

Adapting Simple Prediction Methods to Sound Transmission of Lightweight Foam Cored Panels

K. O. Ballagh

Marshall Day Acoustics, Auckland, New Zealand

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Abstract

A common building product used in industrial buildings consists of thin steel or aluminium skins on each side of a foam plastic core such as polystyrene. Such panels have many attractive properties, they are light weight, have excellent capacity to span between structural supports, excellent thermal insulation and are pre-finished. They are used extensively in many countries, and in New Zealand these types of panels are commonly used in food processing plants which are often noisy and located close to residences. The sound transmission loss of these panels in their basic form is poor, usually less than a simple mass law prediction based on the mass of the components. The performance is characterised by a sharp dip in the sound transmission loss at mid frequencies which causes a big drop in R_w or STC rating. The work described in this paper has developed simple methods of predicting the sound transmission loss of panels both as single panels and more importantly when used as part of a system to achieve higher performance.

Introduction

Lightweight steel panels with a foam core are widely used in the building industry throughout the world. They usually consist of steel skins about 0.5 – 1.0mm thick, with a core of foamed plastic about 50 – 200mm thick. The foam core is often expanded polystyrene (EPS) but other materials such as foamed polyurethane are also used.

These panels have a number of very useful constructional properties including their lightweight, ability to span long distances, the fact they have a high quality pre-finish, and their excellent thermal insulation properties. In New Zealand they are widely used for the construction of food processing plants and coolstores.

However, the sound insulation properties are often inadequate when used for exterior cladding of noisy factories. Alternative construction options such as pre-cast concrete have weighted sound transmission ratings (R_w) of greater than 45 dB. By contrast typical foam cored panels can have weight sound transmission ratings of around 20 dB, significantly less than would be expected from a simple estimate based on the mass law. Single panels of equivalent mass (e.g. gypsum board) have a rating of 28 dB. This paper will examine the reasons for this and propose a relatively simple

method of predicting the performance of such panels both when used as single panels, and as part of more complex constructions.

Sound Transmission Of Single Panels

The measured performance of foam cored panels is quite distinctive, an example is shown in fig 1. At low frequencies the transmission loss increases at 6 dB per octave up to a frequency around 600-800 Hz, where it dips sharply around 1-2 kHz to a value often lower than its value at low frequencies, then increases sharply up to a value of around 40 dB from 2 – 5 kHz. Unfortunately the dip at

around 1 kHz reduces the weighted sound transmission index (R_w) and in practice this dip usually occurs at an important frequency for determining the A-weighted sound reduction of industrial noise.

Prediction Model

It is important to understand the reasons for the poor performance and to be able to predict the sound insulation of such panels. Initial investigation explored the possibility that this was a critical frequency dip, similar to the coincidence dip seen in most isotropic materials (e.g. gypsum board, concrete, glass, timber). However, the shape of the transmission loss versus frequency

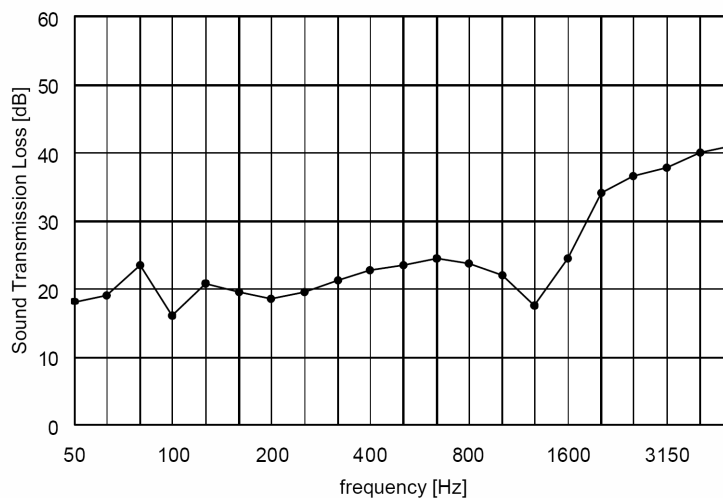


Figure 1. Sound Transmission Loss of a typical foam core panel.

