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A STUDY ON MINERAL WOOLS ACOUSTIC DOUBLE POROSITY MATERIALS

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Abstract. *Acoustic porous materials with macroperforations are considered double porosity materials. Recent studies show its potential in the improvement of sound absorption at low frequencies in acoustic porous materials, known to have a poor performance at this range of frequencies. In this study, the acoustic characterization of these materials is made using glasswool and rockwool. Impedance Tube tests for sound absorption and sound transmission loss were performed. For sound absorption, a small gain was observed for rockwool samples with perforations, in both situations, i.e., with perforations not filled and filled with glasswool. For glasswool samples containing mesopores (filled or not with rockwool), in general, no significant gain in absorption was verified, except for glasswool samples filled with rockwool (with mesoporosities equal to 0.11 and 0.14), in which a small gain in absorption was observed around 2000 Hz. Transmission loss tests show that there is a gain in insulation for all samples of glasswool containing mesopores filled with rockwool. For samples of rockwool containing mesopores filled with glasswool, a TL gain, for all investigated frequency range, was observed only when mesoporosity was very small.*

Keywords: *Acoustics, Double Porosity Materials, Absorption, Transmission Loss*

1. INTRODUCTION

Porous absorbent acoustical materials are widely used in noise control on different fields of study, such as Industrial Noise and Building and Architectural Acoustics. However, they exhibit weak performance at low frequencies. In this context, the use of double porosity materials is one of the alternative solutions for improving the material performance at the low frequency range. In a double porosity material, there are two independent pores networks, leading to three different domains: the macroscopic, the mesoscopic and the microscopic, Fig.1. The characteristic sizes of the domains are separated by at least one order of magnitude. Researchers showed numerically and experimentally that these perforations, called mesopores, can contribute to enhancing the sound absorption at low frequencies (Atalla *et al.*, 2001)(Sgard *et al.*, 2005)(Gourdon and Seppi, 2010).The ratio between the mesopore area and the area of one unit cell representative of the macroscopic domain is defined as the mesoporosity (ϕ_p).

According to Olny and Boutin (2003), a realistic double porosity material should have the following characteristics: a mesoscopic characteristic size $l_p \leq 10^{-2}$ m, considering that the mesoheterogenieties are small enough compared to wavelength in the audible range; a microscopic characteristic size $l_m \geq 10^{-5}$ m; and a proper separation of scales $\frac{l_p}{l_m} > 10$ (Olny and Boutin, 2003).

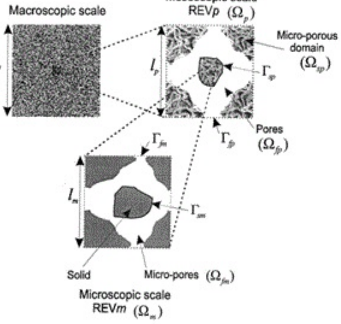


Figure 1. Separation of scales for a double porosity material - Olny and Boutin (2003)

However, in the studies of Atalla et al (2001) and Sgard et al (2005), materials with mesopores of the order of centimeters were tested, differently from the recommendation of $l_p \leq 10^{-2}$ m and achieved good results at low frequencies, where the wavelengths are bigger.

The influence of the mesoporosity and the size of the holes were also studied. They used a standard configuration of a square unit cell of side length $L_c = 66$ mm and a square hole of side $a = 9.4$ mm. For testing the influence of the size of the hole, they maintained the mesoporosity at 0.18 and changed the size of the hole to $\frac{a}{4}$, $\frac{a}{2}$ and $2a$, modifying L_c accordingly. They showed that the smaller the hole, the smaller the value in frequency of the absorption peak and its bandwidth. Also, the absorption peak increases its value if mesoporosity is increased. In this case they tested five configurations: 0.04, 0.11, 0.18, 0.36 and 0.51 maintaining a constant and changing L_c. For low frequencies, the best results appeared for the values of 0.11 and 0.18 (Atalla *et al.*, 2001).

Another situation is the case when mesopores are filled with another porous material. The larger the contrast between the flow resistivity (σ_m) of the material of the mesopore and the material itself, lower is the value of the frequency where a peak of absorption occurs (Atalla *et al.*, 2001). Additionally, it was shown that double porosity materials with its inclusion filled by another porous material have a smaller loss in absorption at very low frequencies, the ones below the peak of absorption found at double porosity materials with mesopores not filled, comparing both cases with the single porosity case (Gourdon and Seppi, 2010).

An interesting case for double porosity materials is the partial coupling between pores and micropores. It occurs when the pressure in the microporous domain is not uniform and the pressure difference between pores and mesopores satisfies a diffusion equation at first order of approximation (Atalla *et al.*, 2001).

