SOUND ABSORPTION OF POROUS MATERIAL IN COMBINATION WITH PERFORATED FACINGS

Michael J. Kingan and John R. Pearse

Department of Mechanical Engineering, University of Canterbury, Christchurch, New Zealand.

Abstract

The absorption characteristics of porous absorbers in combination with perforated facings was investigated. The effect of the hole size, hole pattern and open area ratio were examined. The absorption coefficients for an absorber of uniform cross-section were compared to those for an absorber with a tapered cross-section for various volumes of absorbent and different perforated facings.

Introduction

This work was carried out in the reverberation room in the Department of Mechanical Engineering, University of Canterbury as part of the design of an absorber section for the Department's low noise wind tunnel.

Low frequency tonal noise from the wind tunnel fans, and resonances in the tunnel cross section and walls was required to be reduced. The general design of the absorber section for the wind tunnel was decided upon prior to the testing. The absorber was to have a cross sectional area for airflow of 1.4m × 1.2m and was to be 2.4m long. All four sides were to be of perforated sheet metal of specified open area ratio, behind which polyester sound absorbing material was to be placed.

The sound absorption coefficient α for different facing open area ratios and backing volume sizes and shapes was measured in general accordance with ISO 354:2003 [1].

The absorption characteristics of the absorber section when installed in the wind tunnel would be affected by the airflow. However the effect of airflow parallel to the perforated facing on the absorption coefficient α can be accounted for using established theory [2].

Experimental procedure

Equipment

A Brüel and Kjær Sound Analyser, type 2260B was used with Building Acoustics Software, type BZ 7204 for reverberation time measurements. Pink noise from the sound analyzer was fed to a Brüel and Kjær amplifier, type 2716 and Brüel and Kjær Omnipower speaker, type 4296.

Materials

Six different perforated metal sheets of thickness 1mm were tested.

Table 1. Perforated facing parameters

Facing No.	Hole size mm	Open area ratio %	Hole pattern†
A	4.76	32.7	60° stagger
B	1.60	22.7	60° stagger
C	3.00	22.7	60° stagger
D	4.76	51.0	60° stagger
E	4.76	5.5	45° stagger
F	4.76	2.8	on square

Three frames 1.2m × 2.4m were filled with polyester and each covered with a perforated facing with the same hole parameters. The frames were of either uniform or tapered cross section as recorded below.

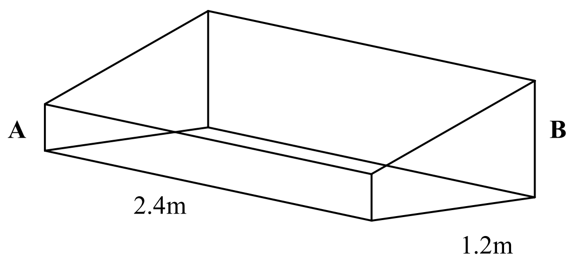

Figure 1. Frame dimensions

Table 2. Frame dimensions

Frame No	**A** (m)	**B** (m)	Volume (m^3)
1	0.0500	0.0500	0.144
2	0.0500	0.1250	0.252
3	0.0500	0.2500	0.432
4	0.0500	0.3750	0.612
5	0.0875	0.0875	0.252
6	0.1500	0.1500	0.432
7	0.2125	0.2125	0.612

† 60° stagger, 45° stagger, on square

Reverberation room description

The materials were tested in a reverberant room of volume 217 m^3. A sufficiently diffuse sound field was established by the inclusion of stationary diffusers.

Measurements

The sound analyser, building acoustics noise software and noise source were used to measure reverberation times in the reverberation room with and without the test specimen present. A total of 4 reverberation decays were measured at a variety of microphone positions and speaker locations for each test specimen. Each test specimen comprised three 1.2m x 2.4m perforated metal facings, mounted on the wooden frames. Absorption coefficients were calculated from the averaged reverberation times of the empty room and averaged reverberation times with the test specimen present in general accordance with ISO 354:2003 [1]. The area of the absorbing surfaces was 8.64m^2 which because of the high absorption, resulted in decay times sufficiently high enough to give accurate results.

