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COMPOSITE MATERIALS USED FOR DECREASING THE NOISE LEVEL INSIDE THE CABINS OF THE MOBILE TECHNOLOGICAL EQUIPMENT

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Abstract: The article presents some experimental data of composite materials with noise absorption and insulation characteristics. The experimental research were made in the Research Center of Machines, Mechanic and Technological Equipments – MECMET with the help of specialists from Vibration and Acoustic Laboratory of the Research Institute for Construction Equipment and Technology - ICECON S.A. from Bucharest. There it is also one case study of global level noise reduction and absorption coefficient inside the cabin of the Romanian frontal loader MMT45.

1. INTRODUCTION

The main scope of using composite structures in the phonic treatments of the cabin of public work equipment is to decrease global level of noise and vibrations into cabin. 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 high frequency sound and one layer of antivibratile material.

Table 1. Requiring sound absorption and insulation performances for the composite materials

Acoustic property	Den.	Unit	Frequency range [Hz]	
			400-1000	1000-4000
Sound absorption coefficient	α	-	0.15÷0.20	0.20÷0.50
Sound transmission loss	ΔL	dB	10÷20	20÷30

Taking into consideration the EU Directives [2] [3] [4] and national legislation [5] in force requests and the usual noise levels of different types of civil work equipment used in Romania [1], the acoustic performances of phonic treatments of the cabins must be characterized by the values from table 1.

2. COMPOSITE MATERIALS - NOISE ABSORPTION AND INSULATION FEATURES

The project “Modular protective systems from sound absorbent and sound insulation composite materials for civil works equipment” developed within the Programme V “Innovation” of [6] proposes some types of composite materials in order to assure the required values for the acoustic properties (table 3). The base materials used to build the composite structures with their physic and mechanic properties are done in the table 2.

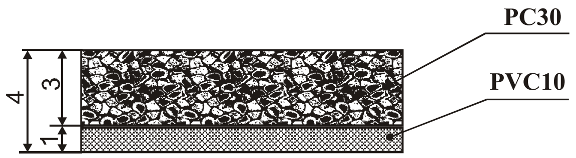
Table 3. Base materials properties

Material	Description	Structure	Thick. [mm]	Density [kg/m^2]
PC10	Cork	composite	1	0,360
PC30	Cork	composite	3	1,200

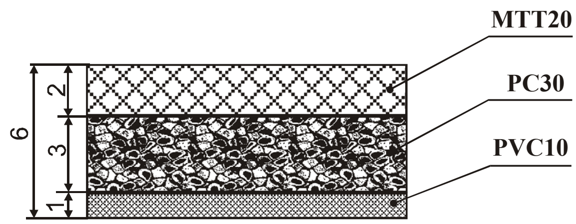
Table 3. Base materials properties

Material	Description	Structure	Thick. [mm]	Density [kg/m^2]
PST10	Polystyrene	close cell low density foam	1	0,130
PST5	Polystyrene	close cell low density foam	0,5	0,060
PST20	Polystyrene	close cell low density foam	2	0,250
PSTM5	Polystyrene	close cell low density foam + Alu foil	0,5	0,240
PVC8	Polyvinyl	high density foil	0,8	1,120
PVC10	Polyvinyl	high density foil	1	1,400
PVCT10	Polyvinyl	textile reinforced PV foil	1	1,150
PVC15	Polyvinyl	cellulose background PV foil	1,5	1,650
PES20	Polyester	open cell foam	2	0,600
PES50	Polyester	open cell foam	5	1,500
PESM40	Polyester	open cell foam with Alu foil	4	1,250
PESMV150	Polyester	open cell foam + Alu + PV textile reinforced	15	4,500
MTT20	Textile + latex	textile reinforced latex	2	2,300

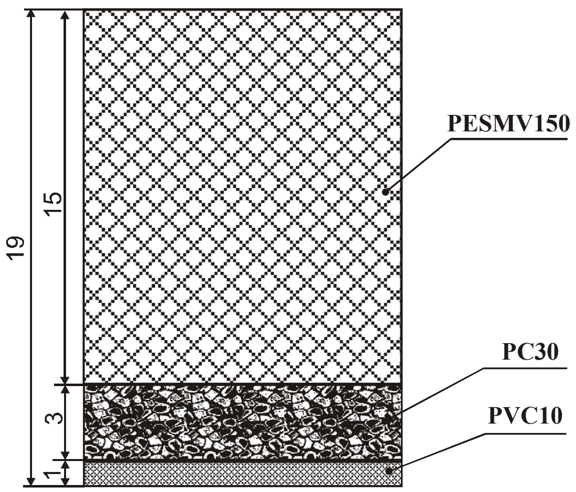
Table 3. Structure of the composite materials