The diffusion frequency (ω_d) is a characteristic frequency which separates the total coupling domain from the non-coupling domain. The coupling occurs for frequencies lower than ω_d. Because of this, it is possible to increase sound absorption coefficient in a given frequency band by fixing ω_d properly. The diffusion frequency (Eq.1) depends on the mesoporosity (ϕ_p), the microporosity (ϕ_m), the atmospheric pressure (P_0) and the flow resistivity (σ_m) and is given by:

$$\omega_d = \frac{(1-\phi_p)P_0}{\phi_m \sigma_m D(0)} \tag{1}$$

$D(0)$ is a geometric factor that depends on ϕ_p and L_c, i.e.,

$$D(0) = \frac{L_c^2}{4\pi} log_{10}\left(\frac{1}{\phi_p} - 2\phi_p - \frac{\phi_p^2}{2}\right) \tag{2}$$

The pressure diffusion effect occurs in double porosity materials according to its physical properties, a high permeability contrast (big difference at the mesoscopic and microscopic characteristic lengths) and the value of frequency studied. It is the variation of sound pressure in the micropores at a mesoscopic scale and an increase of the imaginary part of the bulk modulus, which leads to an increase in the sound absorption (Sgard *et al.*, 2005).

In this study, perforations were made in rockwool and glasswool, two manufactured mineral porous media, in order to create a double porosity material. The acoustic characterization of these materials was performed using an impedance tube with circular samples.

2. METHODOLOGY

The acoustic characterization of the mineral wools, rockwool (density = 160 $\frac{kg}{m^3}$, ϕ_m = 0.97) and glasswool (density = 20 $\frac{kg}{m^3}$, ϕ_m = 0.97), was done by using an impedance tube, with a normal incidence sound excitation. The values of density are given by their manufactures, Isover for glaswool and Rockfibras for the rockwool.

Impedance tube tests were performed using a 60 mm circular cross-section tube, with the following characteristics (Fig. 2): distance between the sample and microphone 2 of 35 mm; distance between the sample and microphone 3 of 100 mm; distance between microphones 1 and 2 and microphones 3 and 4 of 45 mm; distance between microphones 0 and 2 and microphones 3 and 9 of 170 mm. For sound transmission loss tests, the two parts of the tube were used with four microphones positions. For sound absorption tests, only the first part of the tube was used with two microphones positions and a sample holder by the end of the tube to give the rigid termination condition. For the frequency range of 125 - 800 Hz microphones 1 and 2, and microphones 1, 2, 3 and 4, were used for sound absorption and for transmission loss tests, respectively. Also, for the frequency range of 400 - 2500 Hz microphones 0 and 2, and microphones 0, 2, 3, 9 were used for sound absorption and for transmission loss tests, respectively (BSWATech, 2010).

For both tests a loudspeaker that provides the excitation was used, using a white noise (same intensity at different frequencies). It was also used a digital frequency analyzer and a generator system to record signals measured by the microphones and to provide the input for the loudspeaker.

2.1 Sound absorption test using the Impedance Tube

The proceedings of the ISO $10534 : 2 - 2001$ defines the determination of sound absorption of a sample by measuring the transfer functions between microphones. The sample is assembled in a rigid wall at the end of the tube and it is excited

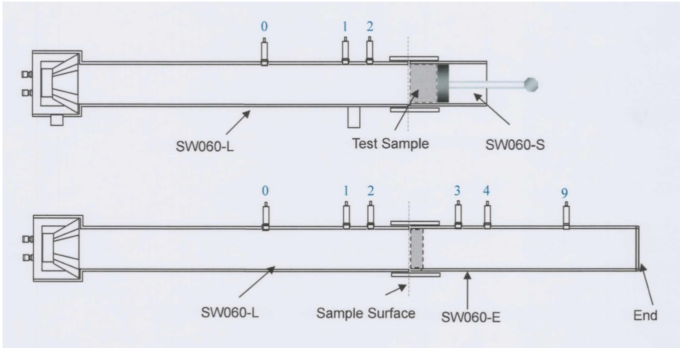
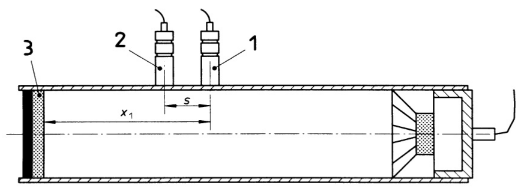


Figure 2. Impedance tube scheme - absorption tests (above) and sound transmission loss tests (below) - BSWA Tech (2010).

by plane sound waves coming from the loudspeaker, at the other end of the tube as in Fig. 3 (ISO, 2001).