Results and discussion

The effect of open area ratio

Figures 2 and 3 show the effect of open area ratio on the sound absorption. The results shown are for absorbers in combination with frames 2 and 3 which were both tapered. However, absorbers with frames of constant cross section exhibited the same trends.

For low frequency sound (less than 250 Hz) the open area ratio had little effect on the sound absorption. All cases tested exhibited similar absorption coefficients for these frequencies. This was expected as low frequency sound typically permeates easily around obstacles (in this case the facing) compared to higher frequency sound. Therefore for low frequency sound even relatively low open area ratio facings appear "acoustically transparent" and therefore has little effect on the absorption (there was little difference between the case with "no facing" and the other cases at low frequencies).

For absorbers with frames of smaller internal volume (frames 1, 2, and 5) an increase in the absorption coefficient was always noted for facings E and F (with open area ratios of 5.5% and 2.8% respectively) over a relatively narrow range of frequencies (in this case 250-800Hz) before a rather drastic reduction in the absorption coefficient, for frequencies above this, relative to the performance of absorbers with a higher open area ratio (≥22.7%).

Improved absorption over a narrow band of frequencies was probably because of an acoustic resonance within the framed absorber. The reduction in performance of the framed absorber at high frequencies is attributed to the high frequency sound being reflected from the steel facing instead of permeating through to the absorbing material beneath, due to the low open area ratio of the facing.

The performance of absorbers with high open area ratio facings (≥22.7%), was very similar to the case where no facing was placed on the polyester-filled frames as shown in Figure 2. This indicates that the facing was effectively acoustically transparent and had little effect on the sound absorption properties of the absorber.

For frames with larger volumes (frames 3, 4 and 7) in combination with low open area ratio facings, the increase in the peak absorption coefficient was not so evident. This was most probably because the large volume of absorbent material in these large frames absorbed a high proportion of the sound permeating through the facings and into the cavity reducing any resonance effect. This is clearly shown in Figure 3, which plots the absorption coefficient of absorbers with facings of different open area ratios mounted on frame 3. The absorption coefficients of the absorbers with lower open area ratio facings (E and F) do not exhibit absorption coefficients significantly higher than the "no facing" case. The large reduction in high frequency performance for absorbers in combination with low open area ratio facings is still observed however as this phenomena is governed purely by the facing open area ratio and not the volume behind it.

Davern [3] conducted a detailed experimental investigation into the effect of perforated facings backed with a porous material in an impedance tube. He investigated a large number of parameters including the effect of percentage perforation of the facing. The volume and depth of the absorber were not investigated. Due to the constraints of testing in an impedance tube the effect of a sloping frame was not investigated.

Davern found that an increase in the open area ratio of the perforated facing increased the frequency of the resonance. Due to the limited number of tests conducted in our investigation it was not possible to verify this, although there appears to be little difference between the 2.8% (F) and 5.5% (E) facings. Davern also found that it was not the hole size and shape, but the total percentage perforation that was important in determining the resonant frequency of the absorber. In Davern's study there was no mention of the reduction in high frequency absorption for low open area ratio facings however the absorption coefficients were only recorded up to 2000Hz.

The effect of frame shape

The main reason for investigating the performance of a tapered absorber was that the variation in depth of the absorber was expected to increase the range of frequencies that were attenuated by the absorber, while perhaps sacrificing some of the peak performance of the absorber relative to an absorber of constant cross section and the same volume of backing absorption material.

As expected the peak absorption of the constant cross section framed absorbers was significantly higher in most cases than that of sloping framed absorbers as is clearly seen in Figure 4. This was not the case for the largest internal volumes (frames 7 and 4). This was probably because stronger resonances occurred in the rectangular cavity of the square absorber bank, while resonances in the sloping bank are not as strong because of the non-regular geometry. The range of frequencies attenuated by the sloping absorber bank was also not increased as may be seen in Figure 4.

