PARAMETRIC STUDY OF LAYERED ABSORPTION MATERIALS

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1. INTRODUCTION

The knowledge of basic phenomena governing the absorption performance of materials belongs to the most essential basic knowledge of acoustic consultants. The accuracy of acoustic designs depends strongly on the absorption properties of selected materials. Product catalogues are primarily used to determine the absorption coefficients. But test results are not always available. Therefore, scientific publications, theoretical graphs, prediction models and experience need to be used to estimate the absorption performances. In this case, experience has an important role because absorption coefficients are determined using different methods and the direct comparison of them is unreliable.

The problem occurs, particularly, when multiple layer constructions are used for which product data is seldom available. Such structures are met in situations where fire and thermal insulation layer of the facade or roof structure acts also as an absorber. Actual absorption mechanism is based on various absorption mechanisms at the same time. The dominating mechanism, resistance loss, viscosity loss, panel resonance, or Helmholz resonance, depends on frequency.

The aim of this study was to investigate systematically the effect of different layer parameters on absorption coefficient. The study was carried out experimentally by determining the absorption coefficient of several layered materials.

2. METHODS

The measured samples included materials glass wool, rock wool and polyester wool, perforated metal sheet, perforated plasterboard, plastic foils, and their relevant multilayer combinations. In addition, every sample was measured with different air cavities. The total number of samples tested was 39, and the number of total systems was 343. All results will not be presented in this study.

The normal incidence sound absorption coefficient was determined with an impedance tube Brüel&Kjær 4206A using the transfer function method according to the standard ISO 10534-2. The test samples were circular with a diameter of 63.5 mm, and the investigated frequency range was 125-2500 Hz in 1/3 octave bands.

3. RESULTS AND EXAMINATION

The results are shown in Figures 1-9 presenting the normal incidence absorption coefficient α_0 versus frequency.

3.1. Mineral wool

The results of suspended and unsuspended porous absorbents were agreed with previous knowledge. An increment of the wool density (and of the flow resistivity) decreased the absorption properties (Figure 1). An increment of the sample thickness increased the absorption coefficient, except for very dense wools where the improvement did not take place at high frequencies. In suspended wools the results depended on the sample and on the air thicknesses (Figures 2, 3 and 4). In low density wools, an increment of the air thickness lead to an overall improvement of the absorption, but also to the appearance of standing wave effects which decrease the absorption at some frequency bands. The peaks and the dips in the absorption curve appeared at

$$f = \frac{nv}{4L} \tag{1}$$

where n = 1, 2, 3... , v is the speed of sound [m/s], and L is the length of the backspace [m]. This resonance effect is clearly seen in Figures 2.1 and 4.3, but it is reduced as the thickness of the wool increased. In high density wool, Figure 3, the resonance effects were weaker. In addition, increasing the wool thickness and air thickness over a certain limit produced almost no improvement.

In Figure 4, the effect of varying the wool thickness was studied while keeping constant the thickness of the system. It is seen that 50 mm of wool and 50 mm of air brings almost same result as 100 mm of wool. As the thickness of the air layer increased the absorption at low frequencies improved considerably. However, resonance caused dips in the absorption curve which decreased the absorption at some frequency bands.

The behavior of suspended polyester wool was similar to glass wool (Figure 5).

The results for coated rock wools are shown in Figure 6. The lower the density is the higher is the absorption. The larger is the air thickness the better is the performance at low frequencies, although resonance effects also bring dips and peaks in the absorption curve.

3.2. Perforated steel and mineral wool

Perforated thin metal plates are used to protect wools and to improve visual appearance. The effect of hole size and perforation ratio is presented in Figure 7, when the back layer is either air or mineral wool. When the perforation ratio was small, i.e. 1 % in Figure 7.1, the plate behaved as a Helmholz resonator, for both studied perforation sizes. As the perforation ratio increased, 4% in Figure 7.2, the plate became more transparent to sound, and when the perforation ratio was 15 % or larger, Figure 7.3, the perforated plate did not decrease the absorption properties of the wool behind it anymore.

Both hole diameters lead to similar results. It is expected that smaller diameter than 1 mm would lead to viscous absorption effect which is utilized in microperforated absorbers.

