THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XIV MECHANICAL ENGINEERING, ISSN 1224-5615
2010

EXPERIMENTAL RESEARCHES ON THE SOUND ABSORPTION COMPOSITES USED FOR PUBLIC WORKS EQUIPMENT

Assoc. Prof. Dr. Eng. Nicusor DRAGAN
MECMET – The Research Center of Machines,
Mechanic and Technological Equipments
"Dunarea de Jos" University of Galati

ABSTRACT

Decreasing of sound and vibration global level inside and/or outside the public works equipment's cabin as well as the reduction the noise pollution or the pollution accounted by the vibration and mechanical shocks on the construction site is an actual matter, especially for the countries having become lately EU members; these countries must harmonize their national legislations regarding the environment pollution and the labor protection according to the EU Directives (98/37/EC, 2000/14/EC, 89/391/EEC, 2003/10/EC, 89/656/EEC, 92/85/EEC). This study presents the problem of designing, manufacturing and testing of some protective systems made of composite materials which can simultaneously perform the next requirements: noise absorption for middle and high range frequencies (400-8000 Hz), noise insulation for low frequencies (40-400 Hz), vibration damping in order to avoid noise transmission by structure and finally, modularity and adaptability for using to different types of public works equipment, also for other technological equipment with a high level of noise, vibration and mechanical shocks. This article presents the experimental data of sixteen composite structures with noise absorption and insulation features and one case study of global level noise reduction ΔL *inside the cabin of a crawler excavator. The experimental research has done with Brüel & Kjær acoustic measuring equipment at the Vibration and Acoustic Laboratory of the Research Institute for Construction Equipment and Technology - ICECON S.A. Bucharest, Romania. The study case for the excavator S1021 was made in the Research Center of Machines, Mechanic and Technological Equipments – MECMET from "Dunarea de Jos" University of Galati, Engineering Faculty of Braila.*

KEYWORDS: composite structures, global noise level, sound absorber, public works equipment

1. Introduction

The goal of using innovative composite structures in the public work equipment is to simultaneously decrease the global level of noise and vibrations into cabin and to dissipate the energy of the emitted sound to the environment. These properties can be assured if the structure of sandwich composites is made up of one layer of material in order to insulate the low frequency noise, one layer of porous material in order to absorb the medium and frequency sound and one layer of antivibratile material. Taking into consideration the usual noise levels of different types of civil work equipment and the EU Directives requests, it can be appreciated that the acoustic performances of soundproofing treatments of the cabins and of the cases must be characterized by the values from table 1.

Table 1. Requiring acoustic performances for the composite materials for acoustic treatments

ACOUSTIC PROPERTY	Den.	Unit	Frequency range [Hz]	
			400-1000	1000-4000
Sound absorption coefficient	α	%	15÷20	20÷50
Sound transmission loss	ΔL	dB	10÷20	20÷30

2. Sound absorbent and insulation modular composites

The project "Modular protective systems from sound absorbent and sound insulator composite materials for civil works equipment" proposes some types of composite materials (see table 2) in order to assure the required values for the acoustic properties.

Table 2. The denomination and structures of different types of composites

Denom.	Composite structure
SCFF1	PVC10+PC30
SCFF2	PVC10+PC30+MTT20
SCFF3	PVCT10+PC30+PESMV150
SCFF4	PVC15+PC10+MTT20
SCFF5	PVC10+PC30+PES20+MTT20
SCFF6	PVC10+PC30+PES50+MTT20
SCFF7	PVC10+PC30+PESM40+MTT20
SCFF8	PVC10+PC30+PESMV150+MTT20
SCFF9	PVC15+PC10+PESM40+MTT20
SCFF10	PVCT10+PC10+PES50+MTT20
SCFF11	PVCT10+PES20+PES50+PESMV150
SCFF12	PVC15+PC10+PESMV150+MTT20
SCFF13	PVC8+PES20+PES50+MTT20
SCFF14	PVC8+PC10+PES20+PES50+MTT20
SCFF15	PVCT10+PES20+PES50+PESM40
SCFF16	PVC8+PC10+PES20+PVC10+PES50+ +MTT20

The significance of the layers of composites from table 2 are:

PC10 – composite cork ≠1mm
PC30 – composite cork ≠3mm
PST5 – close cell low density PS foam ≠0.5mm
PST10 – close cell low density PS foam ≠1mm
PST20 – close cell low density PS foam ≠2mm
PSTM5 – close cell low density PS foam with Alu foil ≠0.5mm
PVC8 – high density PV foil ≠0.8mm
PVC10 – high density PV foil ≠1mm
PVC15 – cellulose background PV foil ≠1.5mm
PVCT10 – textile reinforced PV foil ≠1mm
PES20 – open cell PE foam ≠2mm
PES50 – open cell PE foam ≠5mm
MTT20 – textile reinforced latex ≠2mm
PESM40 – open cell PE foam with Alu foil ≠4mm
PESM150 – open cell PE foam with Alu foil plus textile reinforced PV foil ≠15mm

