

Accuracy of Prediction Methods for Sound Transmission Loss

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Abstract [586] There are various methods for predicting the sound transmission loss of walls and floors that can be used by noise control engineers. It is important to know how accurate these methods are for typical constructions used in Building Acoustics. Results are presented for a number of different constructions showing how accurately the results of predictions match experimental laboratory results. The results will show the accuracy over the frequency range 50 to 5,000 Hz. Both single and double partitions will be discussed.

1 INTRODUCTION

It is important to know the sound transmission loss of walls and floors in order to be able to compare different constructions, to calculate acoustic privacy between apartments or noise levels from outdoor sources such as road traffic, and to engineer optimum solutions to noise control problems. Laboratory measurements have been made for many different types of partitions, but it is impractical to test every possible design and so it is necessary to have reliable methods for predicting the sound transmission loss of typical building constructions.

This paper presents a comparison of experimental measurements of the sound transmission of walls and floors with theoretical models. Single homogeneous panels are examined first, with mass, stiffness, damping and panel size found to be adequate to describe most common building constructions. Double panel walls are then examined, with additional factors of airgap between the panels, connections between the panels and acoustic absorption in the cavity enabling good engineering predictions of sound transmission loss.

2 PREDICTION MODELS

2.1 Homogeneous Panels

For simple homogeneous panels the most important property is the mass per unit area of the panel, and the well-known mass law [1] gives a very simple prediction of the transmission loss R .

$$R = 20 \log(mf) - 47 \quad (1)$$

However, for most practical building materials the static stiffness must be sufficiently high that coincidence between airborne and structure borne waves will occur within the frequency range of interest (50 – 5,000 Hz). This was investigated by Cremer [2] and the mass law modified to include the change in transmission at the critical frequency and above.

$$R = 20 \log(mf) - 10 \log(2hw / pwc) - 47 \quad (2)$$

For most thin homogeneous materials commonly used in building construction this provides an excellent prediction of the transmission loss over most of the frequency range. However, one additional effect must be taken into account to obtain good accuracy at low frequencies. For typical test construction of 10 – 12 m² the radiation efficiency of forced waves must be taken into account for frequencies of less than 200Hz. Sewell [3] gives the correction to the infinite area panel as

$$\Delta R = -\log_{10}[\ln(kA^{1/2})] + 20 \log_{10}[1 - (w/w_c)^2] \quad (3)$$

The simple expressions (1), (2) and (3) however, are not adequate to describe very thick and heavy panels such as concrete or brick. For these types of panel shear waves become the dominant flexural waves at high frequencies. This affects the transmission loss at high frequencies reducing the frequency dependence to 6 dB/octave at high frequencies [4] instead of the 12dB/octave behaviour of thin panels above the critical frequency.

2.2 Double Panels

Predicting the acoustic performance of double panels is often necessary. Many walls and floors are constructed of thin linings with an airspace between, and these can, if correctly designed, give high sound transmission loss. The simplest case to analyse is a partition consisting of two thin homogeneous panels, separated by an airgap containing an acoustically absorbing blanket, and with no interconnections between the two panels. Sharp [5] has developed expressions for the transmission loss in 3 frequency ranges as follows:

$$R = 20 \log(f(m_1 + m_2)) - 47 \quad f < f_0 \quad (4)$$

$$R = R_1 + R_2 + 20 \log(fd) - 29 \quad f_0 < f < f_1 \quad (5)$$

$$R = R_1 + R_2 + 6 \quad f > f_1 \quad (6)$$

Where m_1 and m_2 are the surface masses of each panel and d is the depth of the airspace between, f_0 is the mass-air-mass resonance frequency and f_1 is equal to $(55/d)$ Hz. R_1 and R_2 are the transmission losses for the individual panels calculated from (2).

These expressions do not contain any parameters to describe the variation in performance due to different acoustic absorbers in the airspace and it is a practical problem of some interest to determine this effect. Fahy [1] gives an alternative high frequency solution.

$$R = R_1 + R_2 + 8.6\alpha d + 20 \log_{10}(b/k) \quad f > f_1 \quad (7)$$

where α and β are the real and imaginary parts of the propagation coefficient of the absorptive blanket and k is the wave number.