3.3. Plastic foil and mineral wool

Plastic foils are normally placed over wools in facade construction as vapor barriers, which decrease essentially the absorption at high frequencies. The plastic foils behaves as resonator plates, with a resonance peak at the following frequency

$$f_r = \frac{60}{\sqrt{m \cdot d}} \tag{2}$$

Where f_r is the resonance frequency [Hz], m the surface mass [kg/m^2], and d the cavity size [m].

Placing a plastic foil over glass wool decreased the absorption coefficient at high frequencies, Figure 8. This drawback could be avoided if the plastic foil is sunk inside the wool. The vapor isolation properties of the whole structure are not changed dramatically if the foil is placed inside the wool 1/4th of the total wool thickness.

A sound-absorbing facade construction system is studied in Figure 9.1 consisting of perforated thin metal plate, plastic foil and glass wool in different orders. The effect of placing the foil inside the wool is compared with the case where foil is absent and the results were almost equal. Figure 9.2 shows that the use of air cavity right behind the perforated sheet is not beneficial for the performance of mineral wool.

4. DISCUSSION

The generalization of results decreases by the fact that the impedance tube considers only the normal incidence, by contrast with product data which normally advertise diffuse field coefficient obtained in a reverberant room by ISO 354. In addition, the frequency range was limited to 125-2500 Hz so that all findings are not valid at high frequencies. A wider measurement range 50-6300 Hz is possible with the impedance tube by using two sample sizes, diameters 29 mm and 100 mm for bands 500-6300 and 50-1600 Hz, respectively. However, it was problematic or impossible to prepare acceptable samples to diameter 29 mm for most of the perforated materials. For this reason, it was decided to choose narrow frequency range instead of halving the amount of samples.

A further step of this research is to measure the diffuse field coefficient for some specimens and compare the results with the existing data. Also some samples with larger surface patterns than 20 mm must be studied using ISO 354, e.g. mineral wool covered with laths.

In parallel with these measurements, a research of absorption prediction models for the same range of materials and multilayer has been going on. The validation of these models should be made using this experimental data.

The complete measurement series will be published in English in the future.

5. ACKNOWLEDGEMENTS

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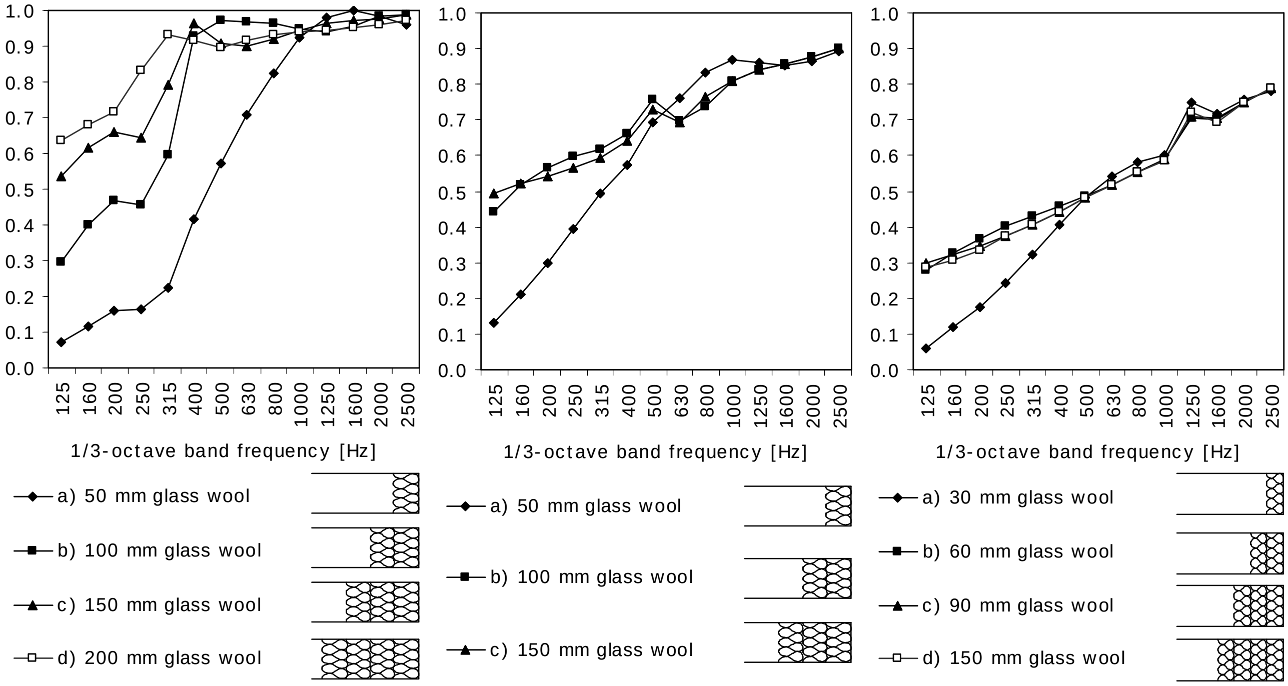