Table 3. The geometrical shapes and sizes of the modular composite structures

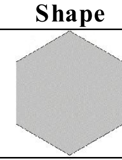
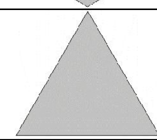
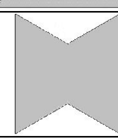
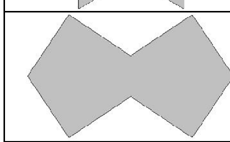
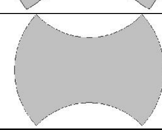
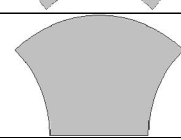
Shape	Size [mm]
	6.6×100 43.3×50
	100×86.6 50×43.3
	100×100 50×50
	50×90 75×45
	141.4×100 70.7×50
	100×70.7 50×35.4

Table 3 shows six different shapes of modules for the composite structures, each of them in two different sizes.

3. Experimental data

The experimental data was determined with Kundt's Tube Bruël&Kjær for 1/3 octave bandwidth (acoustic standing waves method, see [2]). Figures 1 to 4 show the comparisons between the sound absorption coefficients α determined for the composite materials with structures acc. to table 2. The variations of α coefficients are plotted for sound frequencies between 50Hz and 3150 Hz (centered 1/3 octave

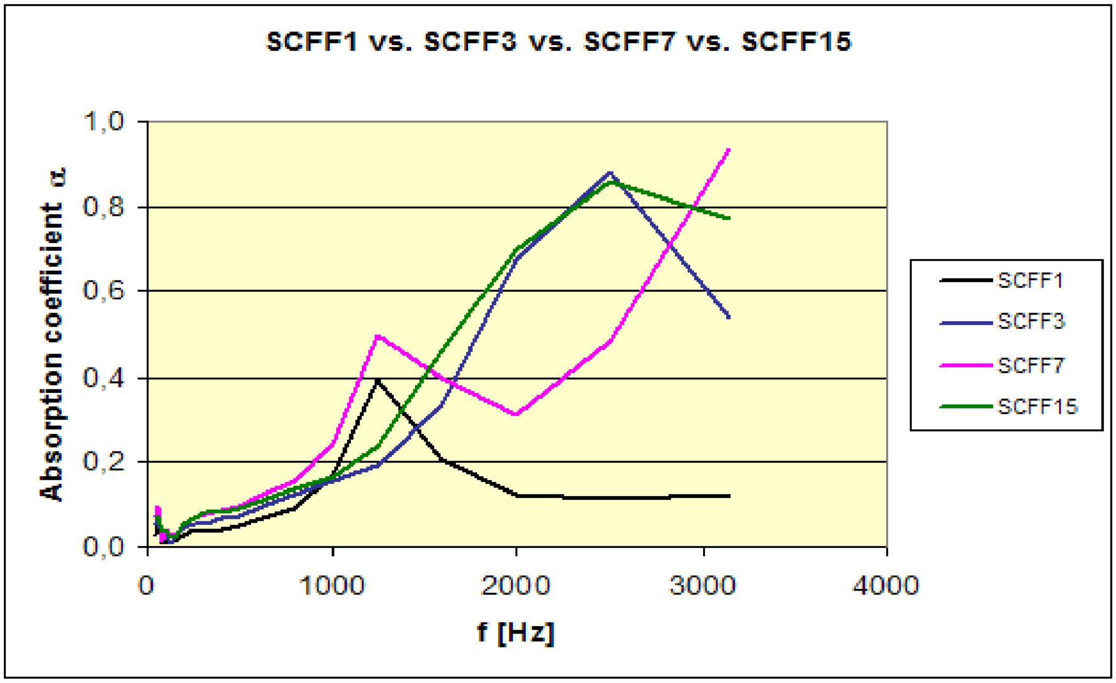


Fig.1 Sound absorption coefficient for composite materials SCFF1, SCFF3, SCFF7, SCFF15