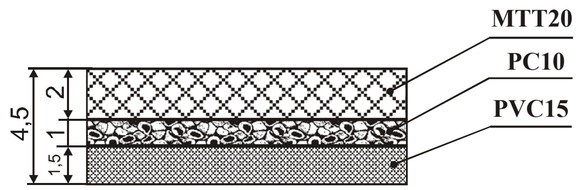
SCFF1



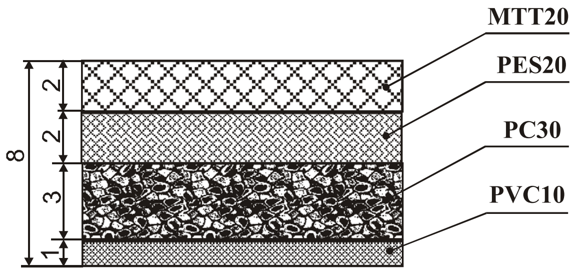
SCFF2



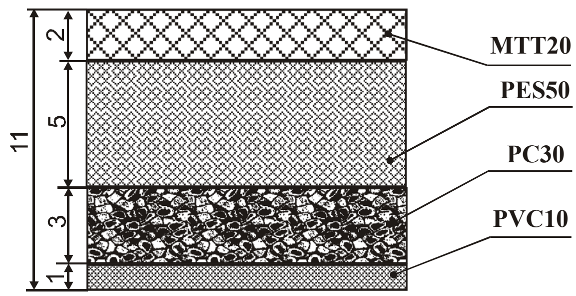
SCFF3



SCFF4



SCFF5



SCFF6

Table 2. Structure of the composite materials

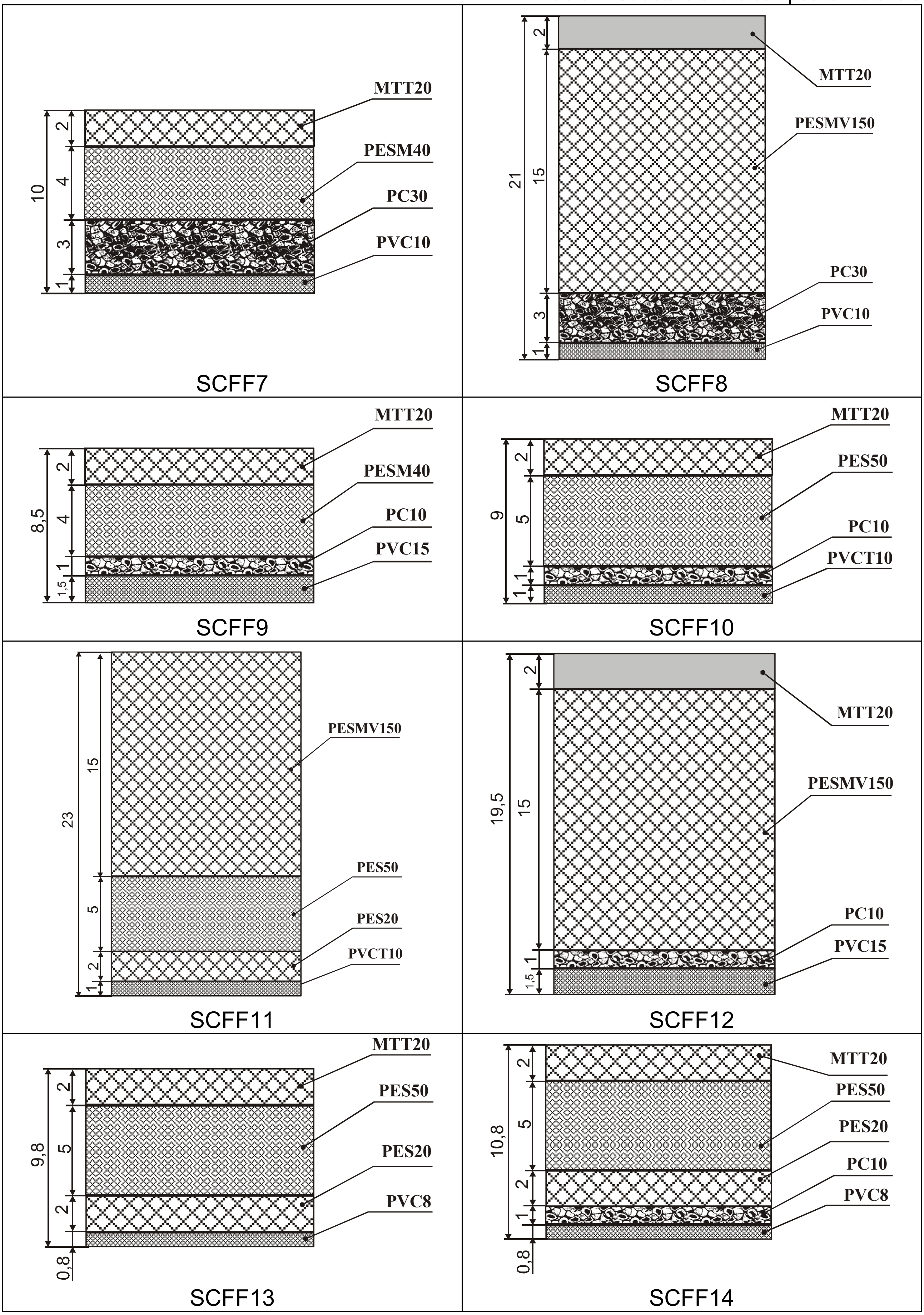
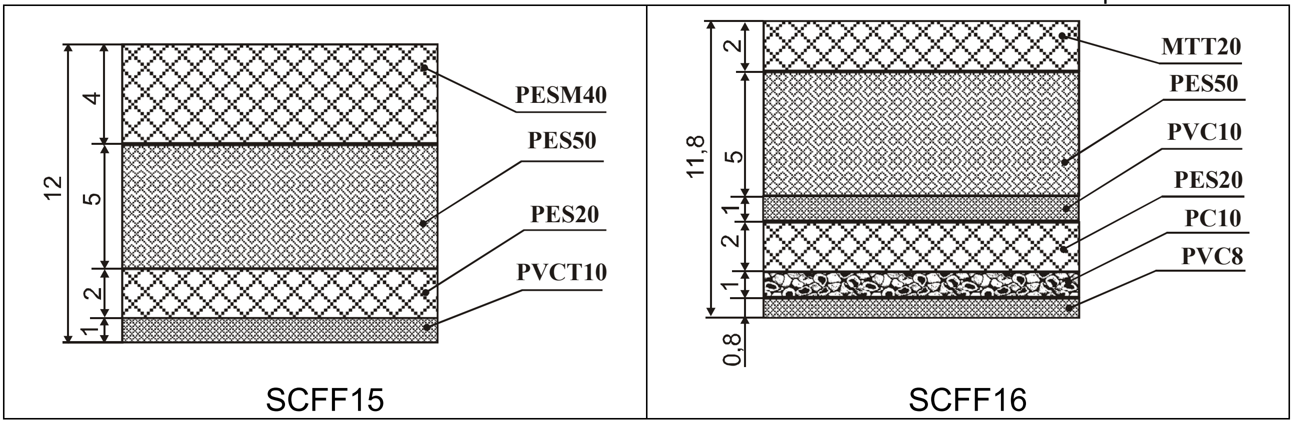


Table 2. Structure of the composite materials



3. ABSORPTION COEFFICIENT - EXPERIMENTAL DATA

The experimental data was determined using acoustic standing waves method [7], for 1/3 octave bandwidth. ***Figure 1*** shows the variations of α coefficients of the base materials (table 2), plotted for sound frequencies between 50Hz and 3150 Hz. ***Figure 2*** shows the the variations of α coefficients for the composite materials of table 3. The values of these coefficients were determinate 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.