Key
1 Microphone A
2 Microphone B
3 Test specimen

Figure 3. Impedance tube, microphones and loudspeakers for the absorption test - ISO $10534:2-2001$

By measuring the temperature of the room and the transfer function between the two microphones, the sound absorption of the sample can be determined. First of all, the sound speed is determined by the temperature in Celsius: $c = 343\sqrt{\frac{T}{293}}$; and the wave number is given by: $k = \frac{\omega}{c}$.

The reflection coefficient can be calculated from the measured transfer function between the microphones 1 and 2 (H_{12}), the distance between the microphones (s) and the distance from the sample to the microphone 1 (x_1) by

$$r = \frac{e^{2ikx_1}(H_{12} - e^{iks})}{e^{iks} - H_{12}} \tag{3}$$

According to the principle of conservation of energy, this leads to

$$\alpha = 1 - |r|^2 \tag{4}$$

2.2 Sound transmission loss test using the Impedance Tube

The transmission loss test in an Impedance Tube is done with the sample placed at the beginning of the second tube as in Fig. 4. The thickness of the sample is d and the positions of the microphones are x_1, x_2, x_3 and x_4. The Transfer Function Method was used to calculate the transmission loss (Bolton *et al.*, 2007). The determination of the sound speed (c) and wave number (k) were done as in the previous section.

The sound pressure downstream and upstream of the sample could be described as a sum of positive and negative exponentials (Bolton *et al.*, 2007).

$$P_{up} = Ae^{-jkx} + Be^{-jkx} \tag{5}$$

$$P_{down} = Ce^{-jkx} + De^{-jkx} \tag{6}$$

The sound pressure and the particle velocity before (x=0) and after (x=d) the sample is given by

$$P_{x_0} = A + B \tag{7}$$

$$V_{x_0} = \frac{A - B}{\rho_0 c} \tag{8}$$

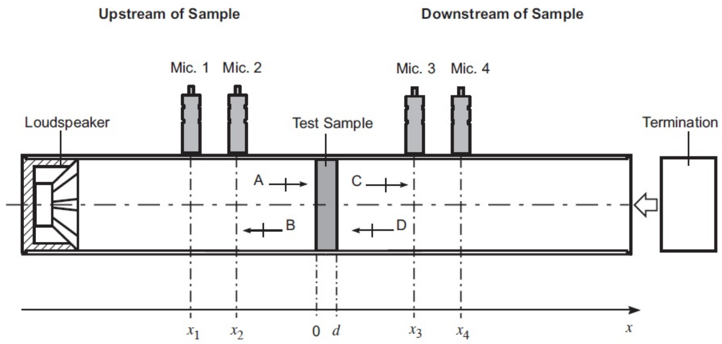


Figure 4. Impedance tube, microphones and loudspeakers for the transmission loss test - Bolton et al (2007)

$$P_{x_d} = Ce^{-jkd} + De^{jkd} \tag{9}$$

$$V_{x_d} = \frac{Ce^{-jkd} - De^{jkd}}{\rho_0 c} \tag{10}$$

T is the transfer matrix of the problem. It relates the sound pressure and the particle velocity before and right after the sample, according to

$$\begin{bmatrix} P \\ V \end{bmatrix}_{x=0} = \begin{bmatrix} T_{11}T_{12} \\ T_{21}T_{22} \end{bmatrix} \begin{bmatrix} P \\ V \end{bmatrix}_{x=d} \tag{11}$$

This is a system of two equations and four unknown variables, so it is undetermined. It is possible to take advantage of the reciprocal nature of the sample, assuming that the transmission coefficient of the sample is the same for both sides. In this case $T_{11} = T_{22}$. Additionally, it is shown that

$$T_{11}T_{22} - T_{12}T_{21} = 1 \tag{12}$$

is valid for symmetrical systems (Bolton *et al.*, 2007). This case of symmetry gives two more equations for the system so it becomes determined. In this case, it is possible to describe the unknown variables as a function of the pressures and particle velocity:

$$\begin{bmatrix} T_{11}T_{12} \\ T_{21}T_{22} \end{bmatrix} = \frac{1}{P_{x=0}V_{x=d} + P_{x=d}V_{x=0}} \times \begin{bmatrix} P_{x=d}V_{x=d} + P_{x=0}V_{x=0} & P_{x=d}^2 - P_{x=d}^2 \\ V_{x=d}^2 - V_{x=d}^2 & P_{x=d}V_{x=d} + P_{x=0}V_{x=0} \end{bmatrix} \tag{13}$$

Considering an anechoic termination at the end of the tube, it can be assumed that D, one of the complex amplitudes, is equal to zero because there are no reflections at the end of the tube. Replacing the Eq. 7 by Eq. 10, it possible to determine the matrix T as a function of the complex amplitudes A, B, C and D.