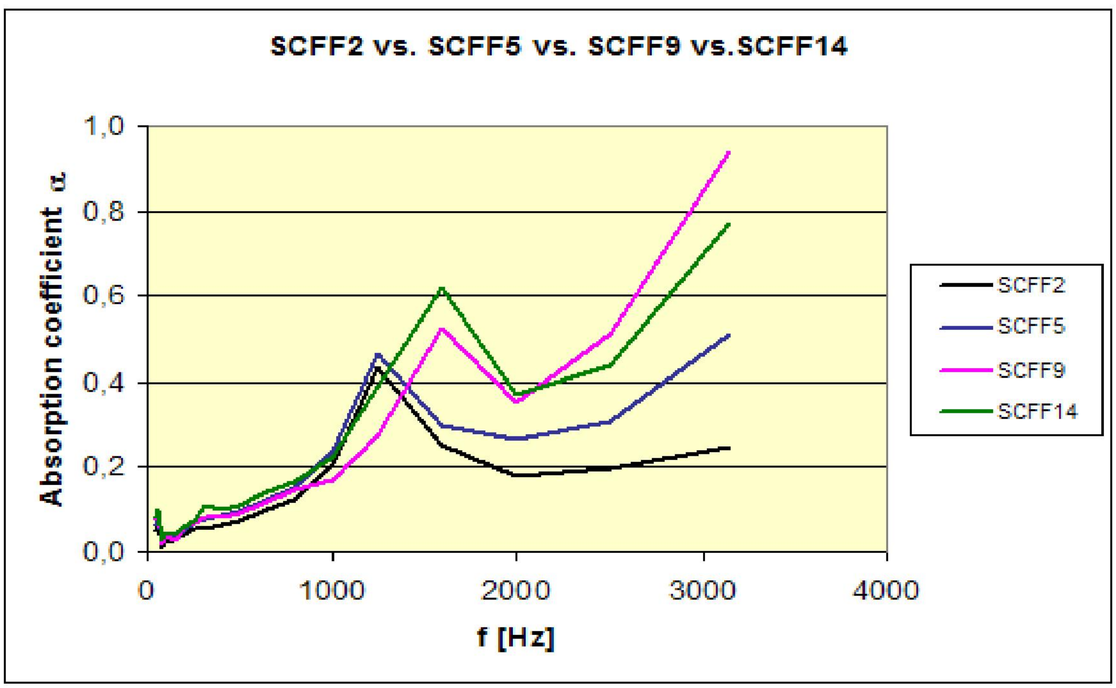


Fig.2 Sound absorption coefficient for composite materials SCFF2, SCFF5, SCFF9, SCFF14

bandwidth frequencies).

According to plotted diagrams from fig. 1 to 4, certain conclusions may be drawn:

►for low and middle-low frequency bandwidth of noise ($f < 800Hz$), the sound absorption coefficient α is smaller than 20%, no matter of the type of composite structure;

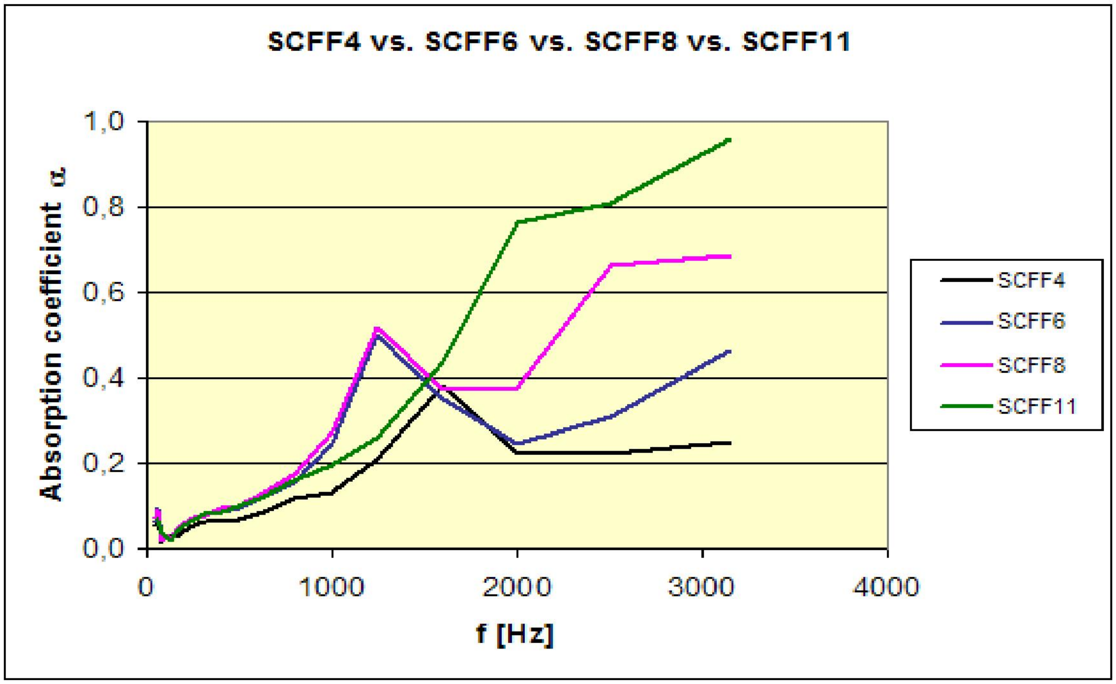


Fig.3 Sound absorption coefficient for composite materials SCFF4, SCFF6, SCFF8, SCFF11