Figure 1. *Influence of thickness in three glass wools of densities 18 kg/m^3, 76 kg/m^3 and 129 kg/m^3.*

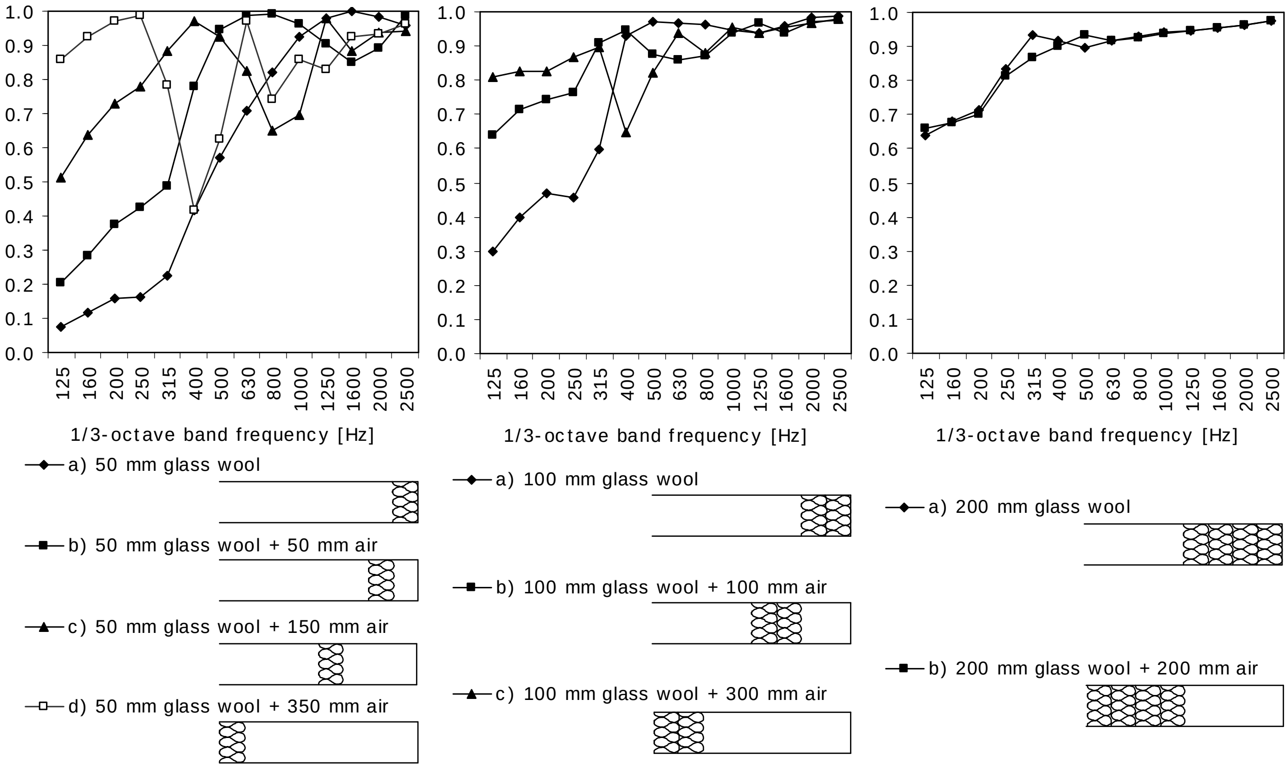

Figure 2. *Influence of different wool and suspension thicknesses in a glass wool of density 18 kg/m^3.*

