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# Predicted sound absorption coefficients of absorber materials lined in a chamber

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## ABSTRACT

**Aims:** The present study was aimed to measurement of sound absorption coefficient of mineral wool and determination of their absorption ability.
**Materials and Methods:** Mineral wool was used to find noise absorption coefficient. Random and normal sound absorption coefficient values were predicted. Then, the measures of transmission loss calculated as an overall value, for applied absorbent material and bare sheet metal.
**Results:** The measured values of noise with one octave band frequency demonstrated an attenuation of 5.5-7 dB for these frequencies. The absorption coefficients of materials showed that mineral wool had more normal sound coefficients than its random sound absorption coefficient values.
**Conclusion:** It can be concluded that predicted normal sound absorption coefficients of used mineral wool materials were near to the areas of standard line. It seems that the amount or thickness of absorbent lining was a main reason of noise reduction in low band frequencies. Mineral wool has a higher density and can provide better acoustical and insulating results than fiberglass. Besides, mineral wool doesn't lose its insulating value when wet and has an outstanding resistance to fire.

**Key words:** Absorption coefficient, mineral wool, noise, transmission loss

## INTRODUCTION

Porous materials obtained from synthetic fibers, such as mineral wool or glass wool, are commonly used for thermal insulation and sound absorption, because of their high performance and low-cost. Their diffuse-field sound absorption coefficient is very high at mid-high frequencies. On the other hand, they have several cons so that they can be harmful for human health if their fibers are inhaled, since, they can lay down in the lung alveoli, and can cause skin irritation. Hence, such materials must be adequately overlaid if directly exposed to the air. Moreover, they can pulverize because of vibrations and are not resistant to water, oil and chemical agents, and this makes unwise their application on absorbing noise barriers.[1]

In recent years, an increasing attention has been turned to natural fibers as alternatives to synthetic ones, in order to combine high acoustic and thermal performances with a

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low impact on the environment and on the human health. Natural fibers have very low toxicity and their production processes contribute to protect the environment. Recycled materials, as recycled plastic fibers, can even be regarded as a sustainable alternative. The aim of the paper is to investigate the acoustic performances of such materials through measurements of sound absorption coefficient applied in a chamber and comparisons with conventional fibrous sound absorbers.[2]

Industrial applications of sound insulation, generally includes the use of materials such as glass wool, foam, mineral fibers, and their composites. Mineral wool is manufactured similarly to fiberglass, with molten rock instead of glass and also comes in bats or rolled blankets, or loose-fill. This material is more common in Europe, Australia, Canada and New Zealand than in the U.S., and it's a good alternative to fiberglass.[3] Mechanical equipment noise is one of the major sources of unwanted noise in a building. Internal duct lining for rectangular sheet metal ducts can be used to provide both thermal insulation and sound attenuation. Figure 1 is illustrating a shape of inlet or outlet of lined duct by absorber material. The thickness of duct linings for thermal insulation usually varies from 50 to 100 mm; density of mineral wool lining usually varies between 80 kg/m$^3$ and 120 kg/m$^3$. For mineral wool duct lining to attenuate fan sound effectively, it should have a minimum thickness of 5 mm.

## MATERIALS AND METHODS

### Duct element sound attenuation

A chamber with the dimension 1.5 × 1.2 × 1.1 of galvanized metal designed to calculation sound absorption coefficients. Absorber was chosen from mineral wool material with a thickness of 10 cm and a density of 80 kg/m$^3$. Chambers are often placed between the outlet of a fan and main air distribution ducts to smooth turbulent airflow. These chambers are typically lined with acoustically absorbent material to reduce fan and other mechanical noise. Chambers are usually large rectangular enclosures with an inlet and one or more outlets.[4]

### Absorption coefficient

For a surface, the ratio of the sound energy absorbed by a surface of a medium (or material) exposed to a sound field (or to sound radiation) divided by the sound energy incident on the surface. The stated values of this are to hold for an infinite area of the surface. The absorption coefficient is a function of both angle of incidence and frequency. Tables of absorption coefficients usually list the absorption coefficients at various frequencies, the values being.