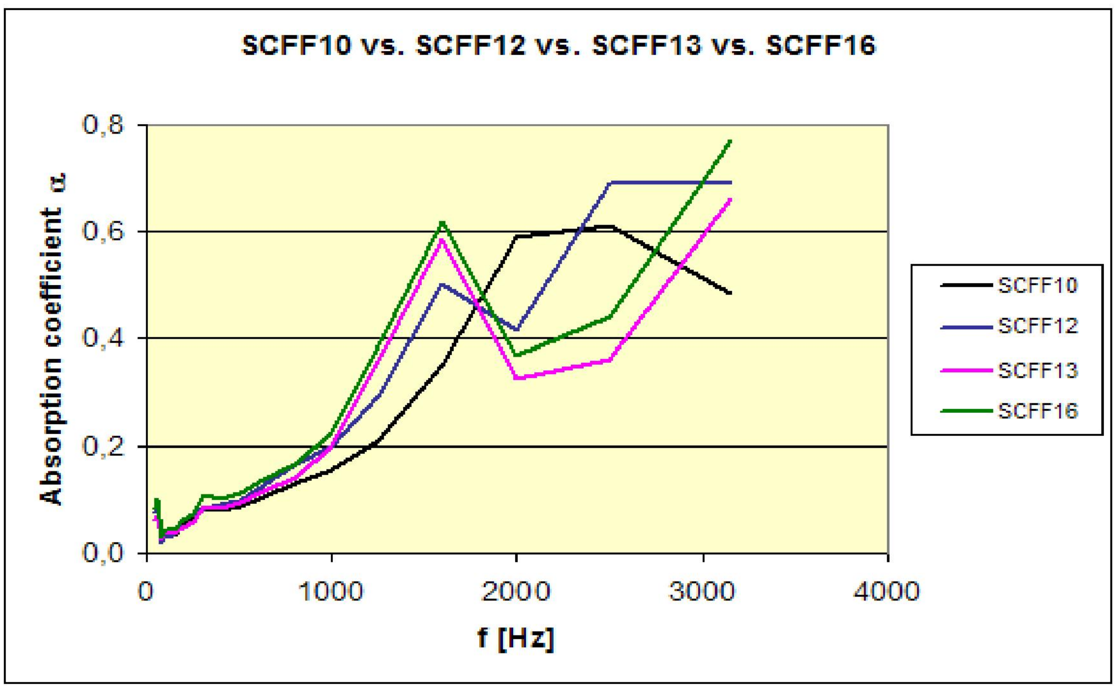


Fig.4 Sound absorption coefficient for composite materials SCFF10, SCFF12, SCFF13, SCFF16

►for middle frequency bandwidth of noise ($800Hz < f < 2000Hz$), the sound absorption coefficient α is growing faster, with values from 15% to 70% (with maxim values for frequencies around 1,2÷1,5kHz);

►for high frequency bandwidth of noise ($f \geq 2000Hz$), the sound absorption coefficient α is growing (from 20% to 95%) for all types

of composite structures excepting SCFF1 (for which the coefficient α is almost constant, with the smallest value of 12÷13%);
►for entire frequency range domain, the thicker the composite structure is, the sound absorption coefficient α is.

Figure 5 shows the variation of sound absorption coefficient α related to the centered