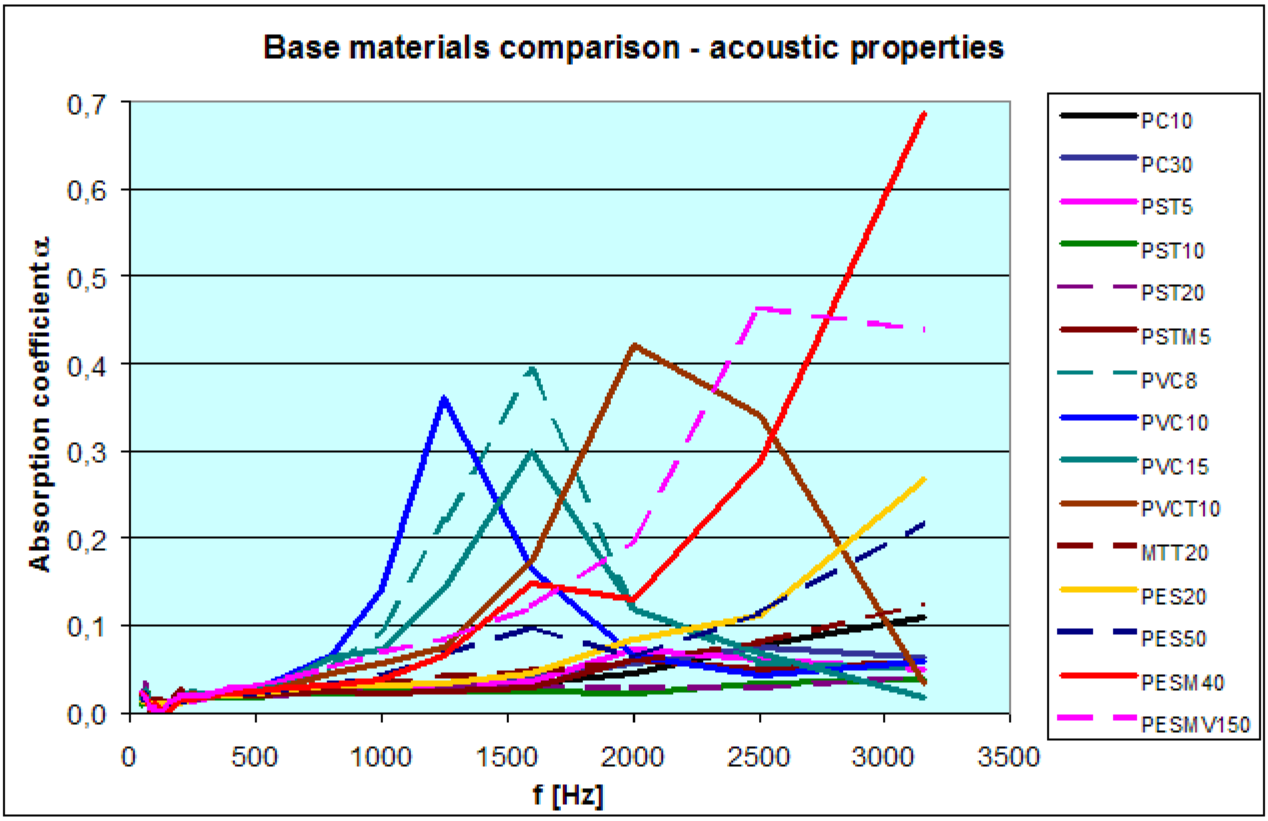


Fig. 1 Sound absorption coefficient α for base materials

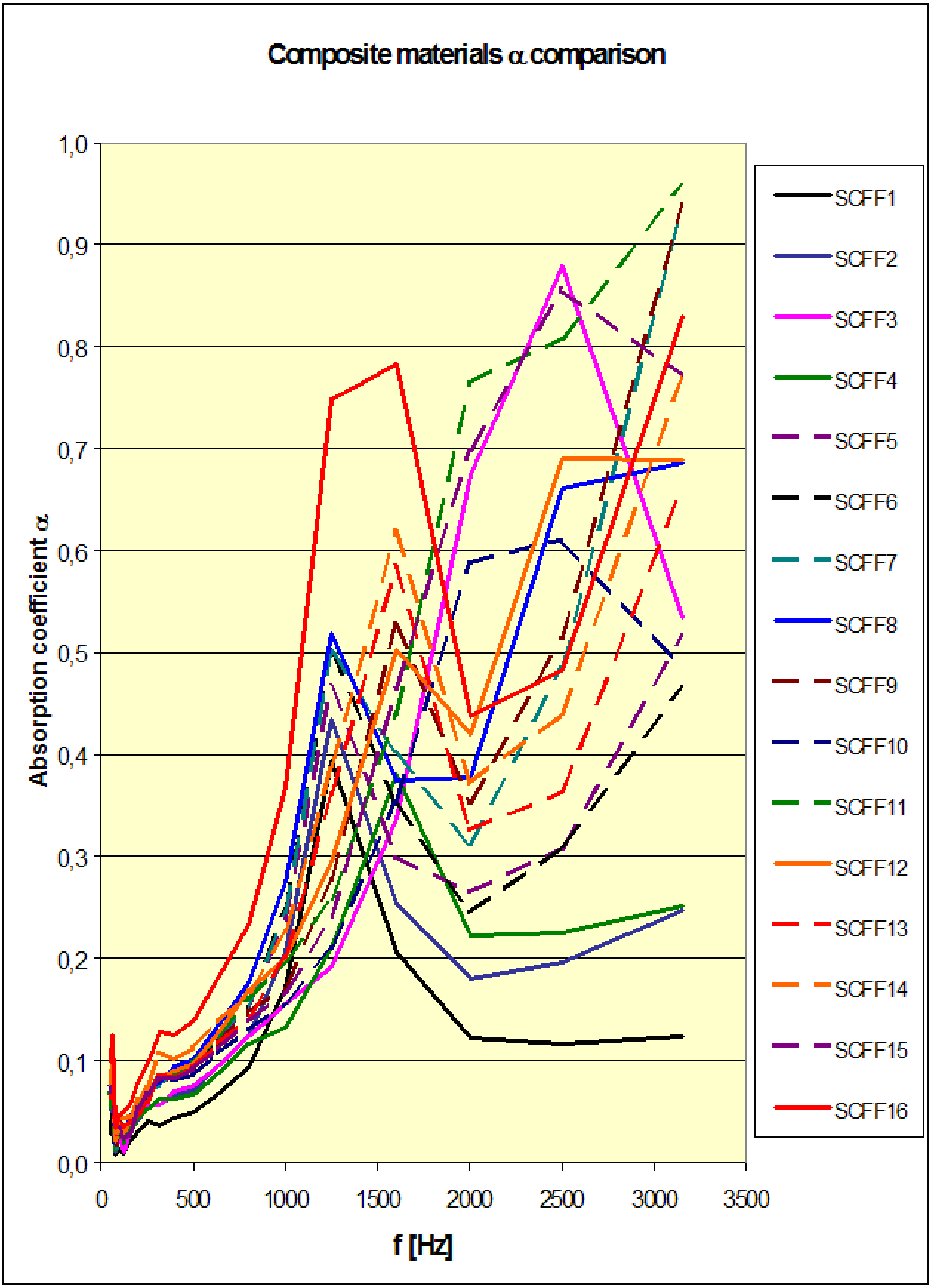


Fig. 2 Sound absorption coefficient α for composite materials

According to plotted diagrams from ***figure1*** and ***figure 2***, we can take some partial conclusions:

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

●for middle frequency bandwidth of noise ($800Hz < f < 2000Hz$), the sound absorption coefficient α is growing fast, 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 frequencies domain, the sound absorption coefficient α is bigger how much more the composite structures is thicker.

4. CABIN'S PHONIC TREATMENT FOR FRONTAL LOADER MMT45 – CASE STUDY

According to [9] and [10], the main acoustic features of the self propelled public work equipment cabins are:

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

-the average absorption coefficient α_{med}

-the global sound level loss ΔL [dB]

-the phonic absorption constant R_α [m^2]

The equivalent absorption area of the construction equipment cabin (with/without phonic treatment) can be calculate as follows:

$$A = \sum_{i=1}^{n} \alpha_i S_i \quad , \tag{1}$$

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 average sound absorption coefficient α_{med} of the cabin is

$$\alpha_{med} = \frac{\sum \alpha_i S_i}{\sum S_i} \tag{2}$$

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

$$\Delta L = 10\, lg \frac{A}{A_0}, \tag{3}$$

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 phonic absorption constant of the cabin is function of the total surface $\sum S_i$ and the average absorption coefficient α_{med} as follows:

$$R_\alpha = \frac{\alpha_{med}}{1 - \alpha_{med}} \sum_{i=1}^{n} S_i \tag{4}$$

In order to calculate the reduction of the global noise level inside the cabin of the frontal loader MMT45, it considers the next dimensional and acoustic features:

► $S_1 = 3.8m^2$ - glass surface area

► $S_2 = 1.7m^2$ - uncoated steel sheet surface area

► $S_3 = 4.7m^2$ - phonic treated surface area with composite structures

► $\alpha_1 = 0{,}03$ - organic glass sound absorption coefficient (average value)

► $\alpha_2 = 0{,}08$ - steel sound absorption coefficient (1mm thickness sheet).

