Predicting Sound Absorption of Perforated and Slotted Absorbers

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Abstract

A method has been developed to predict random incidence sound absorption coefficients of porous materials, with various different facings (slots, perforated board, light panels). Materials are assumed to be locally reacting, with 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. The random incidence coefficients are predicted from normal incidence impedance using diffraction theory. Within certain limits good agreement is obtained between predictions and experiments.

Introduction

It is important to be able to predict the sound absorption properties of slatted and perforated absorbers. These types of absorbers are frequently used to control the acoustics of rooms, and it is often found that there is no test data available for a particular design, or it is necessary to design an absorber to achieve specific characteristics.

This paper describes some analytic methods for predicting sound absorbtion coefficients from simple design information and compares predictions and measurements.

Theory

Researchers have developed impressive theoretical models for predicting acoustical properties of a wide range of materials [1-5]. However in this paper I will concentrate on a simple class of model 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 wide range of common materials, fibreglass, rockwool, polyester, wool, etc.

For room acoustics purposes it is desired to know the sound absorption coefficients as a function of frequency. The usual way of doing this is to first predict the characteristic impedance and complex propagation coefficient and then to derive the normal incidence absorption for a particular thickness and mounting arrangement [1].

$$Z_n = Z_o \,\mathrm{Coth}\,(\gamma\, l)$$

Delany and Bazley [6] developed a so called one parameter model in which a single parameter, in this case the static flow resistivity is used to predict the propagation coefficients etc. Their approach was primarily empirical, but loosely based on theory, and within its stated limits, was an easy and relatively accurate model. Mechel [7] later extended the model to lower frequencies and various other researchers developed variations on the basic approach.