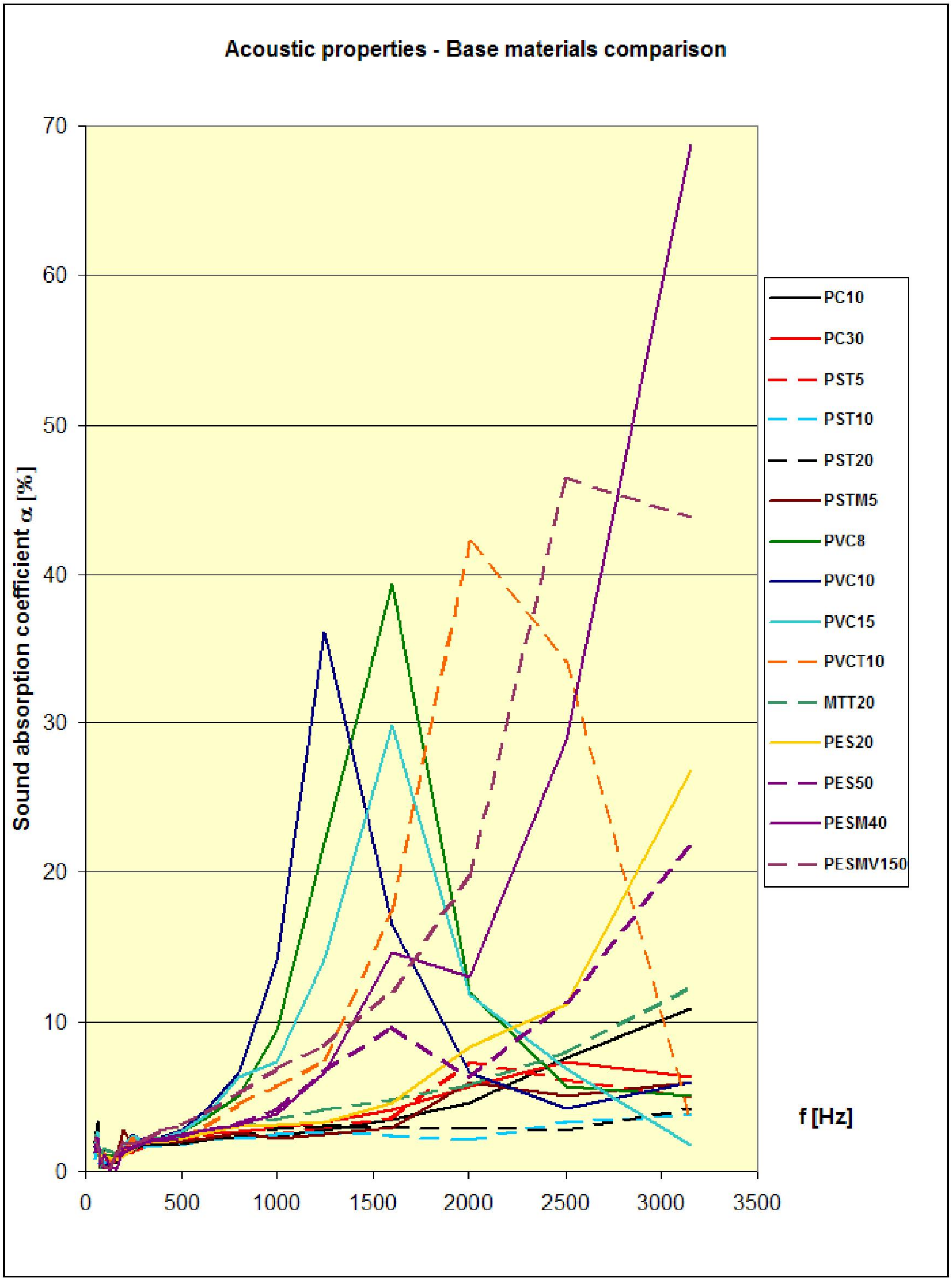


Fig.5 Sound absorption coefficient α for base materials

frequency of 1/3 octave bandwidth for the base materials (acc. to §2). The values of these coefficients were determined with Kundt's Tube Bruël&Kjær type 4206 (acoustic standing waves method) for the frequency bandwidth 0÷3200Hz, with an increment pitch of 4Hz. The experiment data were acquainted and processed by Bruël&Kjær PULSE Platform type 7758.

4. Cabin's phonic treatments for public works equipment – case study

According to [1] and [4], the main acoustic features of the self propelled public work equipment cabins are:

-the equivalent phonic absorbent area A [m^2]

-the average absorption coefficient α_{med}

-the global sound level loss ΔL [dB]

The calculus relation for the average sound absorption coefficient α_{med} is

$$\alpha_{med} = \frac{\sum \alpha_i S_i}{\sum S_i}, \quad (1)$$

where: S_i is the area of the surface number i

α_i - the absorption coefficient of the surface S_i

The calculus relation for the global sound level reduction/loss ΔL is

$$\Delta L = 10 lg \frac{A}{A_0}, \quad (2)$$

where: A is the equivalent absorption area of the cabin after the phonic treatment

A_0 - equivalent absorption area of the cabin without the phonic treatment

The equivalent absorption area can be calculated as follows:

$$A = \sum_{i=1}^{n} \alpha_i S_i \quad (3)$$

In order to simulate the reduction of the global noise level inside the cabin of the excavator S1201, the next dimensional and acoustic features are to be considered:

► $S_1 = 5.1m^2$ - glass surface area

► $S_2 = 1.2m^2$ - uncoated steel sheet surface area

► $S_3 = 3.8m^2$ - phonic treated surface area with composite structures SCFF1→SCFF16

► $\alpha_1 = 0.33$ - organic glass sound absorption coefficient (average value)

► $\alpha_2 = 0.08$ - steel sound absorption coefficient (1mm thickness sheet).

