one described in paper [20]. Some additional technical aspects regarding the use of the impedance tube and the transfer matrix method approaches, in order to capture and to evaluate the acoustical properties of a fibrous-type material, were also presented in the works [21,22,23]. Digital acquisition was performed by using National Instruments 9233/9162® pair devices (see Fig.2.a), with PCB – 130E20 ICP® Electret Array Microphone (see Fig.2.b), and computational processing was developed based on the Matlab® software. A high sampling rate of 25 kHz was used in order to provide highest accuracy of acquired signals.

(a) (b)

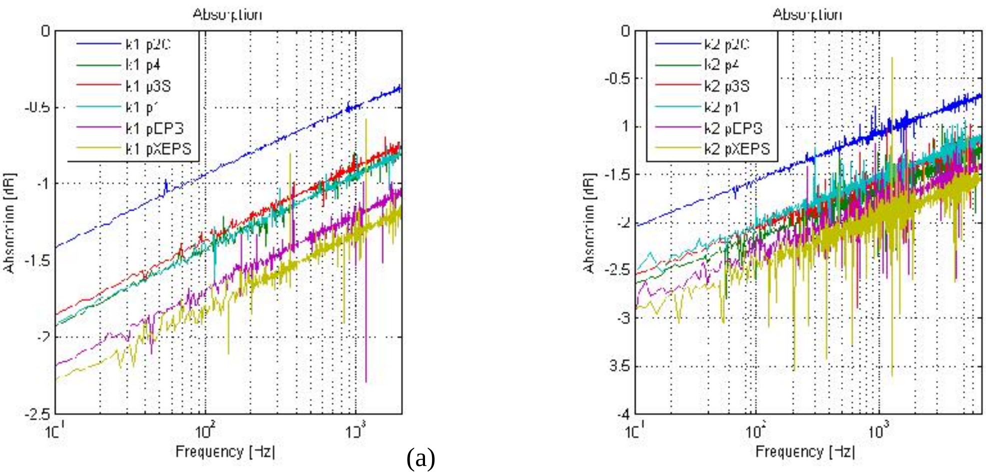
Figure 2: Experimental setup for sound transmission loss measurements:
the large/small tubes (a) and the acoustic transducer – microphone (b)

Based on the four acquired signals of sound pressure within upstream and downstream, respectively, of the sample, it was evaluated a variety of parameters, such as the *normal incidence sound transmission loss*, the *normal incidence reflection* and *transmission coefficients*, the *normal incidence sound absorption* of acoustic material, the *complex wave number*, the *surface normal impedance*, and the *characteristic impedance* of the specimen material, which enabling both global, and particular characterization of the LDC composite availability to be used within noise control applications [20-23]. In this paper, the following characteristics were considered for presentation: normal incidence transmission loss – in order to facilitate comparative analysis it was preferred the fitted data graph, the normal incidence absorption and reflection coefficients, and the sound transmission loss as average values for 1/3 octave band.



(a) (b)

Figure 3: Sound transmission loss within the large tube evaluations (a)
and the small tube evaluations (b) respectively



(a) (b)

Figure 4: Normal incidence absorption within the large tube evaluations (a)
and the small tube evaluations (b) respectively

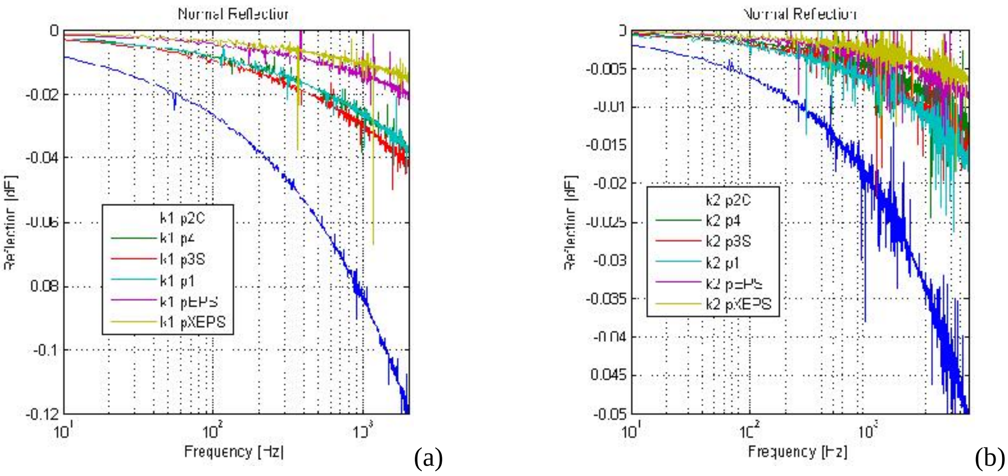


Figure 5: Normal incidence reflection within the large tube evaluations (a) and the small tube evaluations (b) respectively