With the above values for areas and sound absorption coefficients, we can calculate for the MMT45 cabin:

■total surface area

$$S = \sum S_i = S_1 + S_2 + S_3 = 10.2m^2$$

■equivalent absorption area without phonic treatment

$$A_0 = \sum \alpha_i S_i = \alpha_1 S_1 + \alpha_2 (S_2 + S_3) = 0.626m^2$$

■average sound absorption coefficient without phonic treatment

$$\alpha_{med} = \frac{\sum \alpha_i S_i}{\sum S_i} = \frac{0.626}{10.2} = 0.061$$

■phonic absorption constant of the cabin without phonic treatment

$$R_\alpha = \frac{\alpha_{med}}{1 - \alpha_{med}} \sum_{i=1}^{n} S_i = \frac{0.626}{1 - 0.626} 10.2 = 17.1m^2$$

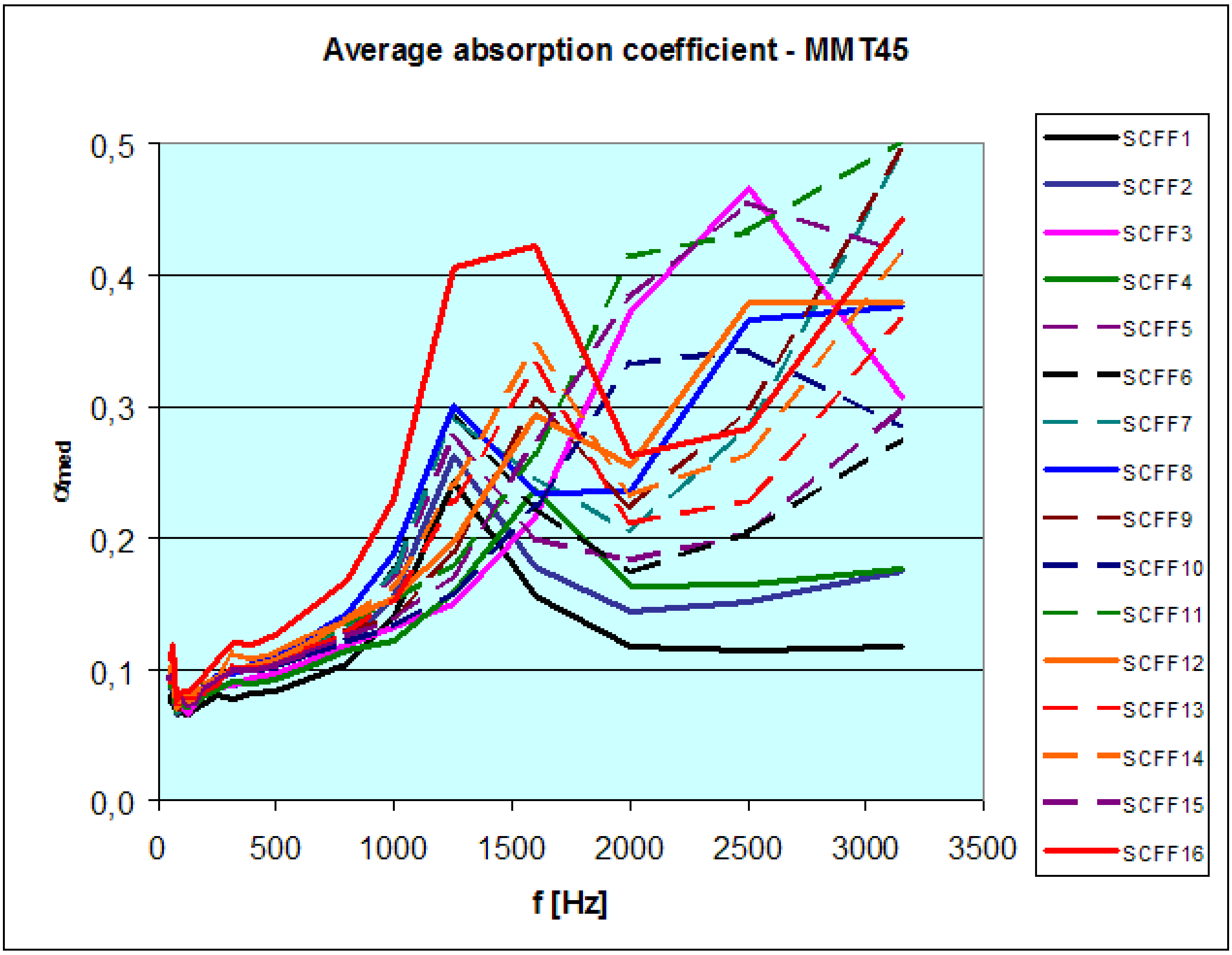


Fig. 3 Average absorption coefficient α_{med} *- MMT45*

Figure 3 shows the values of average sound absorption coefficient α_{med} inside the cabin of the frontal loader MMT45 using the phonic treatments with composite materials tested in the lab (SCFF1 to SCFF16). The coefficients were calculated using (1) and (2), with the dimensional characteristics and acoustical features of the cabin are done above.