At frequencies below $f_{co}$, the plenum chamber can be treated as an acoustically lined expansion chamber.[5] The equation for the transmission loss (TL) of an acoustically lined expansion chamber is

$$\mathrm{TL} = 10\log_{10}\left[\left(\cosh\left[\frac{\sigma l}{2}\right]+\frac{1}{2}\left[m+\frac{1}{m}\right]\sinh\left[\frac{\sigma l}{2}\right]\right)^2 \times \cos^2\left(\frac{2\pi \times f \times l}{c_o}\right)+\left(\sinh\left[\frac{\sigma l}{2}\right]+\frac{1}{2}\left[m+\frac{1}{m}\right]cosh\left[\frac{\sigma l}{2}\right]\right)^2 \times \sin^2\left(\frac{2\pi \times f \times l}{c_o}\right)\right] \quad (1)$$

where σ is sound attenuation per unit length in the chamber (dB/ft), l is the horizontal length of the plenum chamber (feet), $c_o$ is the speed of sound in air (ft/s), f is frequency (Hz), and m is the ratio of the cross-sectional area of the plenum divided by the cross-sectional area of the inlet section of the plenum.

m is given by

$$m = \frac{S_{pl}}{S_{in}} \quad (2)$$

The TL in this higher frequency range are predicted using the following relationship:[5]

$$\mathrm{TL} = -10\log_{10}\left[S_{\mathrm{out}}\left(\frac{Q\cos\theta}{4\pi r^2}+\frac{1-a_A}{Sa_A}\right)\right] \quad (3)$$

Where

TL = transmission loss, dB,

$S_{\mathrm{out}}$ = area of chamber outlet, m$^2$,

S = total inside surface area of chamber minus inlet and outlet areas, m$^2$,

*r* = distance between centers of inlet and outlet of chamber, m,

Q = directivity factor; taken as 2 for opening near the center of wall, or 4 for opening near the corner of the chamber,

$a_A$ = average absorption coefficient of chamber lining,

TL for few layers of absorbent materials,

In case of using few materials and different mediums, the TL will be calculated from below formula.

$$\mathrm{TL} = -10log\left[\frac{\sum_{i=1}^{q} S_i 10^{TL_i/10}}{\sum_{i=1}^{q} S_i}\right] \quad (4)$$

## RESULTS

As can be seen from Figure 1, the chamber dimensions, inlet and outlet have chosen accordance to ASHRAE instructions;

hence, that the noise of fan can be reduced from above 500 Hz frequencies.[6]

The measured values of noise with one octave band frequency before and after installing chamber demonstrate that it can play an important role in noise reduction especially in higher frequencies than cutoff. The sound attenuated in these frequencies is about 5.5-7 dB. It is clear that a larger chamber has more noise reduction, but choosing chamber is depended on the duct dimensions, fan size, enough space to install and required noise reduction measures.

In new research, the scholars try to measure two points of duct at downstream and upstream to compare the results and determine TL.[7]

The barrier's ability to attenuate noise passing through it can be specified by its TL. TL is the loss as sound passes through a barrier. In particular, TL can be defined as the difference between sound pressure level (SPL) on the source side of the barrier, and the SPL on the receiver side:

$$TL = SPL_{source} - SPL_{receiver} \quad (5)$$

It is an important to note that absorption coefficients are based on a linear scale, and TL values are based on a logarithmic scale. Hence, comparing them can be misleading. We define τ as the transmission coefficient, the amount of sound that passes through a material.

Where, $\tau = 1 - \alpha$.