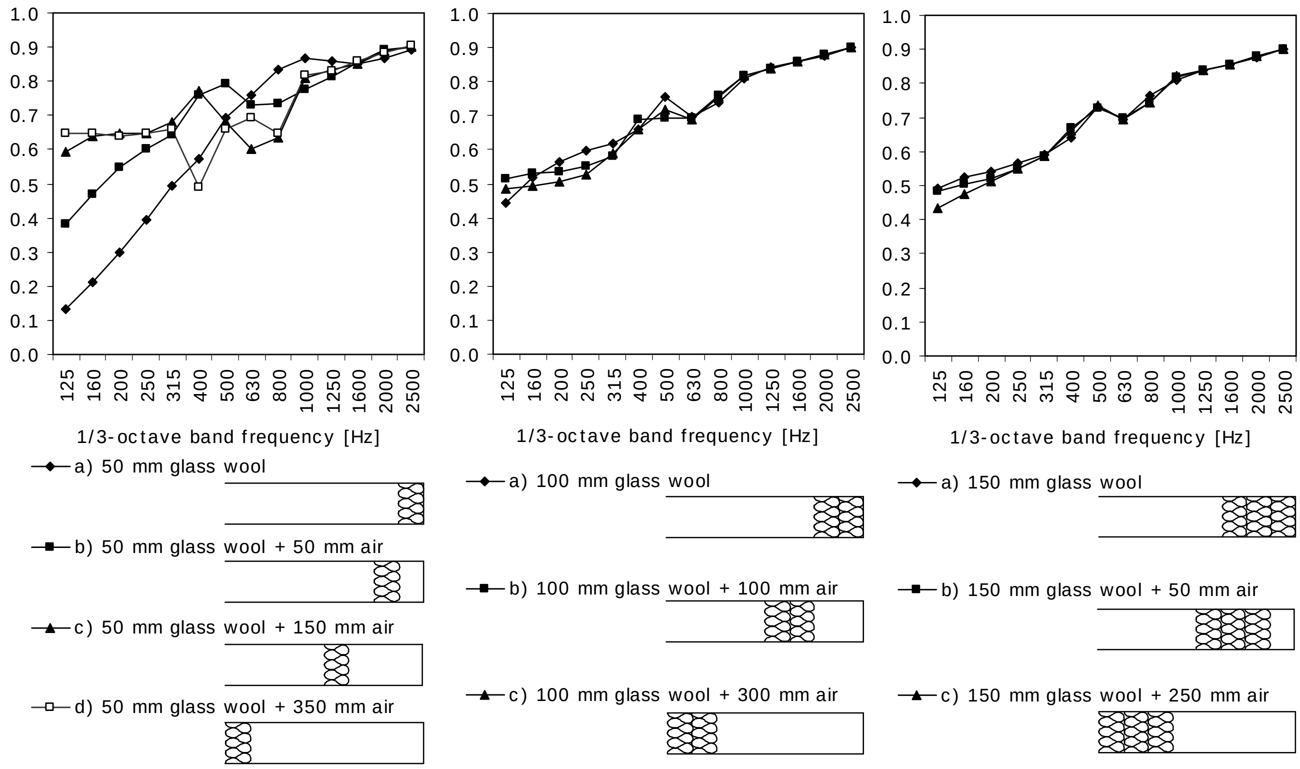

Figure 3. *Influence of different wool and suspension thicknesses in a glass wool of density 76 kg/m^3.*