Analyzing the diagrams which show the variation of the average sound absorption coefficient α_{med} inside the cabin of the frontal loader MMT45, we can conclude:

♦the shapes of curves which show the variations of α_{med} are similar to the shapes of curves of variation of sound absorption coefficients for the composite materials (fig. 1, fig. 2, fig. 3, fig. 4);

♦for low frequencies ($f < 500Hz$), the value of α_{med} is around the value of 0.1 no matter type of composite structure; for middle and high frequencies ($f > 1kHz$), the value of α_{med} is bigger than 0.15;

♦the best absorbent composite material (of the tested in the lab) is SCFF16 for frequencies bandwidth $1kHz < f < 2kHz$ and SCFF11 for frequencies $f \geq 2kHz$.

Figure 4 shows the values of the global sound level reduction ΔL inside the cabin of the frontal loader MMT45 calculated using (3).

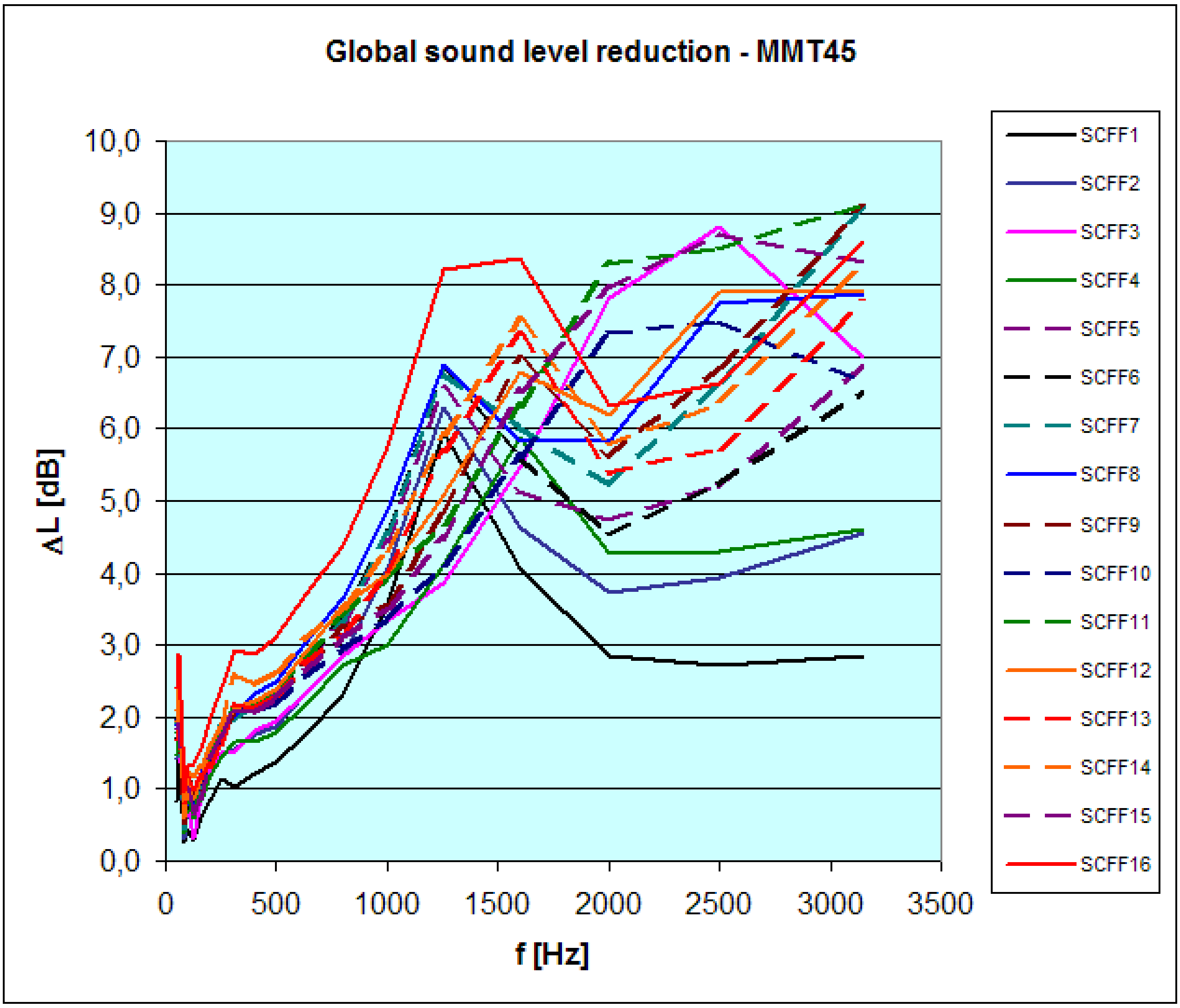


Fig. 4 Global sound level reduction ΔL - MMT45

Figure 5 shows the values of the phonic absorption constant R_{α} inside the cabin of the frontal loader MMT45 wich was calculated with (4) for acoustic treatments using all tested composite materials.