curve was different to a classic critical frequency dip, and the frequency did not seem to be strongly related to the thickness of the panel. An alternative explanation [1] is that the dip is due to a dilatational resonance, or mass-spring-mass resonance. The steel facings are the masses and the foam core forms the spring. The resonance frequency is given by

$$f_0 = \sqrt{\frac{E(m_1 + m_2)}{Tm_1m_2}} \quad (1)$$

where E is the elastic modulus of the core, T the thickness of the core, and m_1 and m_2 the surface masses of the skins. A calculation of the resonance frequency for the panel of fig. 1 indicated this was close to the measured dip in transmission loss curve. For 0.45mm steel skins, and 50mm EPS core the predicted resonance frequency was 1400 Hz, which is quite close to the dip in the transmission loss in the 1250 Hz band.

The hypothesis therefore was that the resonance behaviour of the mass-spring-mass system directly added to the transmission loss of the basic panel (viewed as a simple lumped mass). The increase in velocity of the outer skins due to the resonance is give by the transmissibility curve for a damped single degree of freedom system.

$$\Delta R = -10 \text{Log} \left[\frac{1 + \left(2\xi \frac{f}{f_n}\right)^2}{\left[1 - \left(\frac{f}{f_n}\right)^2\right]^2 + \left(2\xi \frac{f}{f_n}\right)^2} \right] \quad (2)$$

The parameters are the natural frequency of the system f_n and ξ the fraction of critical damping.

A plot is given in fig 3 for seven panels. The panels ranged in core thickness from 50mm to 150mm, and skin thickness from 0.45mm to 0.75mm

In the figure the calculated mass law for the panel is subtracted from the measured transmission loss of the panel.

The results have been normalised or shifted in frequency so the peaks are all at the same relative frequency. It can be seen that all panels exhibit a very similar behaviour. A theoretical curve is shown dotted for the response of a simple mass-spring-mass oscillator, with a resonance frequency the same as the normalised peak and with a fraction of critical damping of 0.08.

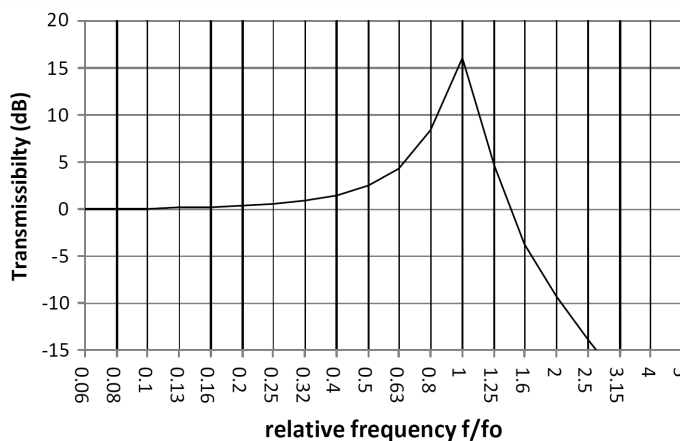


Figure 2. Transmissibility of a damped mass spring mass system.

The theoretical curve is very similar to the measured results. However, there seems to be a plateau in performance above the resonant frequency of between -5 to 5 dB. These results indicate that the mass-spring-mass behaviour is the cause of the dip and subsequent rise in transmission loss at high frequencies. A simple method of prediction therefore would be to use the mass law to predict a base performance of the panel and then subtract the transmissibility curve (equation 2) of a simple mass-spring-mass oscillator.

Results

As an example a prediction has been made for a panel consisting of 13mm thick gypsum plaster board skins with a 64 mm thick EPS core. The comparison between measured and predicted results is shown in fig 4. The frequency of the dip was calculated from the mass of the skins and the thickness and elastic

modulus of the EPS core. Allowance was made in the prediction of the base performance for the critical frequency of the gypsum board [2]. It can be seen that the agreement is good, with the dip at 3.15 kHz due to the critical frequency of the gypsum board. The measured weighted sound insulation (R_w) was 31 dB compared to the predicted 30 dB.