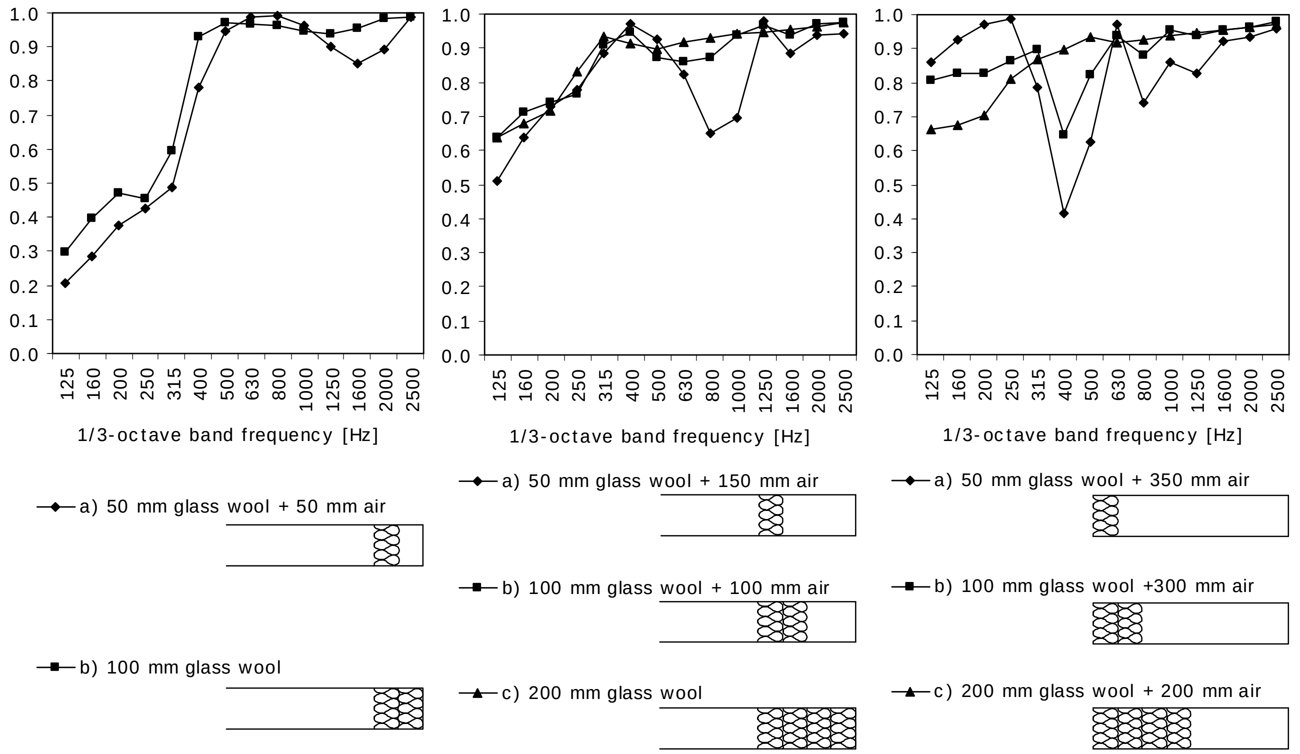

Figure 4. *Effect of the air cavity for constant specimen thickness, in a glass wool of density 18 kg/m^3.*

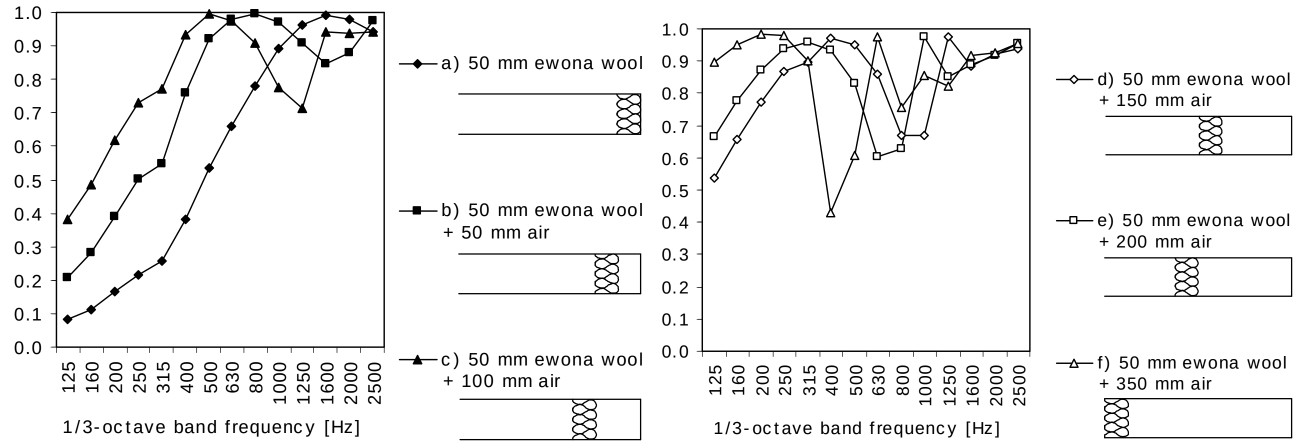

Figure 5. *Effect of the air cavity for constant specimen thickness in a polyester wool of density 38 kg/m3.*