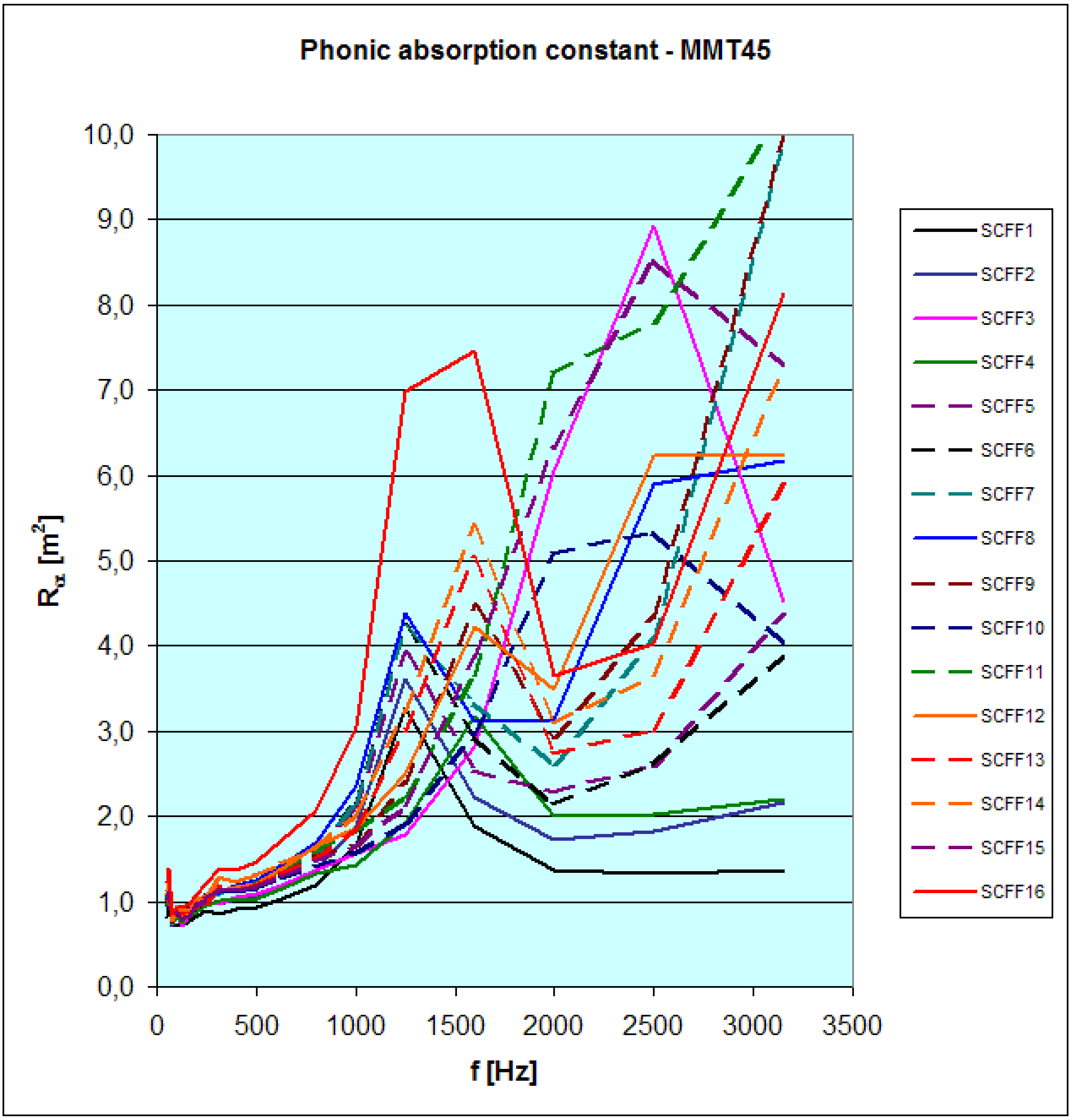


Fig. 5 Phonic absorption constant R_{α} ***- MMT45***

4. CONCLUSIONS

Regarding the noise assessment in construction [1], a reduction of 2dB(A) is good enough for some types of public work equipment: excavators, frontal loaders, asphalt stations, aso. For another 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.

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