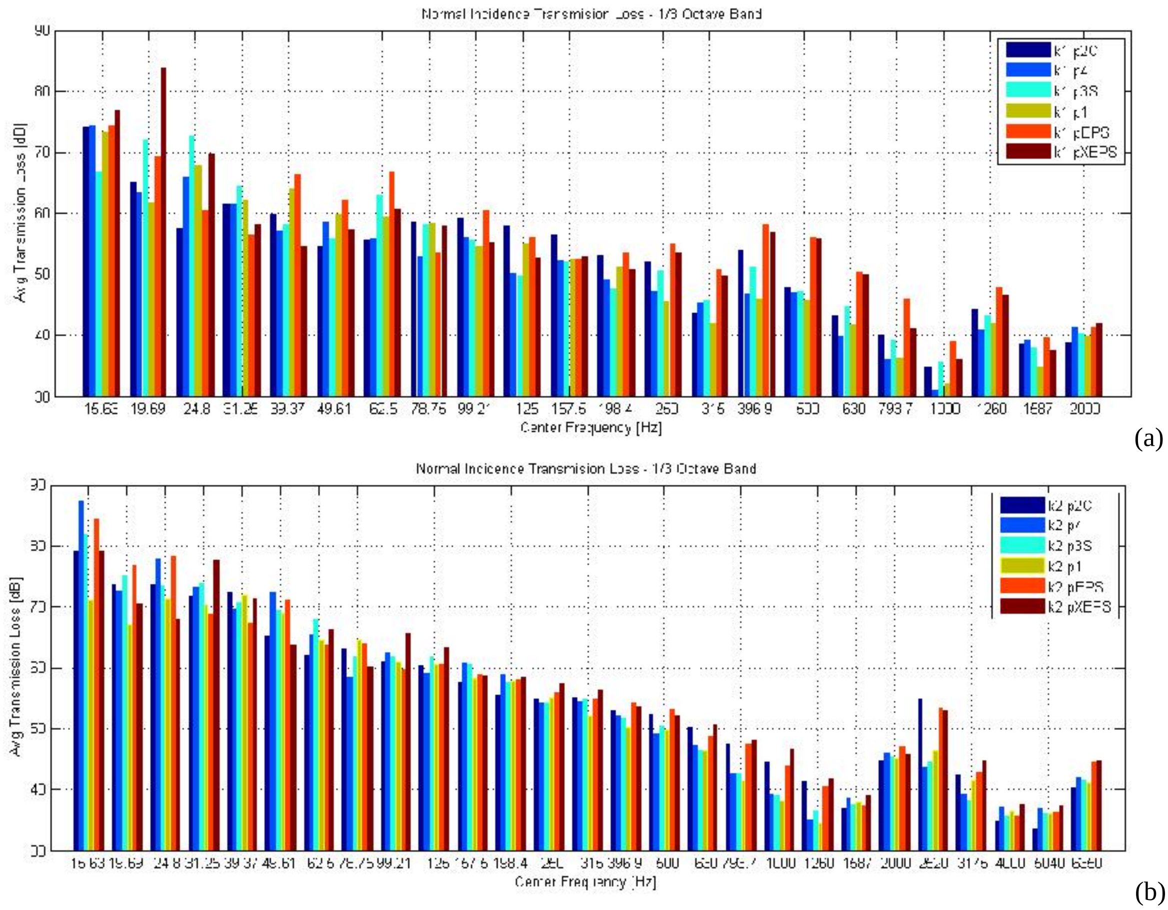


Figure 6: Sound transmission loss in terms of average values for 1/3 Octave Band based on the large tube evaluations (a) and the small tube evaluations (b) respectively

3. RESULTS AND DISCUSSIONS

Taking into account the global evolutions of acoustical coefficients it results a relative constancy of noise control capacity for all the tested materials. The previous observation can be exemplified in terms of high transmission loss (STL) in the range of 10...1000 Hz, with maintaining constant values (35...45 dB) for frequencies greater than 1000 Hz, shown in Fig. 3 diagrams in respect with frequency, as well as in Fig. 6 diagrams in respect with 1/3 octave band. In addition, a general increasing trend of normal incidence absorption coefficient (α), in the same time with a decreasing trend of normal incidence reflection coefficient (R) can be deducted from the Figs. 4 and 5. These concluding remarks put into the evidence a qualitative comparative analysis of the experiments.