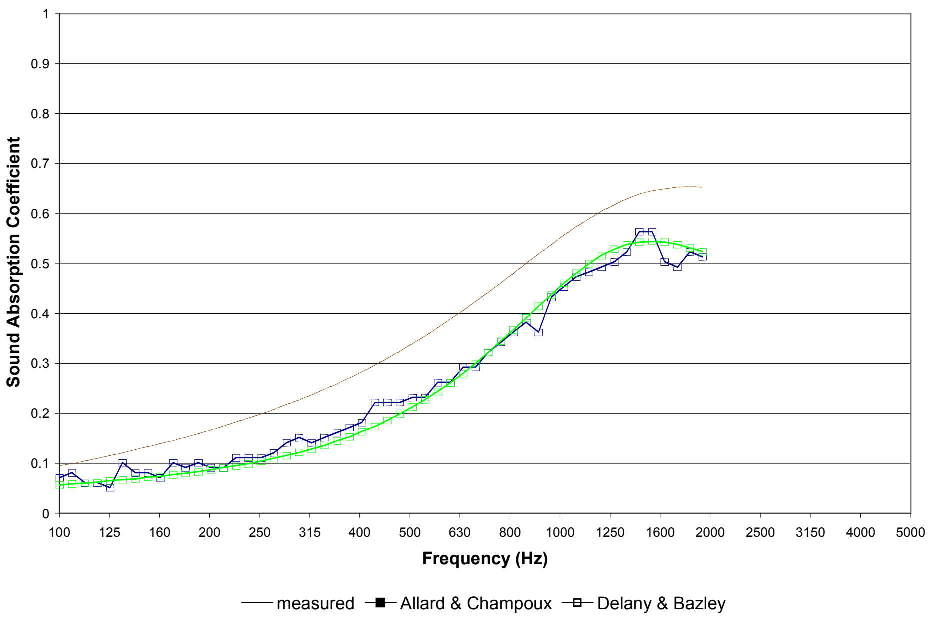

Figure 1: 25mm thick porous absorber, 2000 Rayls/m

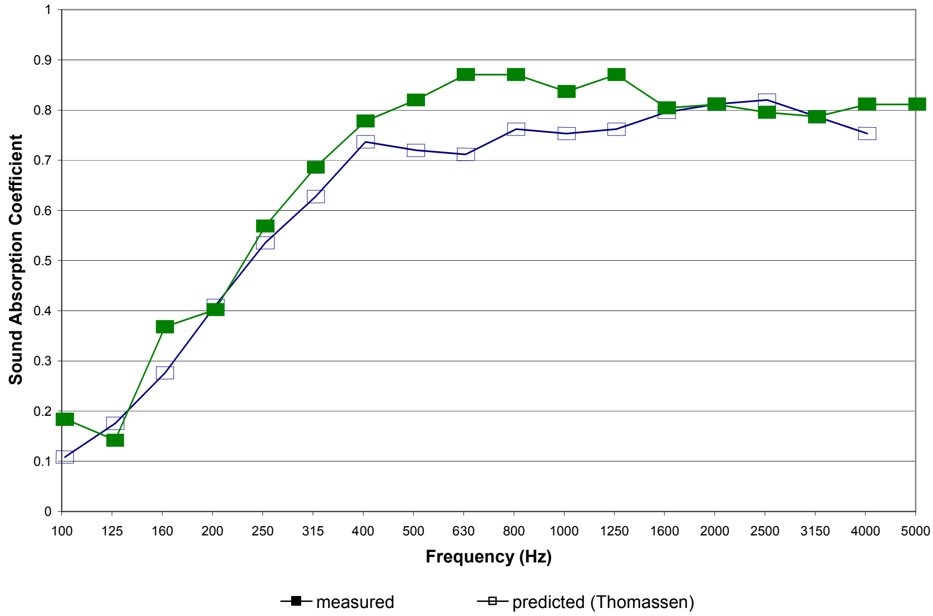

Figure 2: Measured versus Predicted

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 [5]. The arithmetic involved in calculating the propagation coefficients is more tedious than the Delany and Bazley model, but once built into a computer algorithm, can thenceforth be ignored. 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 significantly better for this material. At higher flow resistivities the two models give more similar results.

For materials which have low porosity and high tortuosity (e.g. medium density wood chip board, acoustic plasters, wet felted mineral fibre) this model as it stands is not accurate. A model which is more accurate for these conditions is that developed by Wassilieff [8].

While the normal incidence absorption can be readily and accurately predicted and measured, it is unfortunately of little practical value. The most useful property is the random incidence absorption coefficient (which varies with frequency). Now for most materials which are so called locally reacting, the absorption coefficient varies in a predictable way with the angle of incidence of the sound wave. Paris [9] developed an equation for averaging the absorption coefficient over all angles of incidence, unfortunately this does not agree with measurements because of the effects of diffraction around the edges of the sample. In certain cases the measured absorption coefficient can exceed unity, a fact which is intuitively difficult to understand. For normal test samples the diffraction effects are strongest between 100 and 1000Hz.

An early attempt at predicting diffractive effects was made by Northwood [10], which involved predicting the diffraction for an infinitely long strip. More recently Thomassen [11] has developed a theory for predicting the diffraction of square patches of material which is relatively easy to

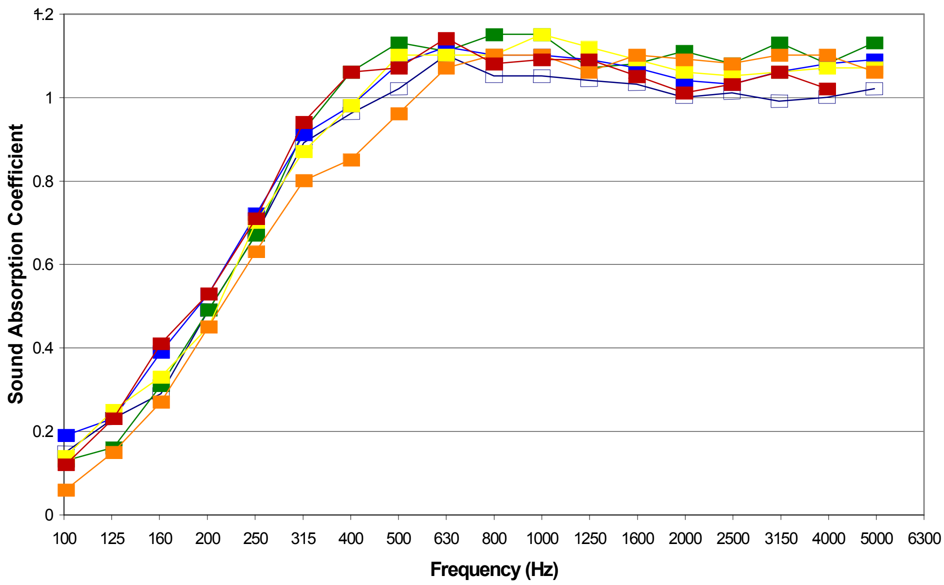

Figure 3: Inter-laboratory comparison of 50mm Rockwool

apply and which appears to be reasonably successful (see figure 2) at least for a useful range of material arrangements.

