The Accuracy of Methods for Predicting Sound Absorption Coefficients

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Introduction

The accurate prediction of sound absorption coefficients for new materials and designs is of continuing practical interest for room acoustic design. This paper will describe a simple class of model for predicting random incidence absorption coefficients and investigate the accuracy of the model.

The model is applicable to absorptive materials in which the porosity is high, the frame or skeleton of the material is infinitely rigid, and the tortuosity of the material is not great. These models are applicable to a very wide range of materials used as sound absorbers such as fibreglass, mineral wool, polyester, wool, etc.

The model can predict random incidence sound absorption coefficients of such porous materials with various different facings (slots, perforated boards, light panels). Materials are assumed to be locally reacting, with acoustic properties determined by their static flow resistivity. The effect of facings is modelled by adding the reactance of the facing to the normal acoustic impedance of the material and modifying the resistive part of the acoustic impedance of the material close to the hole or slot. Random incidence absorption coefficients are predicted from normal incidence impedance using diffraction theory.

Theory and Results

For room acoustics purposes it is desired to know the sound absorption coefficients as a function of frequency. The classic method of doing this is to first predict or measure the characteristic impedance and complex propagation coefficient of the material and then to derive the normal incidence absorption for a particular thickness and mounting arrangement.

Delany and Bazley [1] developed a one parameter model in which a single parameter, the static flow resistivity, is used to predict the characteristic impedance and propagation coefficient of the material. Their approach was primarily empirical, but loosely based on theory, and within its stated limits, was an easy and relatively accurate model. Mechel [2] later extended the model to lower frequencies and various other researchers developed variations on the basic approach. In recent years better models which are more rigorously based on theory have been developed. An attractive model which uses the flow resistivity as the primary parameter, but includes an additional parameter called the shape factor (which for normal materials can be regarded as constant) was developed by Allard and Champoux [3]. The arithmetic involved in calculating the propagation coefficients is more tedious than the Delany and Bazley model, but is easily handled by modern computing methods. A comparison of measured and predicted normal incidence coefficients is shown in figure 1 for a sample 25mm thick and with a flow resistivity of 2000 Rayls/m. It can be seen that the Allard and Champoux model is very accurate and significantly better than the Delany and Bazley model for this material. At higher flow resistivities predictions by the two models converge and both provide good accuracy.

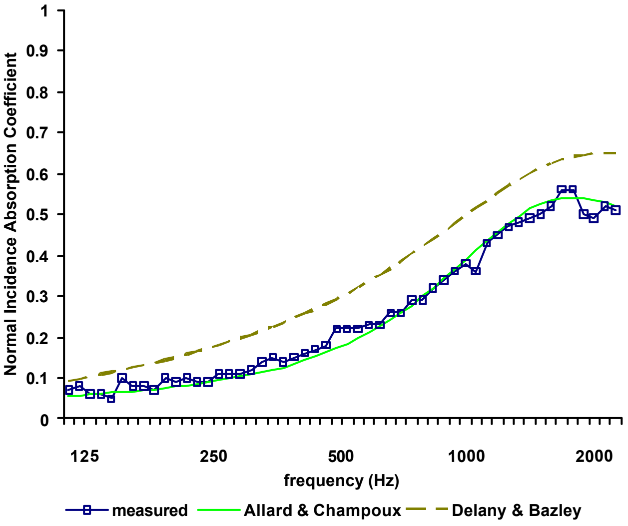

Figure 1: Measured and predicted normal incidence absorption coefficients for polyester fibre of 25 mm thickness and flow resistivity 2000Rayl/m.

To predict the performance of slotted and perforated facings the change in acoustical impedance due to the addition of the perforated covering must be calculated. The model uses a mass reactance term added directly to the normal incidence impedance of the porous absorber, and an additional resistive term. The mass reactance is the mass of the air in the hole or slot plus an end correction which can be derived for simple cases such as slots or perforations.

$$Z_{n'} = Z_n + j\omega\left(\frac{\rho(l+\delta l)}{\sigma}\right) + \frac{R_l \delta l}{\sigma} \qquad (1)$$

- Zn' is the normal impedance of the slot absorber,
- Zn is the normal impedance of the backing material,
- ? is the density of air,
- l is the thickness of the facing,

- d l is the end correction,
- s is the fractional open area of the facing, and
- R1 is the flow resistivity of the backing.