2.3 Double Panels with Connections

While some constructions can approach the ideal of double panels without interconnections, in practice most construction will have some type of solid or resilient connection between the panels. Sharp [5] has developed relatively simple expressions for the transmission loss of double panels with either point or line interconnections.

$$R = R_{1+2} + 20 \log(e.f_c) + 20 \log[m_1 / (m_1 + m_2)] - 45 \quad (8)$$

$$R = R_{1+2} + 10 \log(b.f_c) + 20 \log[m_1 / (m_1 + m_2)] - 18 \quad (9)$$

Where e and b are the spacing between the point and line connections respectively. These expressions are correct only below the critical frequencies of both panels. Using Statistical Energy Analysis expressions can be derived for the frequency range above the critical frequency of both panels [6]. For interconnections that are not rigid, for instance resilient steel rails, or thin steel studs Rindel has derived expressions that take account of the compliance of the connection [6] (see reference for definition of the symbols).

$$R = R_{1+2} - 10 \log \left[\frac{8c^2}{Sp^3 f_{cp}^2} N_p \mathbf{g}_p \mathbf{k}_p + \frac{2c}{Spf_{cl}} (L_l \mathbf{g}_l \mathbf{k}_l + \frac{1}{2} L_r \mathbf{g}_r \mathbf{k}_r) \right] \quad (10)$$

3 COMPARISON BETWEEN THEORY AND RESULTS

3.1 Single Homogeneous Panels

In fig. 1 a comparison is made between 19 mm thick gypsum sheets fixed to one side of a frame consisting of 100x50 mm timber studs at 600 mm centres. The total area of the panel is 10.8 m² and mass per unit area of the gypsum board is 14.2 kg/m². It can be seen that the agreement between theory and measurement is excellent for most engineering purposes. However if the effect of the radiation efficiency of a finite panel is not taken into account then the agreement at low frequencies is not so good.

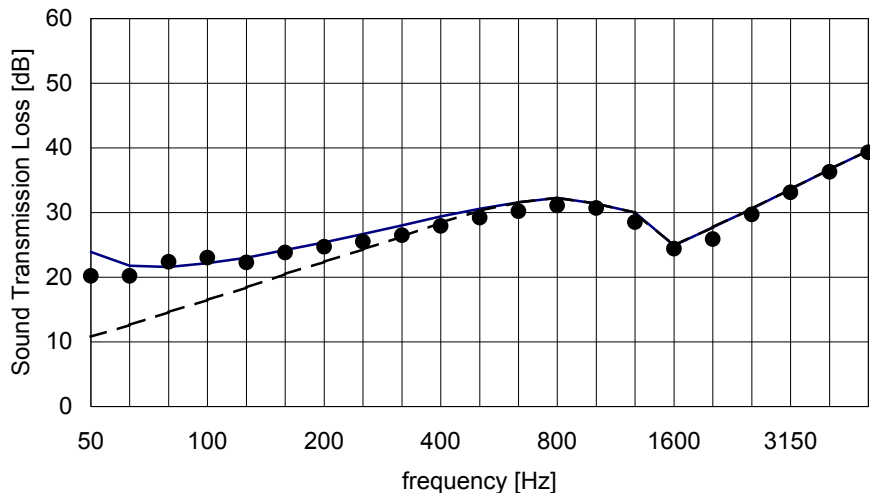


Fig. 1 Sound Insulation of 19mm thick gypsum board(- - - predicted for infinite panel, — predicted for finite panel allowing for radiation efficiency, • measured)

In fig 2, a comparison is made between the measured results for a 190mm thick concrete block wall and the predictions of the mass law with allowance made for the effect of shear waves. It can be seen that while agreement is not perfect above 1000 Hz that the theory with shear waves provides a better prediction than the simple theory of Cremer.