The effect of volume

For absorbers with low open area ratio facings, the frequency of peak absorption was not dependent on the frame shape (see Figure 4) or the open area ratio (see Figure 2). The factor governing the peak frequency of absorption was the volume of the absorber as shown in Figure 5. This also suggested the increased performance of framed absorbers with low volumes and low facing open area ratios over a narrow band of frequencies was due to a resonance within the backing volume.

An increase in the frame volume results in an increase in the absorption coefficient at the frequency of peak absorption, and also at low and high frequencies away from frequencies affected by the resonant absorption characteristics of the framed absorber (see Figure 5).

Conclusions

For low frequency sound (less than 250 Hz) the open area ratio has very little effect on the sound absorption.

Facings with open area ratios ≥22.7% were effectively acoustically transparent and have little effect on the sound absorption properties of the absorber. The results of a facing with an open area ratio of ≥22.7% is very similar to having no facing at all (100% open area ratio).

For framed absorbers constructed of frames with small internal volumes and perforated facings with low open area ratios an increase in absorption coefficient α over a relatively narrow range of frequencies was observed. A drastic reduction in α occurs for higher frequencies.

For frames with larger volumes the increase in performance of framed absorbers with low open area ratios is not as noticeable as for frames with a small internal volume. However the drastic reduction in high frequency absorption still occurred.

Absorbers with square frames provide a higher peak frequency of absorption than absorbers with sloping frames for the same cavity volume.

Sloping frames do not appear to increase the “bandwidth” of frequencies attenuated by the absorber.

The peak frequency of absorption appears to be only dependent on the volume of the cavity behind it. As expected an absorber with a larger volume frame has higher absorption at frequencies away from the frequencies affected by the resonant absorption characteristics of the frame.

References

[1] ISO 354:2003 *Measurement of sound absorption in a reverberation room*. Switzerland: International Organisation for Standardisation; 2003.

[2] Cummings, A., *Sound attenuation in ducts lined on two opposite walls with porous material, with some applications to splitters*, Journal of Sound and Vibration, vol 49, 9-35, 1976.

[3] Davern, W. A. *Perforated facings backed with porous materials as sound absorbers – an experimental study*, Applied Acoustics, vol 10, 85-112, 1977