By measuring the transfer functions between the microphones and the loudspeaker (H_{nr}) and the autospectrum of the loudspeaker (G_{rr}), it is possible to determine the amplitudes as in Eqs. 14,15, 16 and 17.

$$A = \sqrt{Grr}\frac{j(H_{1r}e^{jkx_2} - H_{2r}e^{jkx_1})}{2sin(k(x_1 - x_2))} \tag{14}$$

$$B = \sqrt{Grr}\frac{j(H_{2r}e^{-jkx_2} - H_{1r}e^{-jkx_1})}{2sin(k(x_1 - x_2))} \tag{15}$$

$$C = \sqrt{Grr}\frac{j(H_{3r}e^{jkx_4} - H_{4r}e^{jkx_3})}{2sin(k(x_3 - x_4))} \tag{16}$$

$$D = \sqrt{Grr}\frac{j(H_{4r}e^{-jkx_3} - H_{3r}e^{-jkx_4})}{2sin(k(x_3 - x_4))} \tag{17}$$

The transmission coefficient T_a is defined by

$$T_a = \frac{2e^{-jkd}}{T_{11} + \frac{T_{12}}{\rho_0 c} + \rho_0 c T_{21} + T_{22}} \tag{18}$$

Finally, the transmission loss is given by

$$TL = 10log_{10}\left(\frac{1}{T_a^2}\right) \tag{19}$$

3. RESULTS

Two groups of porous materials were investigated. In the first group, glasswool and rockwool were analyzed as received. In the second group, glasswool and rockwool containing macroperforations (mesopores), which were filled or not filled, were studied. For samples constituted by filled mesopores, two types of samples were used: samples composed by rockwool with mesopores filled by glasswool, and samples composed by glasswool with mesopores filled by rockwool, as showed in Fig. 5. The samples are unit cell cases, consisting of a circular sample with one circular hole. The mesoporosities chosen were similar to those that led to good results in a previous study (Atalla *et al.*, 2001). The hole diameter was calculated according to the chosen mesoporosity and sample size.

Figure 5. Samples with mesopores filled: glasswool filled with rockwool (above) and rockwool filled with glasswool (bellow)

The initials R and G are used for pure rockwool and pure glasswool samples, respectively. The initials Rn and Gn (n=1, ..., 6) are used for samples with not filled mesopores and the initials RPn and GPn (n=1, ..., 6) for samples with filled mesopores. Table 1 shows the configurations of samples that were tested as a function of mesopore radius and the hole diameter.

Table 1. Configurations of the tested samples at the impedance tube.

Sample	Sample Diameter (mm)	Hole Diameter (mm)	Mesoporosity
R, G	60	-	-
R1, RP1, G1, GP1	60	6.4	0.01
R2, RP2, G2, GP2	60	9.5	0.03
R3, RP3, G3, GP3	60	12.5	0.04
R4, RP4, G4, GP4	60	17.5	0.08
R5, RP5, G5, GP5	60	20.2	0.11
R6, RP6, G6, GP6	60	22.3	0.14

The samples described in Tab. 1 were replicated, 3 replicas of each. The curves in the next sections represent the mean values of the replicas. Also, two different ranges of frequencies were measured: 125 - 800 Hz and 400 - 2500 Hz. This implies in two measured curves for each sample. To facilitate comparison between curves of different sample types, in the intersection range, 400 - 800 Hz, the mean value of the two curves are taken. This could lead to some discontinuities in the final curve.

3.1 Results for the sound absorption tests

The modified samples were compared with the pure samples in terms of sound absorption. Figure 6 shows the absorption for samples with not filled mesopores in comparison with pure rockwool sample and Fig. 7 shows the absorption for rockwool samples with mesopores filled with glasswool. Ripples were observed in all curves between 400 - 800 Hz.

Table 2 shows the percentage gain produced by the modification in rockwool samples at 250, 500, 1000 and 2000 Hz. In a general way, for high frequencies, the modifications lead to gains in absorption. Especially for RP1 sample at 1000 Hz the gain is about 17%. Yet, in low frequencies (for example 250Hz), for all samples there are losses in absorption, except for R1 and RP1.

Figures 8 and 9 present sound absorption coefficient as a function of frequency for glasswool samples. Although the values of mesoporosity for G5 and G6 are 0.11 and 0.14 respectively, there was no gain in absorption as described in the study of Allard et al (2001) for samples which mesoporosity values were 0.11 and 0.18. In addition, the glasswool substrate samples do not show ripples in the absorption curves in the frequency range 400 - 800 Hz.