On the other hand, a quantitative comparative investigation of acoustical coefficients in Figs. 3...6 reveals a relative grouping trend of materials. Hereby, the STL coefficients of reference specimens (EPS and XEPS) acquire greater values for almost frequency range of analysis, followed by (2C) sample, which provides much closed STL values for low frequencies (< 200 Hz) and also in the range of 2...4 kHz. In the same time, STL coefficients of composites (1), (4) and (3S) acquire 5...10 dB less values in the range of 100...1500 Hz. The grouping trend was mostly dignified for α and R coefficients (see Figs. 4 and 5).

However, it had to be mentioned that LDC-based composites provide differentiate behaviour depending on particular frequency range. Thus, the (3S) composite have a relative constant 5 dB STL level upper the (1) and (4) into the 300...1300 Hz domain. The (4) sample provide the best performances (in terms of STL) for 1500...2000 and 5500...6000 Hz domains. For frequencies lower than 4000 Hz the (2C) composite acquires higher or about equal at least STL level than the others LDC-based composites, but for frequencies greater than 4000 Hz this material becomes a bad solution. The reference specimens (EPS) and (XEPS), initially adopted in order to enable a suitable comparative analysis between proposed composites and "*classical*" materials, has been provided better performances – in terms of STL and R – for almost analyzed frequency range, but the LDC-based composites has been proved closely characteristics with the references, being here and there up to them.

4. CONCLUSION

The main conclusion of this works, according the previously mentioned results and discussions, dignify the availability level of the composites based on LDC, to supply a very suitable solution for noise control, sound absorption and barrier applications. Authors' future researches in this area will be focused on increasing the utilization level of fibres from recycled paper within the composites solutions, maintaining or reaching higher values of sound insulation and noise absorption parameters. The presented experimental research were performed for only three types of novelty foam-formed composites LDC-based, useable as kernel material for noise control solutions, thus that the next investigations will be directed to provide a practical sandwich-type composite, with LDC-based core and environmental influences protective layers, being able to be adopted for both indoor, and outdoor applications.

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REFERENCES

[1] Romina Del Rey, Jesús Alba, Jorge P. Arenas, Vicente J. Sanchis, An empirical modelling of porous sound absorbing materials made of recycled foam, *Applied Acoustics*, Volume **73**, Issues 6-7, June 2012, 604-609.

[2] David J. Oldham, Christopher A. Egan, Richard D. Cookson, Sustainable acoustic absorbers from the biomass, *Applied Acoustics*, Volume **72**, Issue 6, May 2011, 350-363.

[3] P. Glé, E. Gourdon, L. Arnaud, Acoustical properties of materials made of vegetable particles with several scales of porosity, *Applied Acoustics*, Volume **72**, Issue 5, April 2011, 249-259.

[4] Francesco Asdrubali, Survey on the Acoustical Properties of New Sustainable Materials for Noise Control, *Proceedings of the Euronoise 2006*, Tampere, Finland.

[5] Asdrubali Francesco, Green and Sustainable Materials for Noise Control in Buildings, *Proceedings of the 19th International Congress on Acoustics*, Madrid, 2-7 September 2007.

[6] Ghotbi Ravandi, M.R., Mardi, H., Langari, A.A.A., Mohammadian, M. and Khanjani, N. (2015) A Review on the Acoustical Properties of Natural and Synthetic Noise Absorbents. *Open Access Library Journal*, 2: e1598. http://dx.doi.org/10.4236/oalib.1101598.

[7] Stanciu, M. D., Curtu, I., Cosereanu C., Lica, D., Nastac, S., Research Regarding Acoustical Properties of Recycled Composites, *Proceedings of the 8th International DAAAM Baltic Conference "Industrial Engineering"* 19-21 April 2012, Tallinn, Estonia.