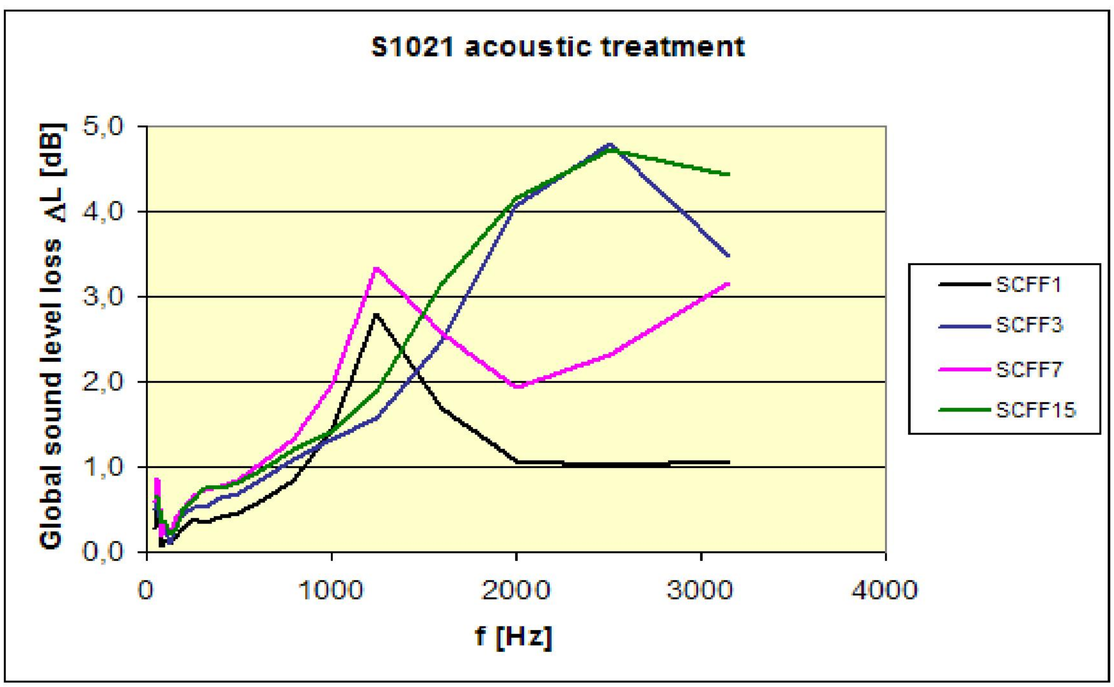


Fig.6 Global sound level reduction ΔL for S1201 excavator's cabin
Comparison between phonic treatments with SCFF1, SCFF3, SCFF7, SCFF15