It relates to TL as:

$$TL = 10\log\frac{1}{\tau} \quad (6)$$

Figures 2 and 3 have shown a comparison of the values of absorption coefficient mineral wool and sheet metal chamber with their references. This is because of the chamber can reduce fan-induced noise about 7 dB and therefore the noise has significantly declined in ducts and workplace. A lined chamber with an absorber like mineral wool has increased this reduction to 13 dB in high frequency. In this case, absorption coefficient of chamber increased about 40 percent by using mineral wool material which [Figure 4]. There is a significant noise reduction in low frequencies (frequencies from 31.5 Hz to 500 Hz) in spite of having a cutoff frequency of 436 Hz. Figure 5 shows the measures of TL calculated as an overall value, for applied absorbent material and bare sheet metal.[8]

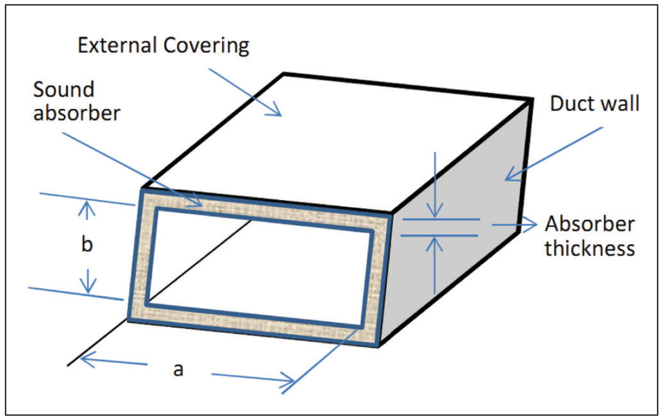


Figure 1: Lined duct by means of sound absorbing material

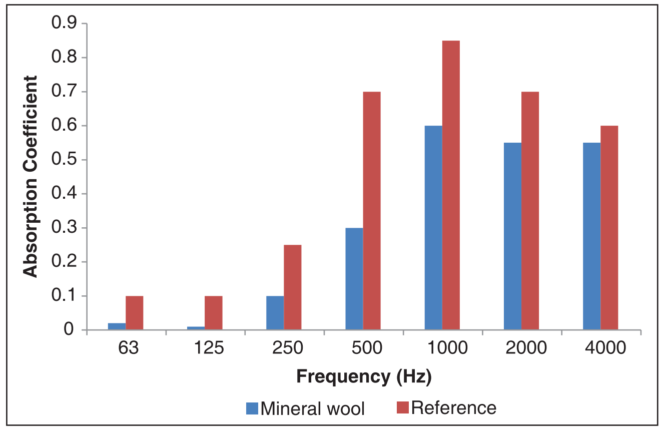


Figure 2: Comparison of predicted sound absorption coefficients of mineral wool absorber and standard values

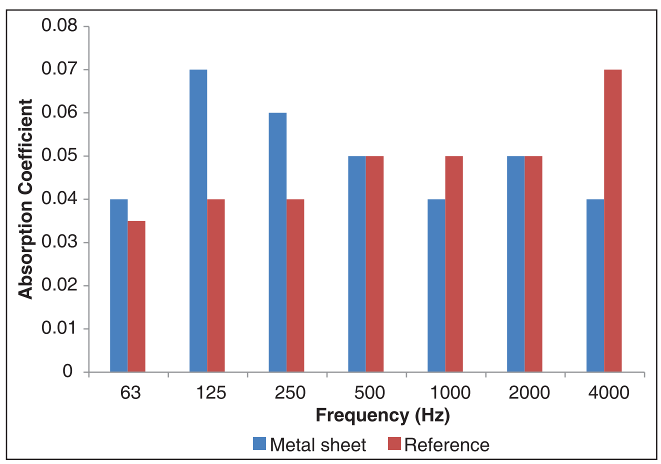


Figure 3: Comparison of predicted sound absorption coefficients of galvanized sheet metal and standard values

## DISCUSSION

A sound-absorbing chamber is an economical device for achieving significant attenuation. Chamber performance can be increased by increasing the ratio of the cross-sectional area of the chamber to the cross-sectional area of the entrance and exit ducts, and by increasing the amount or thickness of absorbent lining.[9] A chamber located at the fan discharge can be an effective and economical way to decrease noise entering the duct system. Based on the ASHRAE standard guidelines, sound frequencies below the cutoff frequency will be seen less likely to drop. SPLs in ducts and chambers are sensitive to duct dimensions and duct discharge types but insensitive to duct locations and room dimensions.[10]