The model can be used to explore ways of improving the performance of foam core products. However it quickly becomes apparent that it is difficult to avoid the deleterious effect of the mass-spring-mass resonance. To move the dip either above or below the normal building acoustical frequency range of 100 – 4,000 Hz would require a very large change in parameters. For instance, increasing the thickness of the core by a factor of 100, or decreasing it by a factor of 20. Likewise, changing the skin surface masses by similar factors. These changes are clearly impractical.

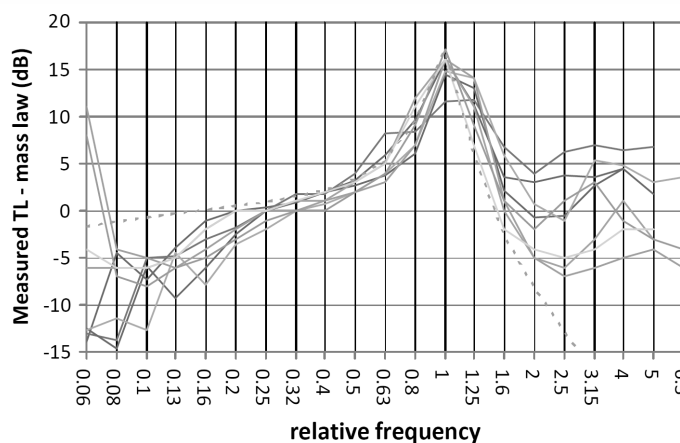


Figure 3. Calculated mass law minus measured transmission loss for 7 different foam core panels.

Alternatively the foam core panel can be used as a component in a multipanel system. The prediction model can be extended to double panel systems, where two panels (one or both of which are foam cored), are separated with an airgap.

Simple models are available for predicting double panel systems either with or without mechanical connections between the panels [3]. Foam cored panels can be handled by using these methods for equivalent isotropic panels, and then adding the effect of the mass-spring-mass resonance.

The double panel prediction models require the point impedance of the panel, and for a foam cored panel this has been assumed to be the point impedance of one skin.

So with a relatively trivial addition the well established prediction methods can be extended to include foam cored panels.

A comparison is given in fig. 5 of the measured and predicted sound transmission loss of a double panel system consisting of a 60mm thick steel faced, foam cored panel, fixed to one side of 100mm wide steel studs, with a 12.5mm thick gypsum board fixed to the other side of the steel studs. The measured weighted sound insulation (R_w) was 41 dB compared to the predicted 38 dB. The agreement is acceptable for engineering purposes.

A second comparison is given for a system comprising foam cored panel 50mm thick with 0.6mm skins and a

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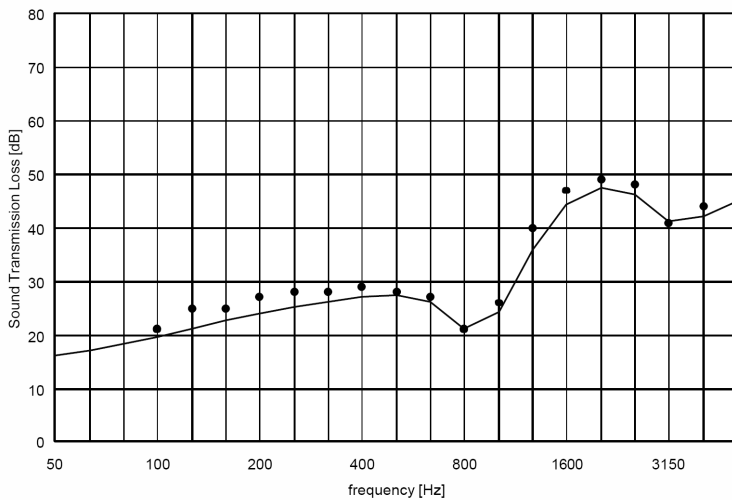


Figure 4. Sound Transmission Loss of a panel with gypsum board skins and 64mm EPS core (• measured, – predicted).