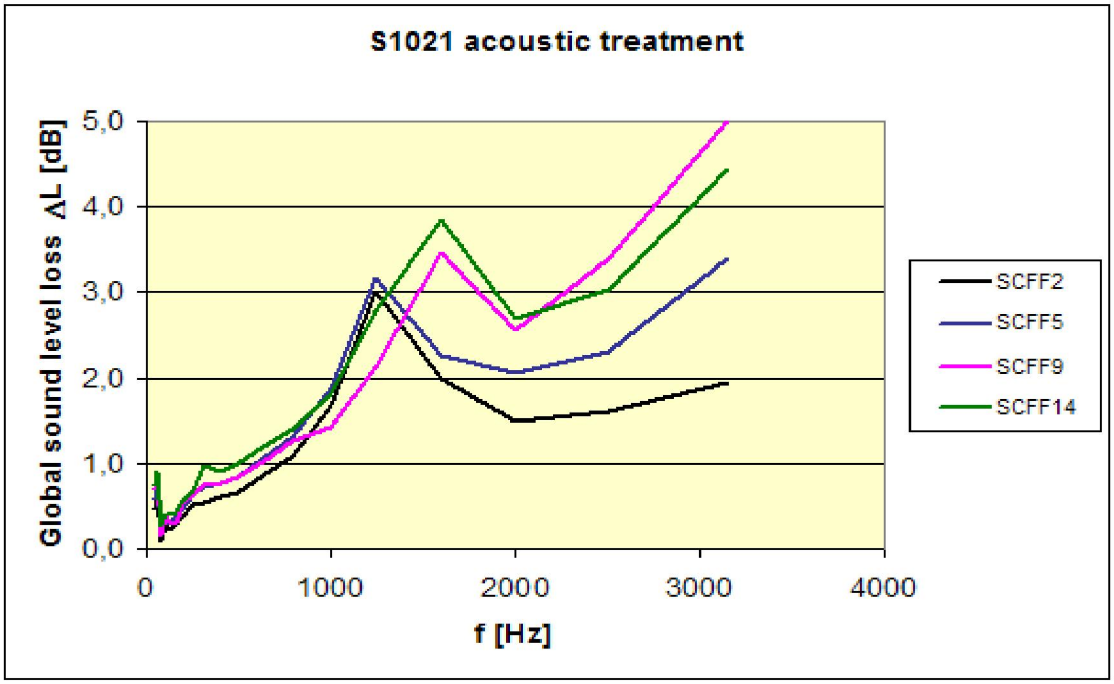


Fig.7 Global sound level reduction ΔL for S1201 excavator's cabin
Comparison between phonic treatments with SCFF2, SCFF5, SCFF9, SCFF14

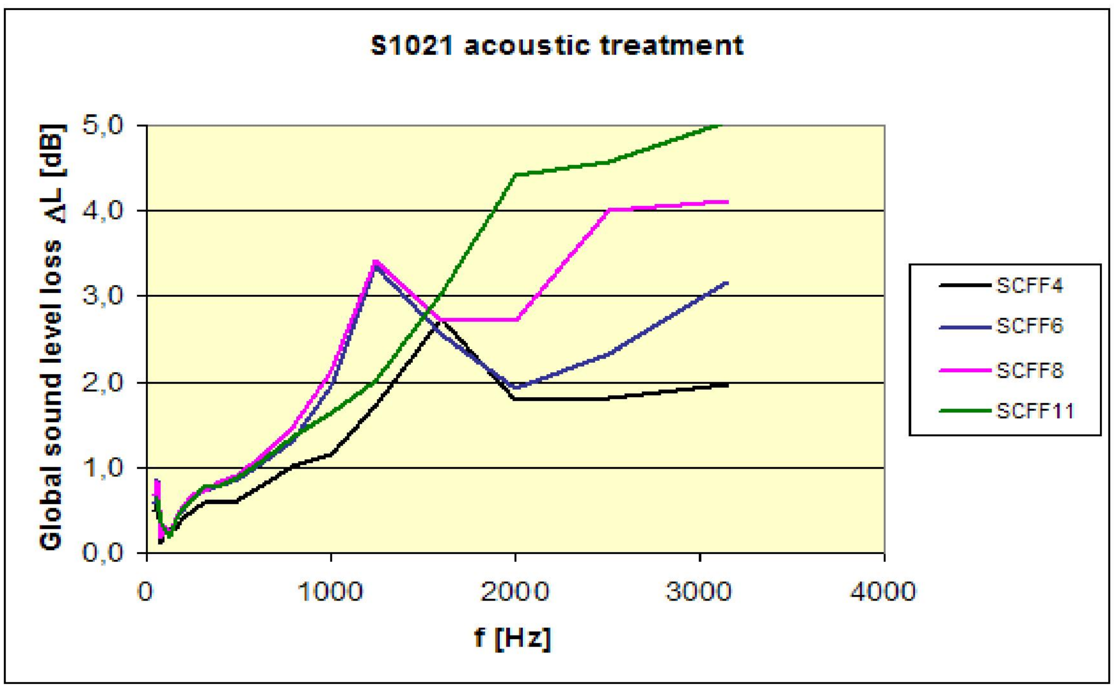


Fig.8 Global sound level reduction ΔL for S1201 excavator's cabin
Comparison between phonic treatments with SCFF4, SCFF6, SCFF8, SCFF11

With the considered values, we can calculate for the S1201 cabin:
■total surface area