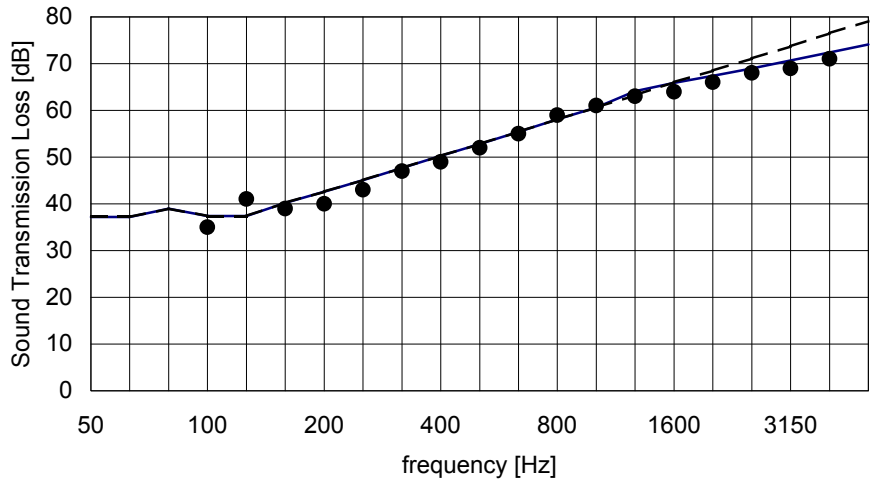


Fig. 2 Sound insulation of 190mm thick concrete block wall
 (--- predicted with no shear waves, — predicted with shear waves, • measured)

3.2 Ideal Double Panels

Timber or steel framed walls that use two rows of independent studs can be modeled as ideal double panel walls provided that as in a laboratory test, there is no significant flanking. The data in fig 3 shows a separate timber stud wall with two layers of 13mm thick fire rated gypsum board each side, and with a 75mm thick fiberglass blanket of flow resistivity 1800 Rayls/m in the wall cavity. The general agreement is good over the whole frequency range. In fig 4 a double stud wall is shown that has a much thicker and denser absorbing blanket (160mm thick mineral wool with flow resistivity of 25,000 Rayls/m). The measurement results show that adding the additional propagation losses in the acoustic blanket improves agreement between theory and measurement.

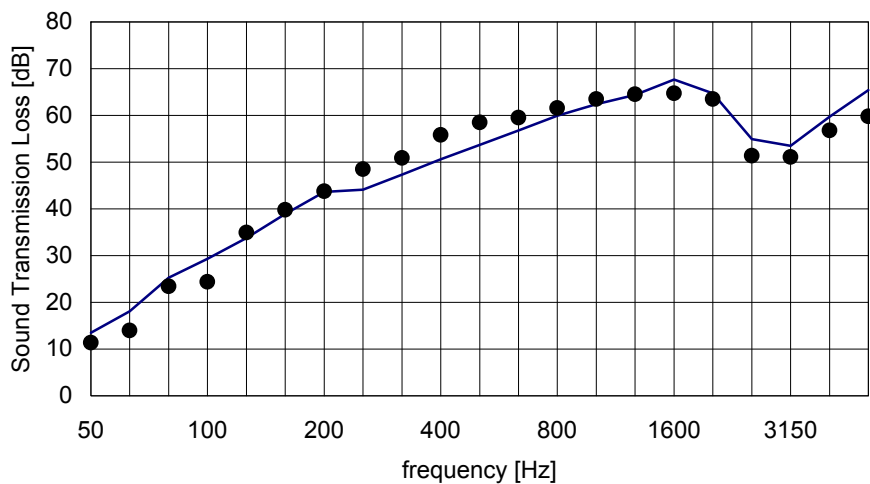


Fig. 3: Sound insulation of double stud wall consisting of 1 layer of 13mm fire rated gypsum board each side of 90mm steel studs with a 100mm thick polyester blanket in the cavity, total airspace 224mm
 (— predicted, • measured)

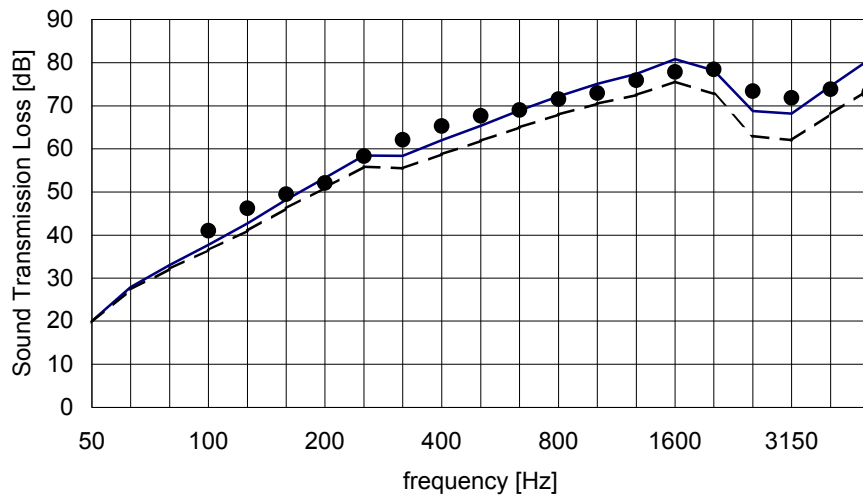


Fig. 4: Sound insulation of double stud wall consisting of 2 layers of 13mm gypsum board each side of 90mm steel studs with a 2 layers of 80mm thick mineral wool blanket in the cavity, total airspace 260mm (--- predicted by expressions 4-6, — predicted with propagation losses in blanket, • measured)

3.3 Double Panels with Interconnections

A simple timber framed wall can be modeled with good accuracy as two panels with line connections between them. This is demonstrated in fig 5, which shows good agreement over the frequency range.