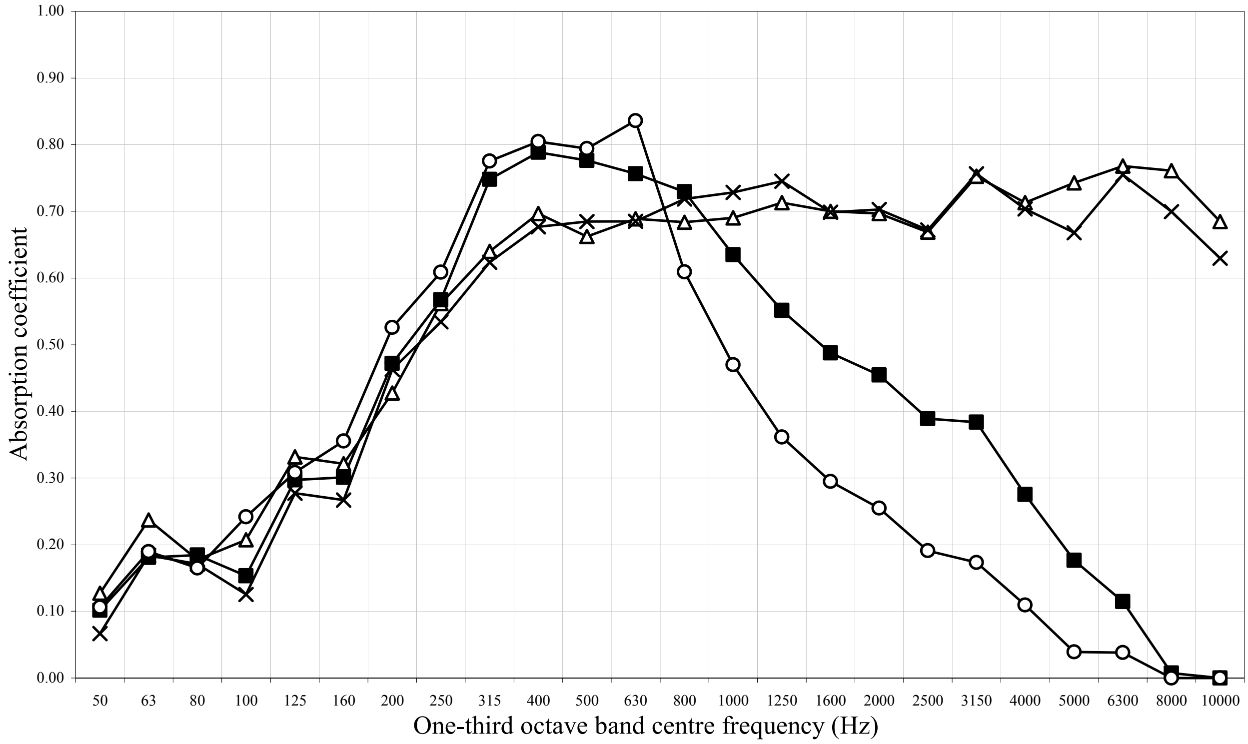

Figure 2. Absorption coefficient of various perforated facings mounted on a sloping frame (No. 2, 50-125mm) with polyester backing: No facing, facing C (22.7%), facing E (5.5%), facing F (2.8%) †