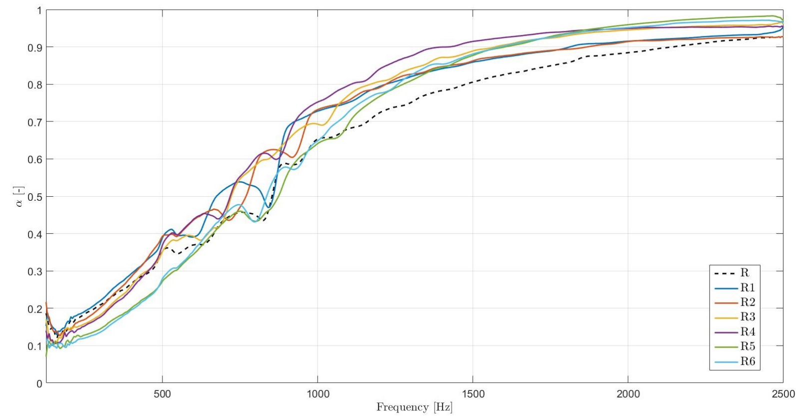


Figure 6. Sound absorption for pure sample and samples with mesopores not filled - rockwool substrate

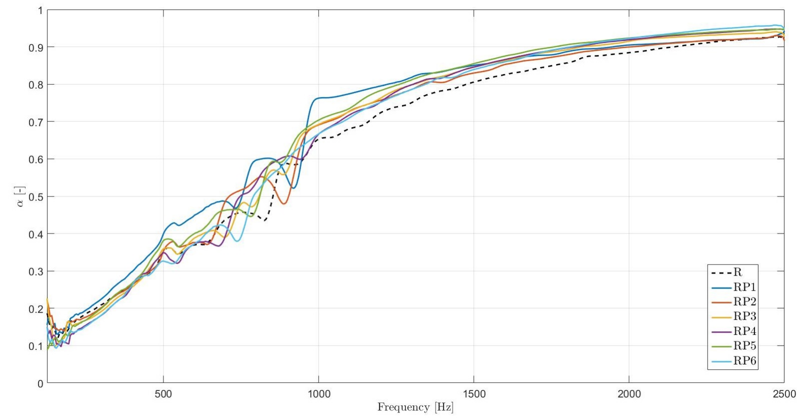


Figure 7. Sound absorption for pure sample and samples with mesopores filled - rockwool substrate

Table 2. Sound absorption percentage gain at 250, 500, 1000 and 2000 Hz produced by the modified rockwool samples compared to the pure case (R)

Sample/ Frequency	**250**	**500**	**1000**	**2000**
R1	3,9%	10,4%	11,5%	3,5%
R2	-7,7%	11,5%	12,1%	-0,1%
R3	-14,0%	-0,1%	6,2%	3,5%
R4	-17,2%	4,9%	15,2%	0,5%
R5	-30,4%	-22,7%	-1,8%	1,1%
R6	-34,9%	-20,7%	-0,7%	-0,9%
RP1	5,5%	13,4%	16,8%	2,3%
RP2	-4,5%	0,2%	5,8%	1,7%
RP3	-8,9%	2,0%	6,0%	3,5%
RP4	-16,3%	-1,0%	2,1%	3,9%
RP5	-9,0%	8,2%	7,8%	4,4%
RP6	-17,7%	-7,4%	2,1%	4,3%

Table 3 shows the absolute gain produced by the modification of glasswool samples. The gain is obtained by the subtraction of the value of absorption coefficient in some frequencies compared to the pure case (G). The absolute gain was considered in these cases in order to better comparing these results with the ones shown in Tab. 4, as described below. It is noticed that larger holes cause a loss in absorption, when mesopores are not filled. For GPn samples, the results showed in Tab. 3 suggest that filling mesopores with rockwoll could promote an absorption gain in a general way. But, if we consider the results shown in Fig. 9, the conclusions about these results can be different.

Previous tests of sound absorption and sound transmission loss were performed placing and removing the same sample (for both glasswool and rockwool) into the impedance tube. Replacements were carried out 10 times for each sample in order to verify the effect of sample manipulations on the sound absorption and transmission loss results.