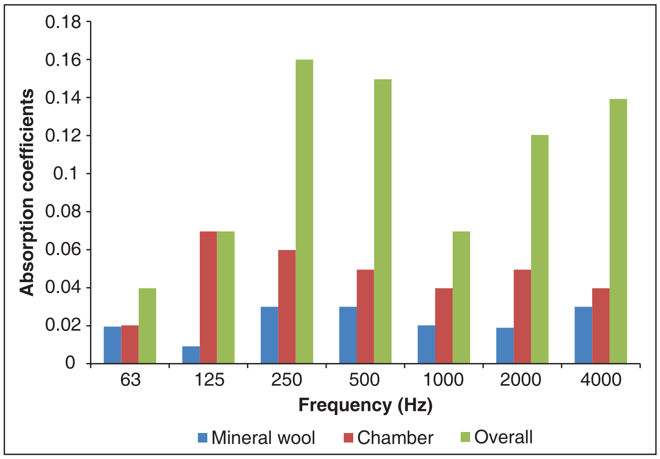


**Figure 4:** Predicted sound absorption coefficients of mineral wool in comparison with galvanized sheet metal

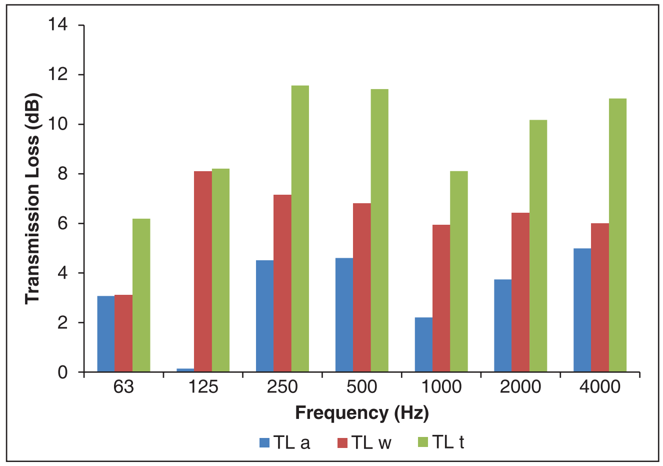


**Figure 5:** Predicted sound transmission loss of mineral wool in comparison with galvanized sheet metal

**Table 1: Predicted random sound absorption coefficient values for mineral wool and galvanized sheet metal**

| Frequency (Hz) | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 |
|---|---|---|---|---|---|---|---|
| Absorption values of galvanized sheet metal | 0.02 | 0.07 | 0.06 | 0.05 | 0.04 | 0.05 | 0.04 |
| Absorption coefficient values of mineral wool | 0.02 | 0.01 | 0.03 | 0.03 | 0.02 | 0.02 | 0.03 |

**Table 2: Predicted normal sound absorption coefficient values for mineral wool**

| Frequency (Hz) | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 |
|---|---|---|---|---|---|---|---|
| Absorption coefficient values of mineral wool | 0.03 | 0.15 | 0.2 | 0.68 | 0.7 | 0.87 | 0.90 |

As mentioned before, there is a significant noise reduction by 7 dB in low frequencies (frequencies from 31.5 Hz to 500 Hz) while using the chamber in spite of having a cutoff frequency of 436 Hz. This value of reduction reaches to 11 dB with lined chamber. This is an important point that sometimes the chamber can also be effective at reduction of noise in low frequencies. It seems the amount or thickness of absorbent lining is a main reason of noise reduction in low band frequencies. It concludes from Tables 1 and 2 and figures that predicted normal or random sound absorption coefficients of used mineral wool materials are near to the areas of standard line. Some health experts claim that fiberglass fibers, when inhaled, are carcinogenic and these products may promote microbial growth. Mineral wool has a higher density and can provide better acoustical and insulating results than fiberglass. Besides, mineral wool doesn't lose its insulating value when wet and has an outstanding resistance to fire.

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