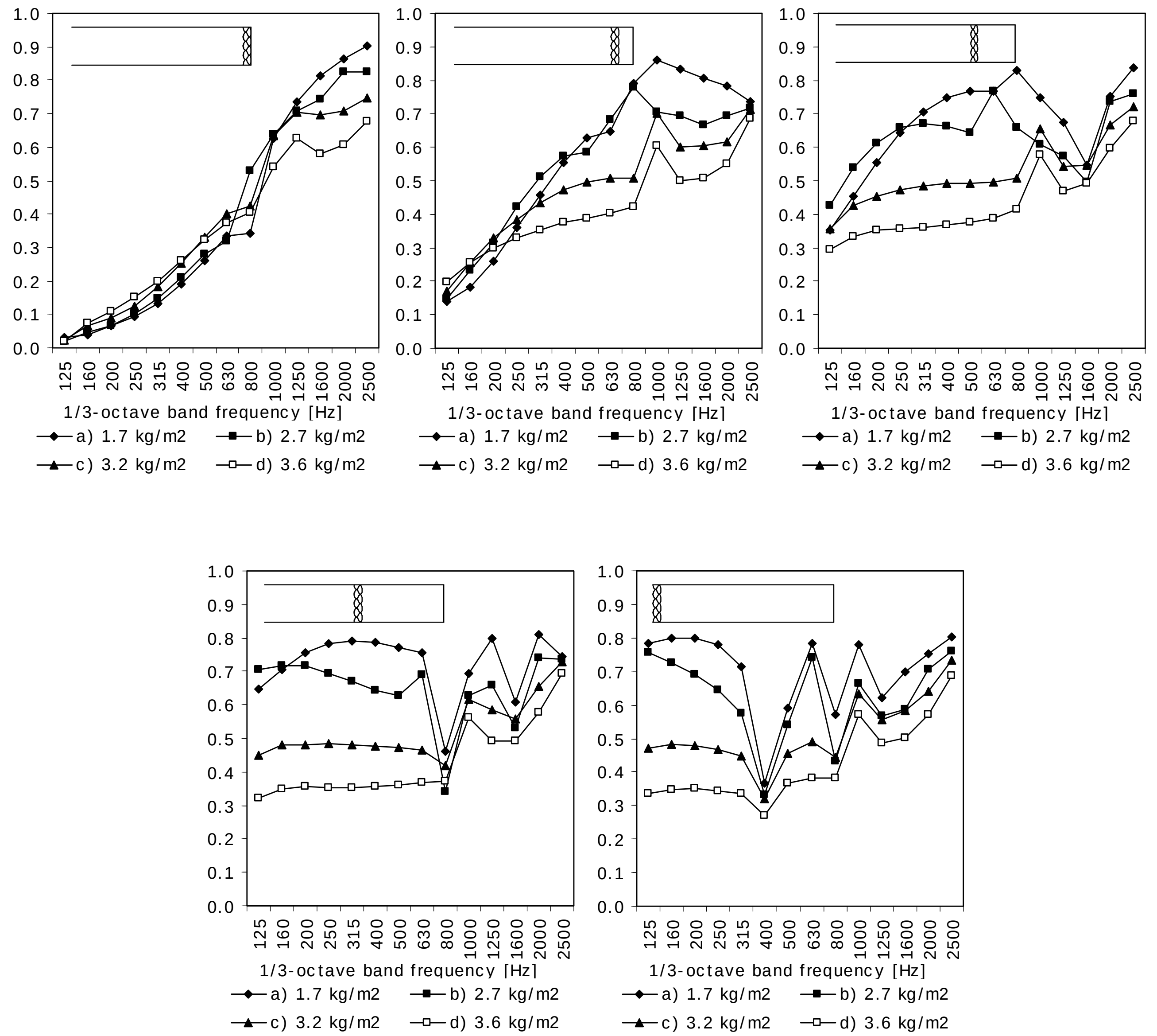

Figure 6. *Effect of the air cavity for different coated mineral wools. Air cavities 0 mm, 32 mm, 82 mm, 182 mm and 382 mm. Wool thickness in all cases is 18 mm.*