[8] Gino Iannace, Umberto Berardi, Characterization of Natural Fibers for Sound Absorption, *Proceedings of the 22nd International Congress on Sound and Vibration*, ICSV22, Florence (Italy) 12-16 July 2015.

[9] Ancuta Elena TIUC, Ligia MOGA, Improvement of Acoustic and Thermal Comfort by Turning Waste into Composite Materials, *RJAV*, vol **X** issue 2/2013, 77-82.

[10] Victor Desarnaulds, Ezilda Costanzo, António Carvalho and Blaise Arlaud, Sustainability of Acoustic Materials and Acoustic Characterization of Sustainable Materials, *Proceedings of the Twelfth International Congress on Sound and Vibration*, ICSV12, Lisbon, 11-14 July 2005.

[11] Jorge P. Arenas, Juan Rebolledo, Romina Del Rey, Jesús Alba (2014), Sound Absorption Properties of Unbleached Cellulose Loose-Fill Insulation Material, *BioResources* 9(**4**), 6227-6240.

[12] Jérôme Lefebvre, Alexandre Leblanc, Benoît Genestie, Thierry Chartier and Antoine Lavie, Acoustic Properties of Aerogel Encapsulated by Macroporous Cellulose, *Proceedings of the 23rd International Congress on Sound and Vibration*, ICSV23, Athens (Greece), 10-14 July 2016.

[13] S.T. Nguyen et al., Advanced thermal insulation and absorption properties of recycled cellulose aerogels, *Colloids and Surfaces A: Physicochem. Eng. Aspects* **445** (2014) 128– 134.

[14] Pouyan Jahangiri, Banda Logawa, Reza Korehei, Murray Hodgson, D. Mark Martinez and James A. Olson, On acoustic properties of foam formed cellulose based materials, *Available electronically at* http://www.fibrenetwork.org/wp-content/uploads/2015/01/FOAM-PAPER-PaperNo2-Pouyan.pdf

[15] P. Bratu, *Indoor Acoustics for Construction and Machines*, Impuls Publishing House, Bucharest, 2002.

[16] S Nastac, D Anghelache, M Stanciu, I Curtu, On acoustic panels with high performances for pollutant individual working place insulation, *Proceedings of the 8th International DAAAM Baltic Conference "Industrial Engineering"* 19-21 April 2012, Tallinn, Estonia, 69-73.

[17] D. Anghelache, S Nastac (2010), Noise and Vibration Protective Solutions Analysis for Technological Equipments, *The Annals of " Dunarea de Jos" University of Galati, Fascicle XIV Mechanical Engineering*, 81-86.

[18] D. Anghelache (2008), Acoustic absorption coefficient variation of sound absorbing structures and materials, *The Annals of "Dunarea de Jos" University of Galati, Fascicle XIV Mechanical Engineering*.

[19] Nechita P., Nastac S., Ionescu S.M., Foam-formed cellulose-based composite materials for use in cushioning and insulation applications, *Proceedings of the Ninth National Conference on Chemistry Science and Technology for Better Life, 18th National Symposium on Polymers*, September 29 – October 1, 2016, Union of Chemists in Bulgaria.

[20] J. Stuart Bolton, Taewook Yoo and Oliviero Olivieri, Measurement of Normal Incidence Transmission Loss and Other Acoustical Properties of Materials Placed in a Standing Wave Tube, *Brüel&Kjær Technical Review*, No.1 2007, Editor: Harry K. Zaveri, Brüel&Kjær Sound&Vibration Measurement A/S.

[21] Benjamin J Doty, Ali R Kolaini, Development of an Acoustic Impedance Tube Testbed for Material Sample Testing, *SLAMS Young Professionals Workshop*, NASA Johnson Space Center, 23–25 July 2012.

[22] Maria A. Kuczmarski and James C. Johnston, Acoustic Absorption in Porous Materials, *NASA/TM—2011-216995*, *Available electronically at* http://www.sti.nasa.gov.

[23] Jason Kunio, Taewook Yoo, Kang Hou, Jan Enok, A Comparison of Two and Four Microphone Standing Wave Tube Procedures for Estimating the Normal Incidence Absorption Coefficient, *Proceedings of the INTER-NOISE 2009* Ottawa, Ontario Canada.