$$S = \sum S_i = S_1 + S_2 + S_3 = 10.1 m^2$$

■equivalent absorption area without phonic treatment

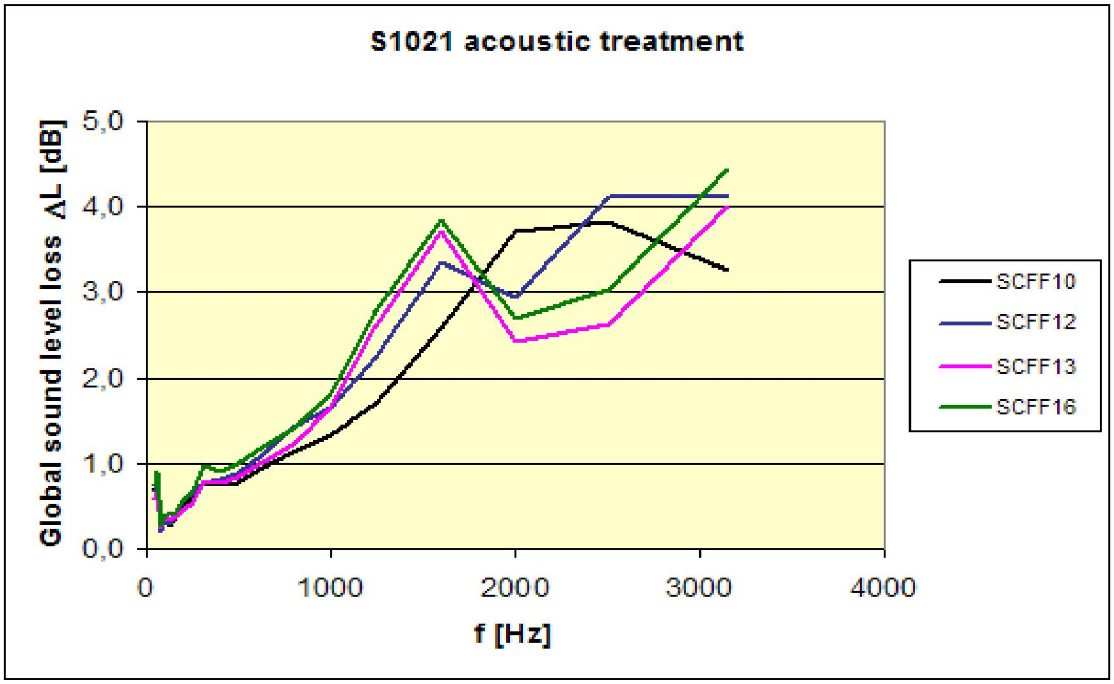


Fig.9 Global sound level reduction ΔL for S1201 excavator's cabin
Comparison between phonic treatments with SCFF10, SCFF12, SCFF13, SCFF16

$$A_0 = \sum \alpha_i S_i = \alpha_1 S_1 + \alpha_2 (S_2 + S_3) = 2.083 m^2$$

▪average sound absorption coefficient without phonic treatment

$$\alpha_{med} = \frac{\sum \alpha_i S_i}{\sum S_i} = \frac{2.083}{10.1} = 0.206$$

Figures 6 to 9 show the global level of sound ΔL inside the cabin of the Romanian crawler excavator S1201 using the phonic treatments with composite materials tested in the lab (SCFF1 to SCFF16).

Analyzing the diagrams which show the reduction of the global sound level inside the cabin of the excavator S1201, we can conclude:

♦the shapes of curves which show the variations of global sound level reduction ΔL (fig. 6, fig. 7, fig. 8 and fig. 9) are similar to the shapes of curves of variation of sound absorption coefficients (fig. 1, fig. 2, fig. 3 and fig. 4);

♦for low and middle-low frequencies ($f < 800Hz$), the reduction is 0.5÷1.5dB(A) no matter the type of composite structure; for high frequencies ($f > 2kHz$), the reduction is 1.5÷5dB(A).

5. Conclusions

Regarding the noise assessment in construction [3], a reduction of 2dB(A) is good enough for some types of public work equipment: excavators, frontal loaders, asphalt stations, aso. For other types of construction machines and equipment (vibrating compactors, boards and rammers, pneumatic hammers, some hand-tools), a reduction of 3÷5dB(A) is desirable.

From the diagrams which show the variation of sound absorption coefficient, we can say that the materials with "high" specific density (like Polyvinyl) have good property of absorption for middle frequencies and the thick materials with open cell foam macrostructure (like Polyurethane, Polyester) have good sound absorption properties especially for high frequencies. The materials type cork based (natural cork, macro composite cork) have good properties for vibration damping and structural noise attenuation.

6. References

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

[2] **Bratu, P.**, *Noise reduction in case of mobile machinery cabins*, Proceedings of 10th International Conference on the Theory of Machines and Mechanisms IFTOMM, Prague, 2008

[3] **Dragan, N.**, *Assessing and controlling the noise in construction. Romanian and EU legislation*, The Annals of "Dunarea de Jos" University of Galati, Fascicle XIV Mechanical Engineering, 2008

[4] **Vasile, O., Dragan, N.**, *Innovative Sound Insulation and Absorption Modular Systems for Public Works Equipment*, Proceedings of the 5th International Vilnius Conference "Knowledge-based technologies and OR methodologies for strategic decisions of sustainable development" KORSD-2009, Ed. "Technika", Vilnius, ISBN 978-9955-28-482-6