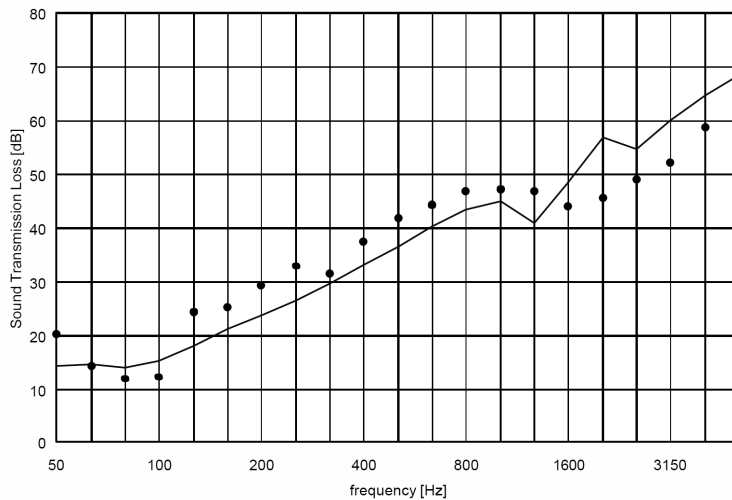


Figure 5. Sound Transmission Loss of a foam core panel, air gap and gypsum panel. (• measured, – predicted).

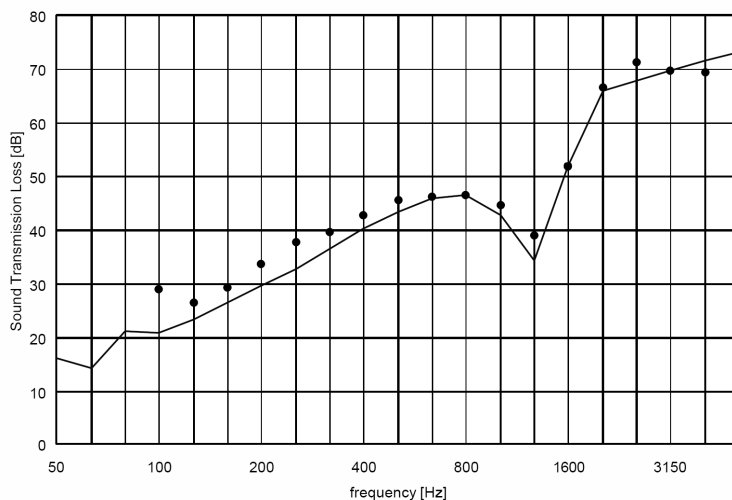


Figure 6. Sound Transmission Loss of a foam core panel, air gap and foam core panel. (• measured, – predicted).

Continued from page 30

layer of 12.5mm thick gypsum board in the centre, fixed either side of a 200mm airgap. No details of the frame that the panels were fixed to were available, so it was assumed to be a steel girt 300mm wide at 1200 mm centres.

Again the agreement between measured and predicted is acceptable, with measured R_w 45 dB and predicted R_w 42 dB.

Conclusions

A simple method has been developed for predicting the sound transmission loss of lightweight foam cored panels.

Conventional prediction methods for isotropic panels are modified by adding on the transmissibility of a single degree of freedom resonant system. The method can be used for single panel constructions and for more complex constructions including double panel constructions with mechanical bridges between panels.

Three additional parameters are required, of which one can be calculated (resonance frequency) and the other two (damping and plateau level above resonance) must be found experimentally. Reasonable agreement is obtained between measured and predicted transmission loss for complex constructions.

References

- [1] F.Fahy, Chap. 5 section 5.12 in "Sound and Structural Vibration Radiation, Transmission and Response", Academic Press, London, 1985.
- [2] L. Cremer, "Theorie der Schälldämmung dünner Wände bei Schrägen einfall", Akust. Ztg, 7, pp81 (1942).
- [3] K.O.Ballagh, "Accuracy of Prediction Methods for Sound Transmission Loss", Proceedings of INTERNOISE 2004, paper in04_586, 2004.