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

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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 very poor, usually worse 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 overcome their inherent poor performance.

## INTRODUCTION

Lightweight steel panels with a foam core are widely used throughout the world in the building industry. 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 foam polyurethane are also used.

These panels have a number of very useful 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 30 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, or as part of more complex constructions.

## SOUND TRANSMISSION OF SINGLE PANELS

The measured performance of foam cored panels is quite characteristic, an example is shown in fig 1. At low frequencies the transmission loss increases at 6 dB per octave up to a frequency around 1 kHz, where it dips sharply 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 reduced 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 if 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 explores 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 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 being the spring. A calculation of this resonance frequency 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 1200 Hz, and the dip in the transmission loss was at 1000 Hz. The resonance frequency is given by

$$f_0 = \frac{1}{2\pi}\sqrt{(\frac{E(m_1+m_2)}{Tm_1m_2}}$$

where E is the elastic modulus of the core, T the thickness of the core, and $M_1$ and ${}_M{}^2$ the surface mass of the skins.

The effect of the resonance is to add the resonance behaviour of the mass-spring-mass system to the transmission loss of the basic panel (viewed as a simple lumped mass).

A plot is given in fig 3 for seven panels. In the figure the mass law for the panel is subtracted from measured transmission loss of the panel. The results are shifted in frequency to the frequency of the dip. 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 dip. It can be seen that the curve is quite similar though not exactly the same. The theoretical curve is the transmissibility curve for a damped single degree of freedom system.

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

The parameters are the natural frequency of the system fn and $\xi$ the fraction of critical damping.

These results, based on 7 panels with thickness from 50mm to 150mm, and skin thickness from 0.45mm to 0.75mm 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 the basic performance and then subtract the resonance curve of a simple mass-spring-mass oscillator.

The predicted performance is shown in fig 4. It is now possible to simply predict the effect of increasing the thickness of the skins, or the thickness of the foam core.

## RESULTS

As an example a panel consisting of gypsum board skins with a 64 mm thick core is shown in fig 5. The frequency of the dip was calculated from the mass of the skins and the thickness of the polystyrene core, and allowance was made 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 model can be used to explore ways of improving the performance of foam core products. It becomes apparent that it is different 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 involve 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.

Alternatively the foam core panel could be used as a component in a multipanel system. The model can be extended to double panel systems, where two panel (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 connection between the panels. Foam cored panels can be handled by using these methods for 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 the 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 100mm wide steel studs, with a 12.5mm thick gypsum board fixed to the other side of the steel stud.

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 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 performance of a single degree of freedom resonant system. The method can be used for single panel construction and for more complex construction including double panel construction with mechanical bridges between panels.

Three additional parameters are required, of which one can be calculated and the other two must be found experimentally.

Reasonable agreement is obtained between measured and predicted transmission loss.

## REFERENCES

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