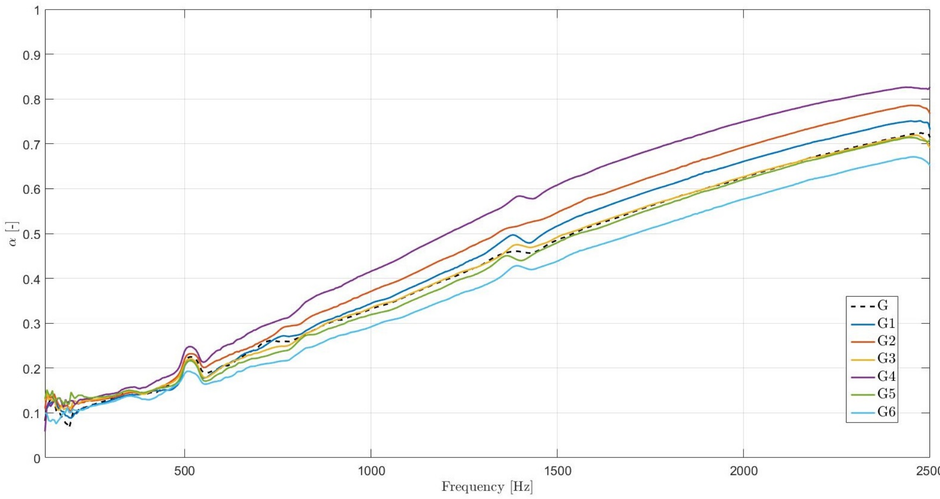


Figure 8. Sound absorption for pure sample and samples with mesopores not filled - glasswool substrate

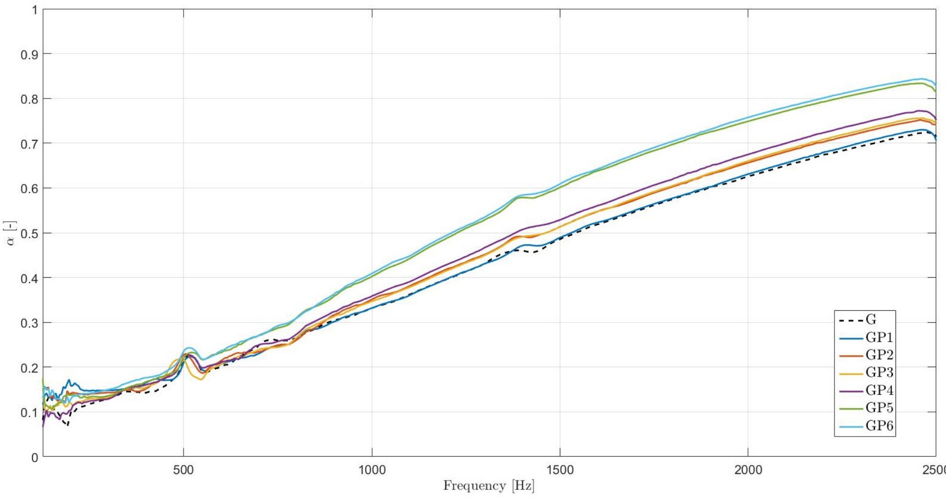


Figure 9. Sound absorption for pure sample and samples with mesopores filled - glasswool substrate

Table 3. Values of sound absorption gain at 250, 500, 1000 and 2000 Hz, for the modified glasswool samples compared to the pure curve (G)

Gain / Frequency (Hz)	**250**	**500**	**1000**	**2000**
G1-G	-0,0021	-0,0105	0,0125	0,0355
G2-G	0,0085	0,0052	0,0395	0,0673
G3-G	0,0112	-0,0047	0,0023	0,0012
G4-G	0,0141	0,0226	0,0843	0,1242
G5-G	0,0154	-0,0094	-0,0124	-0,0049
G6-G	-0,0036	-0,0275	-0,0398	-0,0485
GP1-G	0,0286	-0,0046	0,0002	0,0056
GP2-G	0,0218	0,0124	0,0197	0,0309
GP3-G	0,0111	0,0015	0,0152	0,0349
GP4-G	0,0061	0,0055	0,0267	0,0494
GP5-G	0,0154	0,0056	0,0708	0,1235
GP6-G	0,0232	0,0205	0,0775	0,1321

For the rockwool samples, there were almost no effects on the final results of absorption and transmission loss. However, for the glasswool samples, for the absorption tests, it was noticed a considerable difference between the curves of absorption for the same sample. For transmission loss of the glasswool samples, the obtained curves are similar. Figure 10 presents the sound absorption coefficient as a function of frequency for one sample of glasswool which was replaced

10 times into the impedance tube. Glasswool sample has low density, which make it very soft and easier to compress. The sample holder has a piston, as in Fig.2, that allows to adjust samples with different thickness into the impedance tube. Due to the glasswool softness, when it is placed into the sample holder and the piston is moved to fit it to avoid an air gap behind the specimen, the user can unintentionally compress the sample in a different way. So, the sound absorption behavior can be more affected by the sample replacement into the impedance tube.