A word of caution is probably in order at this point. Measurements of the random incidence coefficiences are carried out in standardised test rooms with standardised configurations of materials, but even so the spread of results between laboratories is rather large. In a series of round robin experiments a sample of 50mm thick rockwool was measured in 21 different laboratories in Australia and New Zealand [12]. The difference between laboratories was large, and even when only those six rooms which conformed to the ISO test standard are included the agreement is still not exact (figure 3). Remember this is for the same sample, measured with the same equipment. So it can be seen that we can not hope to achieve "exact" agreement between our theory and a single set of measurements.

Now to predict the performance of slotted and perforated absorbers a final step is necessary. The change in acoustical impedance due to the addition of the perforated covering must be calculated. The proposed 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 simply the mass of the air in the hole or slot plus an end correction which can be derived theoretically for simple cases such as slots or perforations [13].

$$Z_{n'} = Z_n + j\omega\left(\frac{\rho\,(l+\delta l)}{\sigma}\right) + \frac{R_1\,\delta l}{\sigma}$$

where Z_n is the normal impedance of the backing material, $Z_{n'}$ is the normal impedance of the slot absorber, ρ is the density of air, l is the thickness of the facing, δl is the end correction, σ is the fractional open area of the facing, and R_1 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. Whilst this could no doubt be done analytically, it was decided to try a simple empirical approach. 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