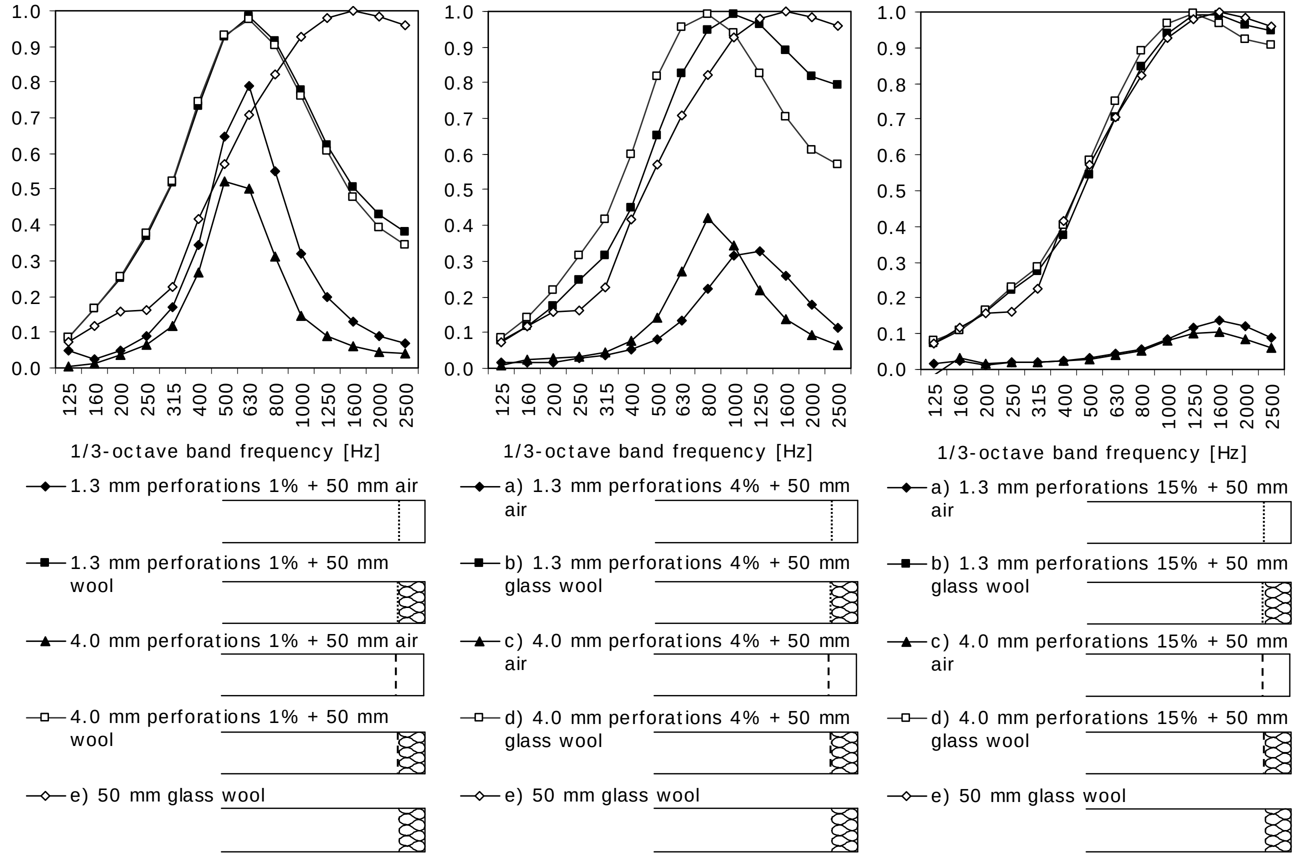

Figure 7. *Effect of material in the cavity for different perforated metal plates. Size of hole in mm and area of perforation in % is described in label. Glass wool density is 18 kg/m^3.*