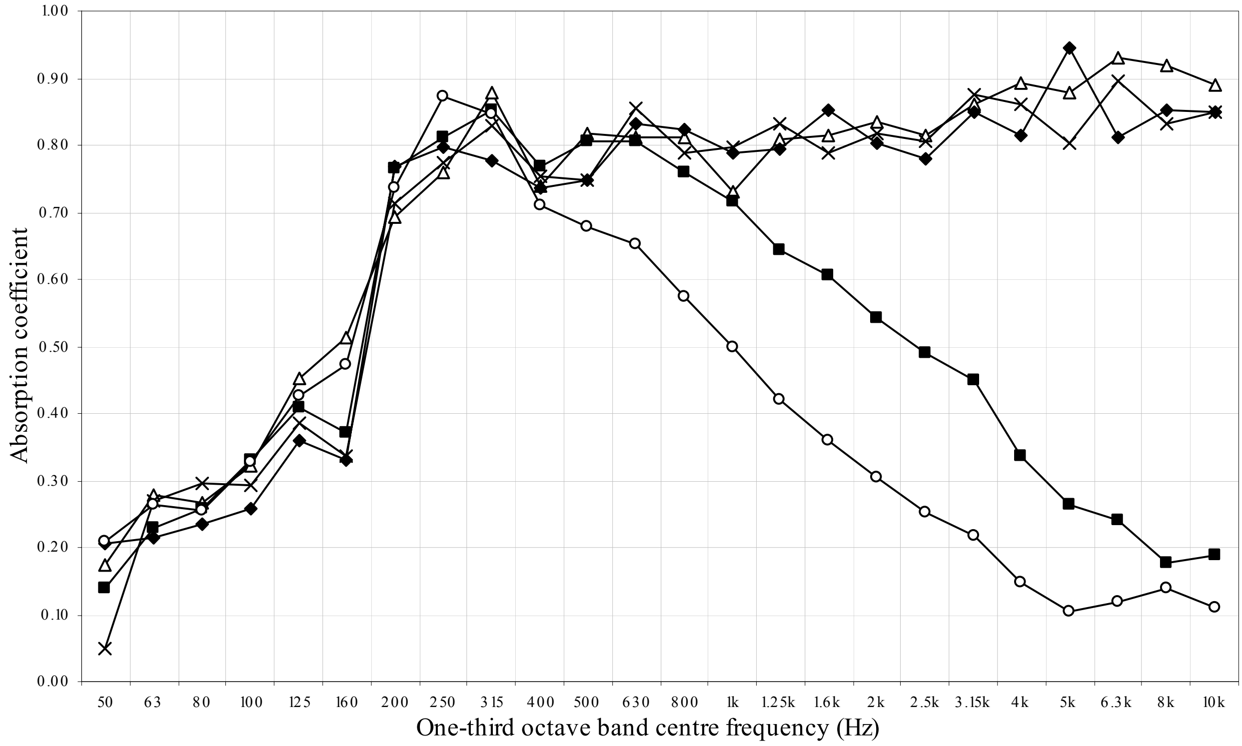

Figure 3. Absorption coefficient of various perforated facings mounted on a sloping frame (No. 3, 50-250mm) with polyester backing: No facing, facing C (22.7%), facing E (5.5%), , facing F (2.8%), facing A (32.7%) †

† Percentages in brackets indicate the facing open area ratio

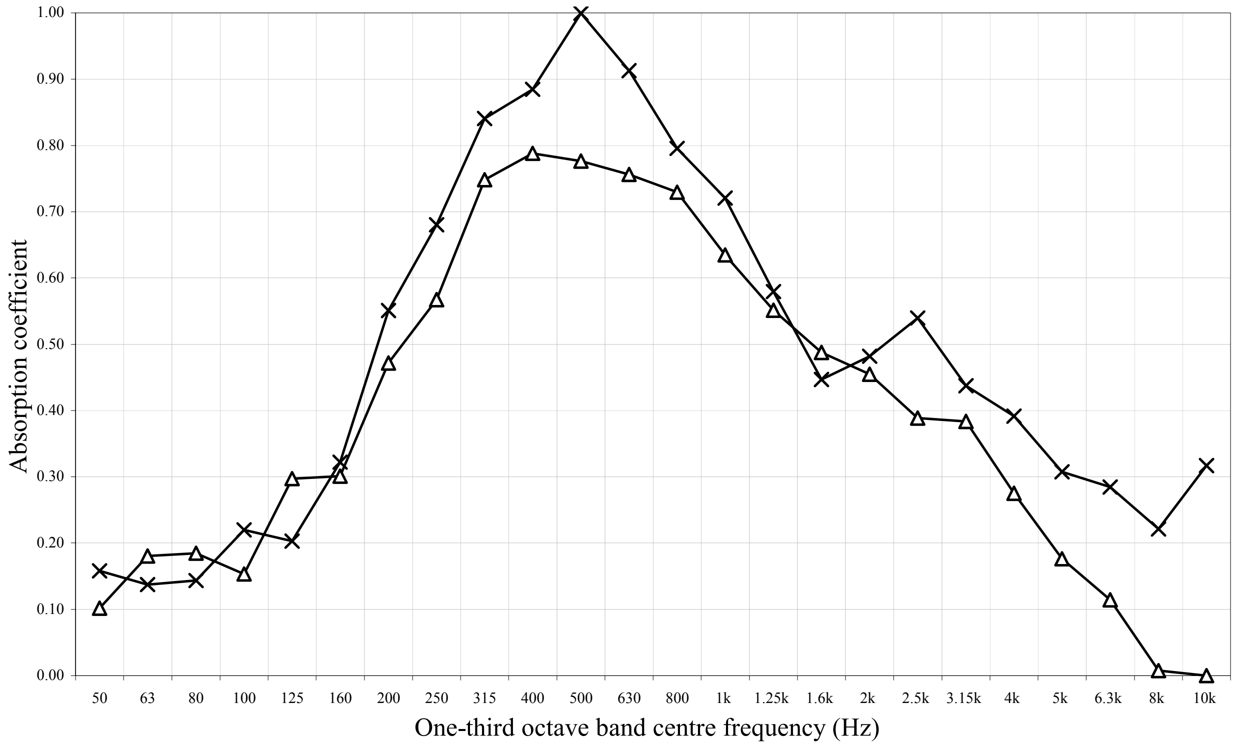

Figure 4. Absorption coefficient of perforated facing E (5.5%) mounted on a square (frame 5) and sloping (frame 2) frame with polyester backing†