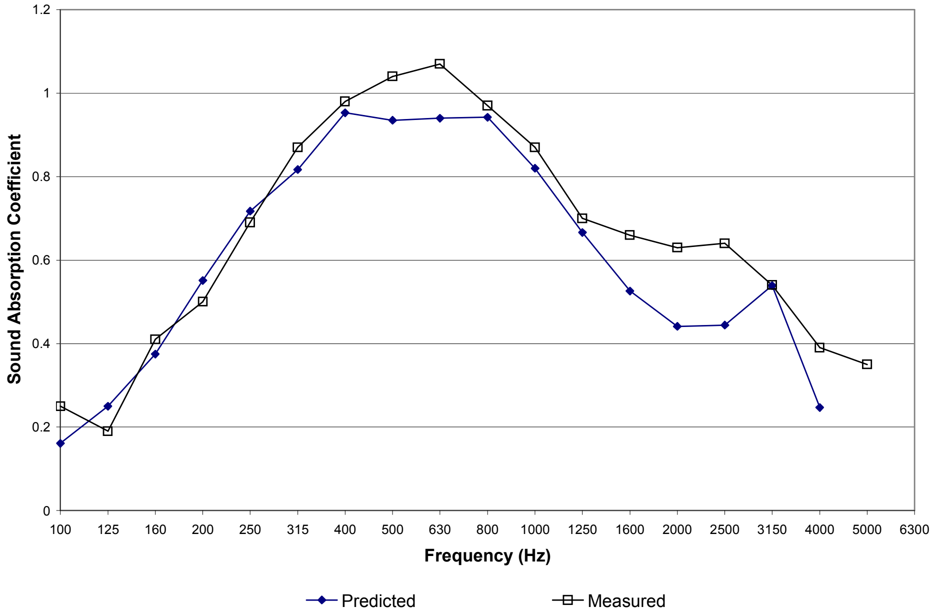

Figure 4: Double Punched Pegboard on 50mm Foam

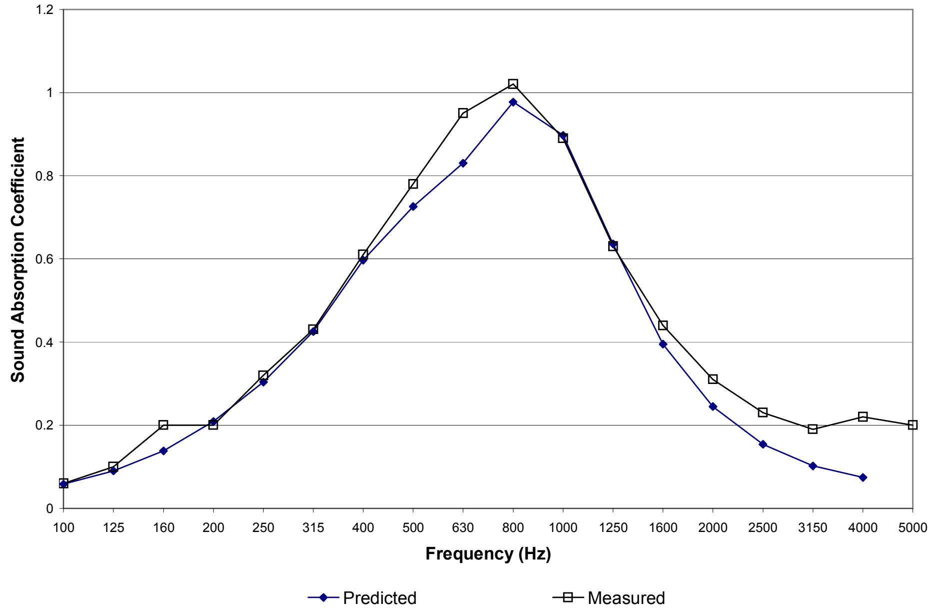

Figure 5: Single Punched Pegboard on 25mm Foam

cloth of flow resistance equal to the flow resistivity of the material times a distance equal to the end correction, divided by the fractional open area of the perforated covering. Over the range of absorbers studied this gave rather good agreement for perforated absorbers (figure 4,5) but not for slotted absorbers. It was found empirically that better agreement was achieved for slotted absorbers if the thickness of the additional absorptive layer was made twice the thickness of the end correction (figure 6).

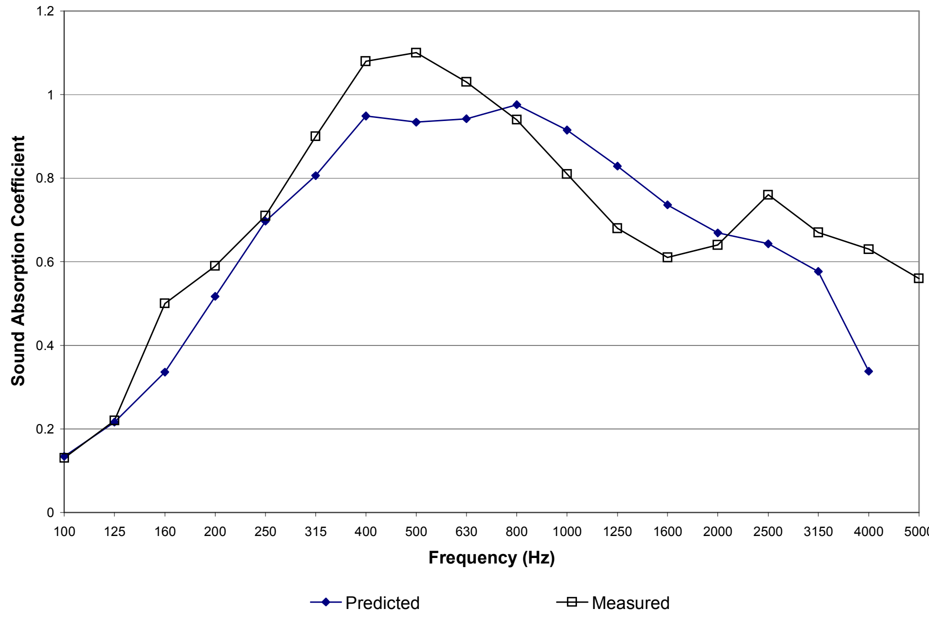

Figure 6: 50x25 Battens on 50mm Foam

For panel absorbers the overall impedance was obtained simply from the impedance of the porous absorber plus the mass reactance of the panel (obtained from the mass/unit area of the panel) (figure 7). It can be seen that the agreement is excellent for the 75gram/m^2 covering, but not as good for the 2mm or 6mm cardboard.