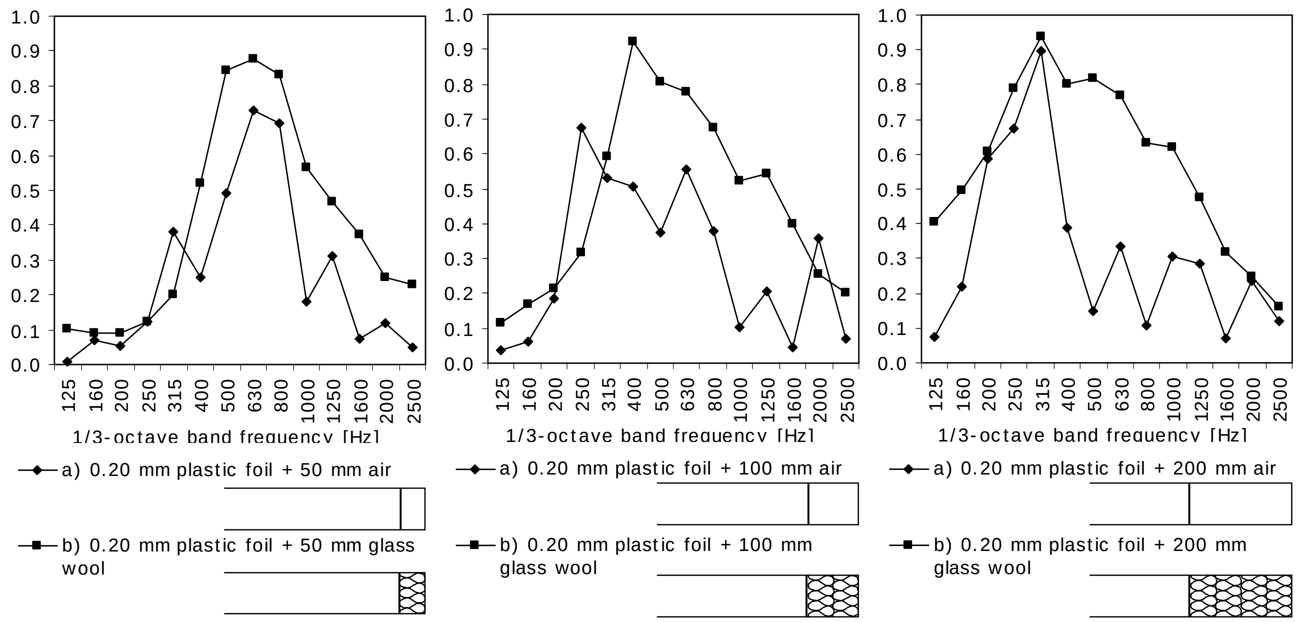

Figure 8. *Effect of material behind a plastic foil. Glass wool density is 18 kg/m^3.*

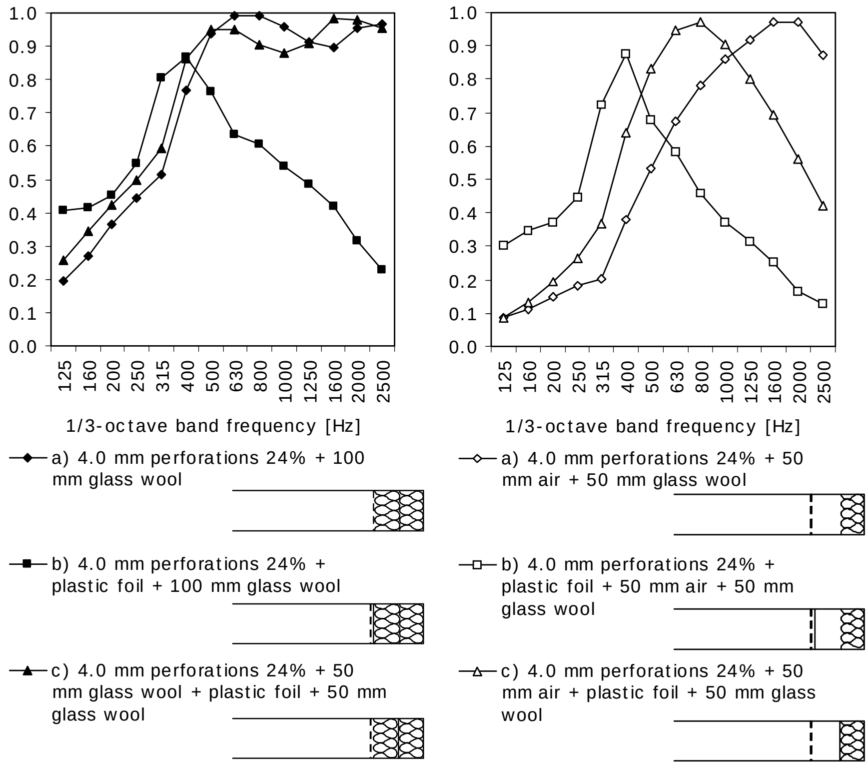

Figure 9. *Effect of the location of plastic foil in facade constructions. Glass wool density is 18 kg/m*^{3}.