The additional resistive term is used to model the additional resistive losses that are associated with the increased velocity of air particles in the immediate vicinity of the neck. An initial hypothesis was made that the increased resistance was the same as if the sound wave was forced to pass through an additional thin resistive cloth of flow resistance equal to the flow resistivity of the material times a distance equal to the end connection, divided by the fractional open area of the perforated covering. Over the range of absorbers studied this gave good agreement for perforated and slotted absorbers

While the normal incidence absorption can be readily and accurately predicted and measured, it is not of great practical value in room acoustic design. The most useful property is the random incidence absorption coefficient which is used for calculating the room response. For materials which are locally reacting, the absorption coefficient varies in a predictable way with the angle of incidence of the sound wave and can be averaged over all angles of incidence. However this does not agree with measurements. The effects of diffraction around the edges of the sample are very strong for typical sized absorbers. In certain cases the measured absorption coefficient can significantly exceed unity. For normal test samples the diffraction effects are strongest between 100 and 1000Hz.

An early attempt at predicting diffractive effects was made by Northwood [4], which involved predicting the diffraction for an infinitely long strip. More recently Thomassen [5] has developed a theory for predicting the diffraction of square patches of material which is relatively easy to apply and which appears to be reasonably accurate in predicting absorption of finite sized areas in a diffuse sound field. (see figure 2,3).

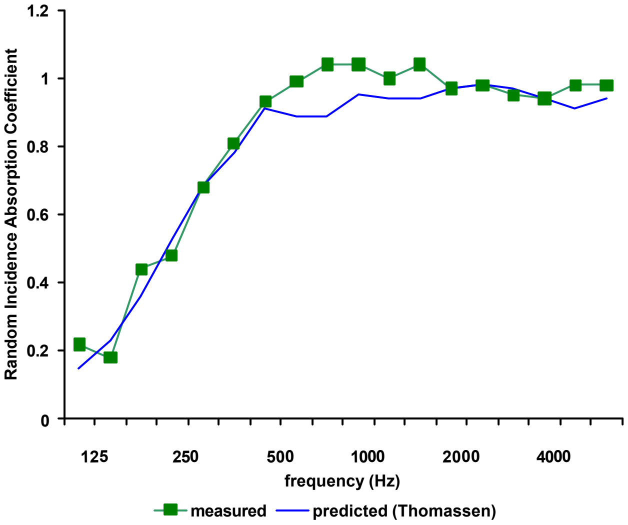

Figure 2: Measured and predicted random incidence absorption coefficients for 50mm thick Sillan Rockwool.

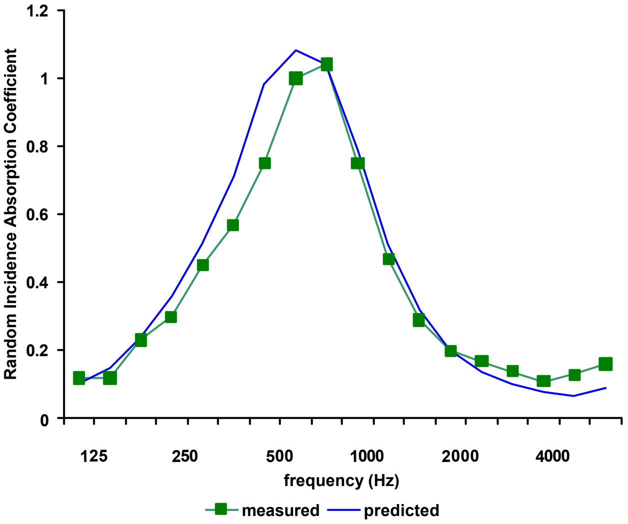

Figure 3: Measured and predicted random incidence absorption coefficients for 25mm polyester blanket covered by 17 mm thick plywood with 8 mm holes at 27 mm pitch.

Limitations

The model gives reasonable agreement for materials which have a porosity greater than about 80%, a flow resistivity between 1,000 Rayl/m and 100,000 Rayl/m. Coverings with perforation ratios as low as 5% and porous absorption thicknesses between 10mm and 150mm can be predicted with acceptable accuracy for room acoustics purposes. It should be used with caution outside these limits. It can not be used for absorbers with a significant aircavity as these arrangements are not locally reacting.

Conclusions

Useful predictions of random incidence sound absorption coefficients of perforated, slotted and panel absorbers can be obtained using simple models of porous materials together with simple empirical adjustments for the effect of the facings.

References

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