Conclusions

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

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Limitations

The model gives reasonable agreement for perforation ratios as low as 5% and porous absorption thicknesses between 10mm and 150mm. 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.

It can not be used with porous materials which have a porosity less than about 80% or flow resistivity more than 100,000 Rayls/m or less than 1,000 Rayls/m.

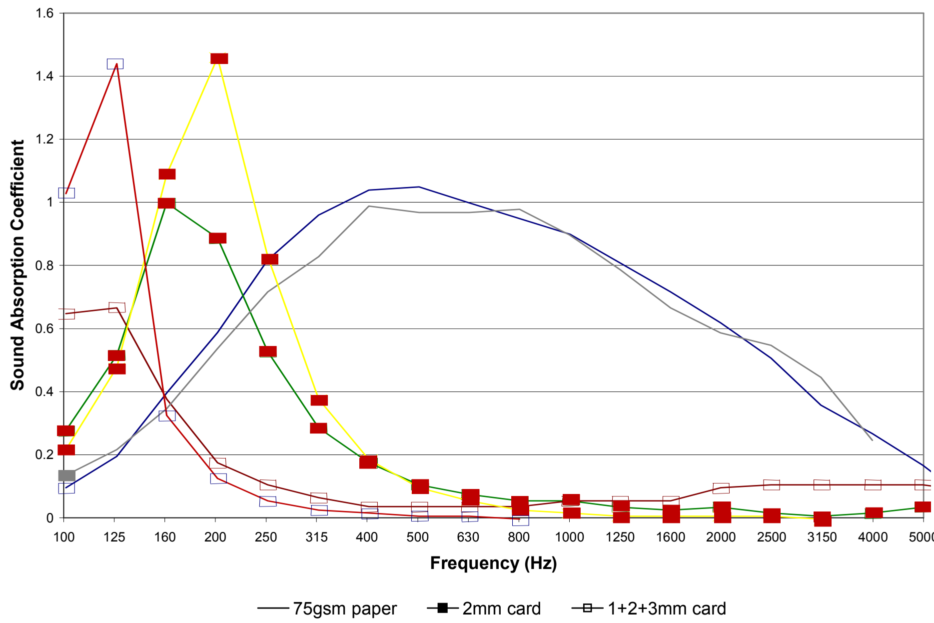

Figure 7: Cardboard on 50mm Siliner Fibreglass

A Method for Testing & Comparing Classroom Floor Noise

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An abbreviated version of a paper submitted as part fulfillment of an Acoustics Course at Auckland University

Abstract

There is a growing acceptance in this country that the acoustic properties of classrooms render them inadequate to operate as effective teaching spaces. Recent studies conducted by the New Zealand Classroom Acoustics Research Group (Dodd, Wilson et.al., 2001) incorporating both subjective questionnaires and objective measurements of classrooms have confirmed this concern, and have indicated that in relocatable classrooms, a likely source of the acoustical problems is the floor. Even so this is a largely subjective observation, one which is difficult to correlate with identifiable measurable properties of the space. Nor is there a recognized method for creating a standardized sound field in a classroom to measure those properties, whatever they might be. This investigation is an effort to obtain such a method for testing and comparing classroom floor noise.

The Method suggested consists of:

- The use of a tapping machine to create floor noise in a standardised, repeatable fashion that would approximate the way in which floor noise is created in a real classroom situation.
- The sound pressure levels (50 Hz – 5 kHz) are recorded in the classrooms for the tapping machines impacting on the floor diaphragm.
- The levels are adjusted to give the floor noise component only, specific to the room tested (by logarithmically subtracting the background noise and the machine noise).
- The floor noise level component from the room is then normalised to remove the room effect.
- Comparisons are then made of the different classroom floors by looking at these normalised levels.
- The resultant levels describe the quality of the acoustics in the classroom, i.e. there is a difference in the adjusted, normalised floor noise levels for rooms with poor acoustics than for those with good acoustics. Generally lower noise levels relate to better classroom acoustics.
- A database of classrooms would

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