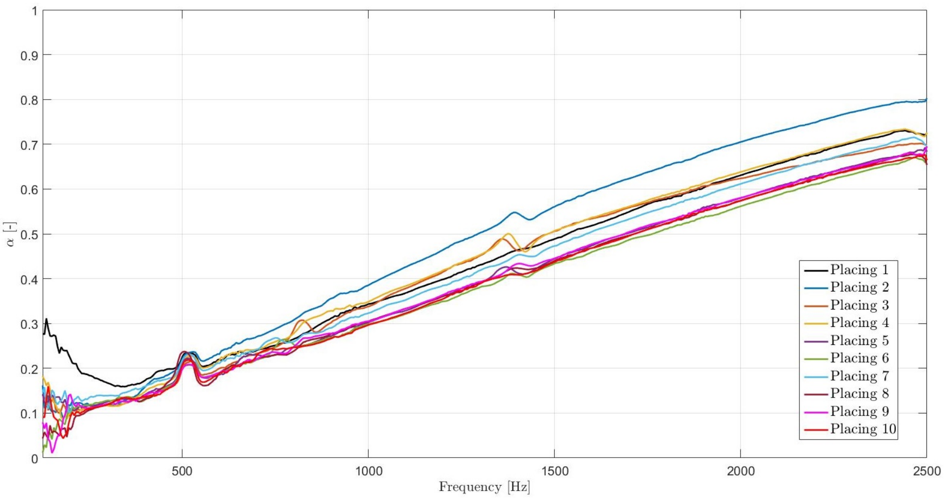


Figure 10. Variation on the absorption of a glasswool pure sample by 10 replacements on the sample holder

Table 4 shows the values of sound absorption coefficient at 250, 500, 1000 and 2000 Hz which were obtained from curves of Fig.10, as well as the mean value and the standard deviation considering the replacements.

Table 4. Sound absorption coefficient at 250, 500, 1000 and 2000 Hz, mean value of the curves and respective standard deviation for the glasswool pure sample placed 10 times into the sample holder

Placing / Frequency (Hz)	**250**	**500**	**1000**	**2000**
Placing 1	0.1841	0.2256	0.3121	0.6309
Placing 2	0.1186	0.2202	0.3559	0.7053
Placing 3	0.1104	0.1996	0.302	0.6239
Placing 4	0.1102	0.2125	0.3284	0.6382
Placing 5	0.117	0.2116	0.272	0.5801
Placing 6	0.1185	0.1986	0.2685	0.5616
Placing 7	0.1348	0.2177	0.29	0.6116
Placing 8	0.1067	0.2359	0.277	0.5739
Placing 9	0.1112	0.1979	0.2774	0.5807
Placing 10	0.1101	0.2073	0.2667	0.5745
Mean Value	0.1222	0.2127	0.295	0.6081
Standard Deviation	0.0232	0.0125	0.0295	0.0436

Analyzing the standard deviation on Tab. 4 and the gain in absorption on Tab. 3, it is noticed that the standard deviation was of the same order of magnitude or even higher than the values of the gain in absorption produced by the use of the perforations, for both filled and not filled samples, for the majority of the cases. Because of it, the gain cannot be considered effective, except for samples GP5 and GP6, with mesoporosity 0.11 and 0.14, respectively, at 2000 Hz. In this situation, the gain in absorption could be approximately 20%.

3.2 Results for the sound transmission loss tests

Transmission loss tests were performed for samples containing filled mesopores. The presence of a hole itself, as expected, would decrease the transmission loss. However, the situation where the mesopores are filled with another porous material is interesting to investigate, especially due to the great difference in density between both materials. For transmission loss tests there was no influence of the error due to the positioning of the sample replacement into the impedance tube.

Figure 11 shows the transmission loss for rockwool samples with mesopores filled with glasswool. In this case, the double porosity just provided enhancement effects for RP1 and RP2 samples. For samples from RP3 to RP6, as the percentage of glasswool increases, the transmission loss decreases because of the lower capability of insulation of the glasswool (pure case).

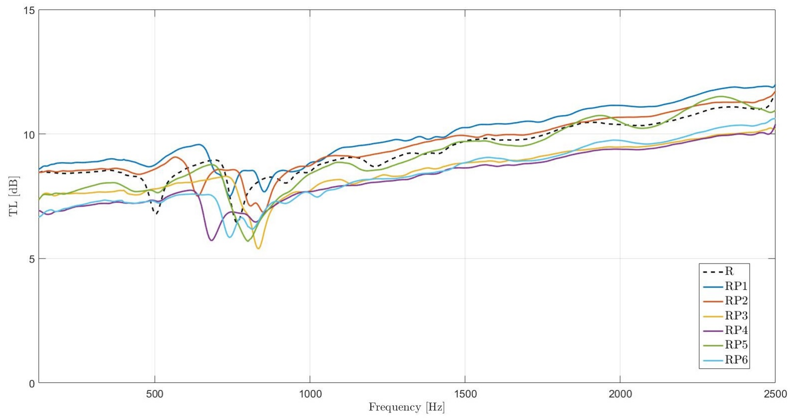


Figure 11. Sound transmission loss for pure sample and samples with mesopores filled - rockwool substract