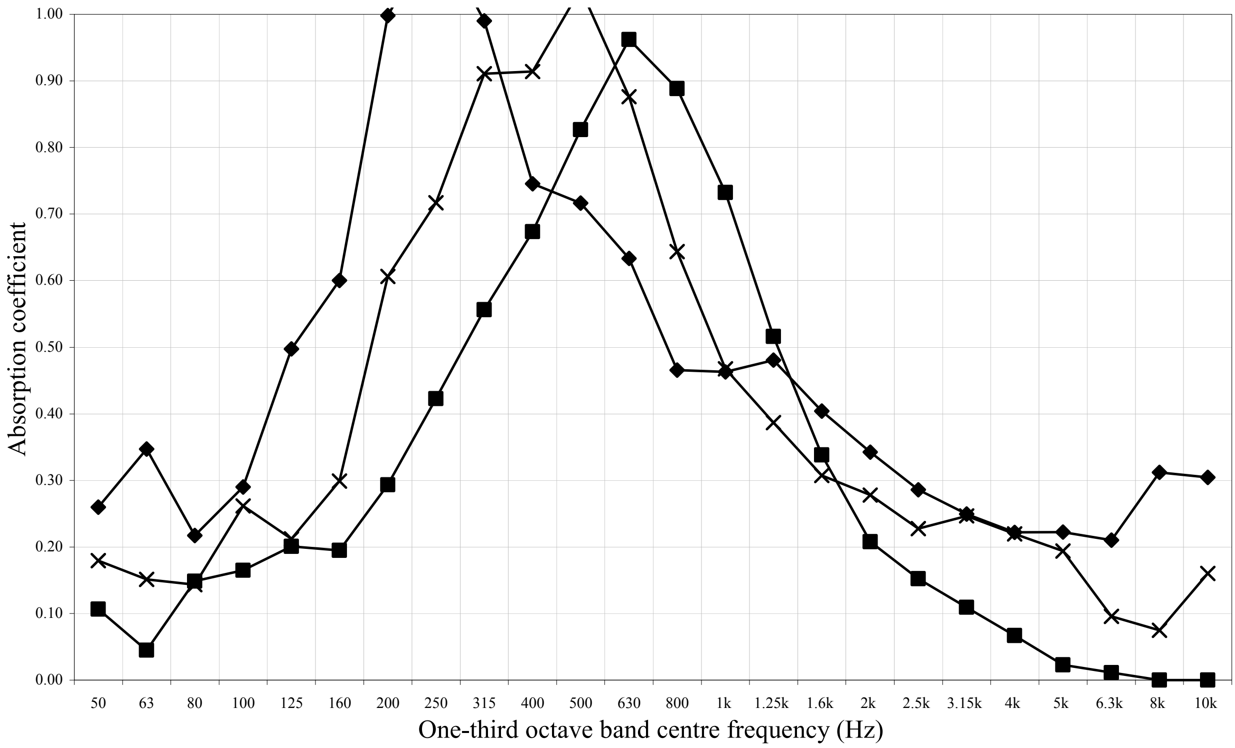

Figure 5. Absorption coefficient of perforated facing F (2.8%) mounted on various sized square frames with polyester backing: frame 1 ($0.144m^3$), frame 5 ($0.255m^3$), frame 6 ($0.432m^3$) †

† Percentages in brackets indicate the facing open area ratio