Figure 12 shows the transmission loss for glasswool samples with mesopores filled with rockwool. GP5 shows the best result for transmission loss. The behavior observed for the others samples are very similar to that presented by the G sample. Both rockwool and glasswool have heterogeneities (darker regions and lighter regions) which can be viewed with the naked eye. Maybe if one of the GP5 replicas had a mesopore filled with a piece of rockwool with a locally higher density (darker regions), the insulation behavior of this GP5 replica would be more efficient, leading to a better performance of these samples ensemble.

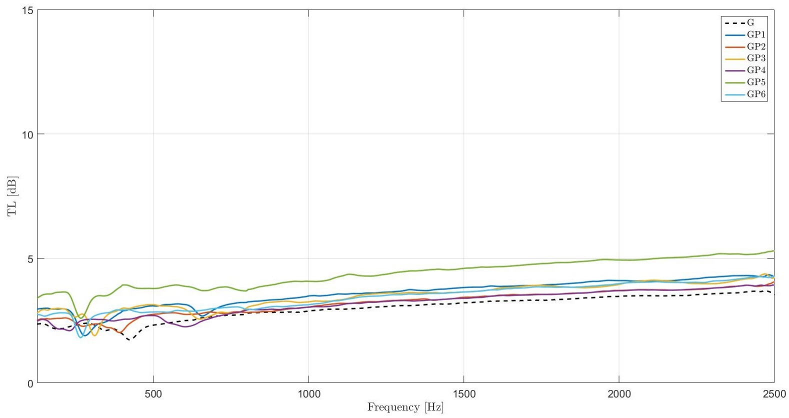


Figure 12. Sound transmission loss for pure sample and samples with mesopores filled - glasswool substract

Also, it is noticed that the region where TL reaches minimum values (resonance region) of all modified samples curves was displaced to lower frequencies compared to the pure glasswool. On the other hand, the opposite is verified for rockwool modified samples, where the minimum in transmission loss curves is displaced to higher frequencies. This effect occurs due to the differences in the mechanical parameters between the pure sample and the modified samples. The addition of rockwool or glasswool changes the mass and stiffness of the entire sample, and this consequently changes its resonance frequency which is responsible for drops on the transmission loss curve.

Table 5 shows the transmission loss gain (in dB) for rockwool and glasswool modified samples, respectively. It is possible to notice the predominance of gains at 500 Hz, which is a region of the TL drop for pure rockwool or glasswool.

4. CONCLUSIONS

Rockwool and glasswool containing filled or not filled mesopores were investigated. The sound absorption tests demonstrate that rockwool samples, with mesopores filled and not filled, present a gain in absorption, especially at frequencies above 1000 Hz. For glasswool samples, the manipulation of the specimens led to a great variation in the sound absorption coefficient curves, so it is not possible to evaluate if the gain produced by double porosity on sound absorption is really effective. In terms of transmission loss, both rockwool and glasswool samples containing filled mesopores presented gains at 500Hz.

Table 5. Sound transmission loss gain in dB at 250, 500, 1000 and 2000 Hz produced by the modified rockwool (RPn) and glasswool (GPn) samples compared to the pure cases (R and G)

Gain (dB) / Frequency (Hz)	**250**	**500**	**1000**	**2000**
RP1 - R	0,4	2,0	0,3	0,8
RP2 - R	0,1	1,8	0,2	0,3
RP3 - R	-0,8	1,0	-0,8	-0,9
RP4 - R	-1,3	0,5	-0,8	-1,0
RP5 - R	-0,7	0,9	-0,1	0,1
RP6 - R	-1,3	0,5	-0,9	-0,6
GP1 - G	0,2	0,8	0,6	0,6
GP2 - G	0,1	0,4	0,2	0,2
GP3 - G	0,3	0,8	0,4	0,5
GP4 - G	0,0	0,4	0,2	0,2
GP5 - G	0,6	1,5	1,2	1,5
GP6 - G	-0,1	0,5	0,3	0,5

Although the gains obtained for transmission loss, they demonstrated the possibility to offset the TL curves to higher values. Further studies are necessary to evaluate the use of more cells on a single sample and different distribution of mesopores to evaluate if this condition contributes to increase or decrease sound absorption and sound transmission loss.

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