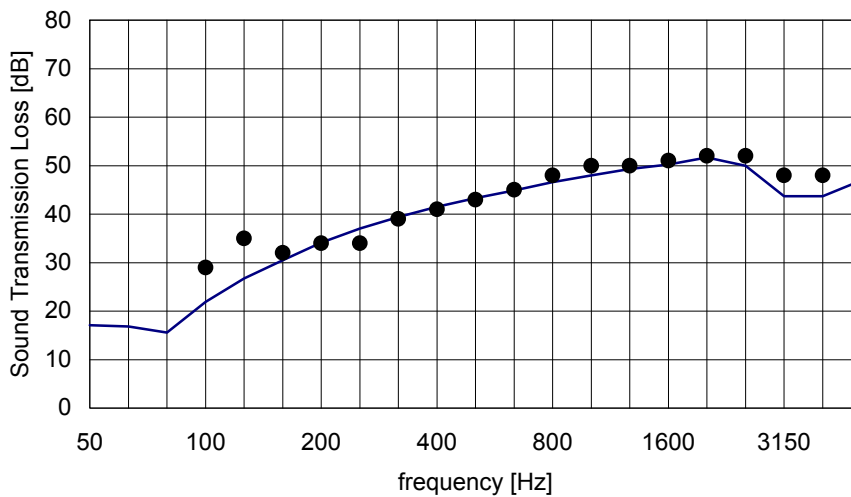


Fig. 5: Sound insulation of timber stud wall consisting of 1 layer of 10mm gypsum board screwed to one side of 90mm studs with 2 layers of 10mm gypsum board screwed to the other side, with a 75mm fibreglass blanket in the cavity (— predicted, • measured)

Another common situation is a masonry wall with an attached lining. In this case expressions (4), (5), and (6) are not applicable because the critical frequency of the masonry wall is low. In fig 6 the agreement between theory using the modified SEA expression [6] and measurement is shown.

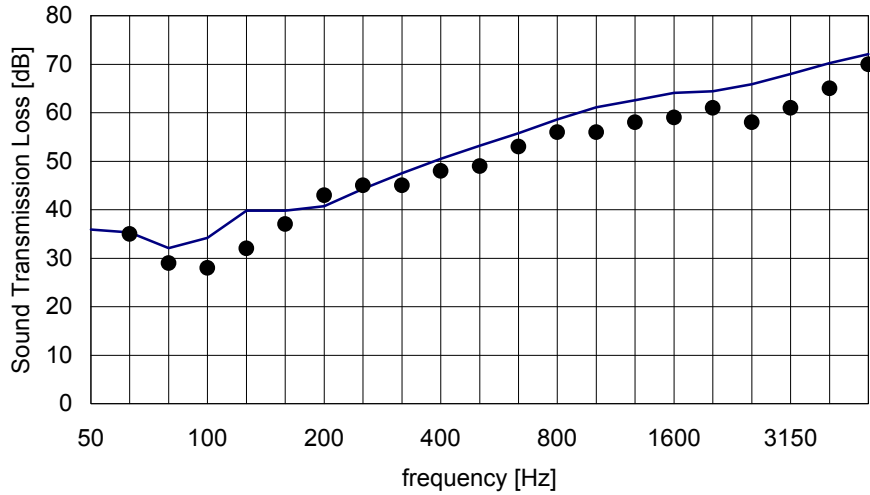


Fig. 6: Sound insulation of 190mm concrete block wall with 16mm gypsum board fixed to 40mm timber battens fixed to wall, with a 38mm fibreglass blanket in the cavity (— predicted, • measured)

The effect of resilient interconnections can be modeled with good accuracy using expressions (4), (5), and (6) modified to account for the compliance of the interconnections. The comparison between measurement and prediction is shown in figs 7 and 8.

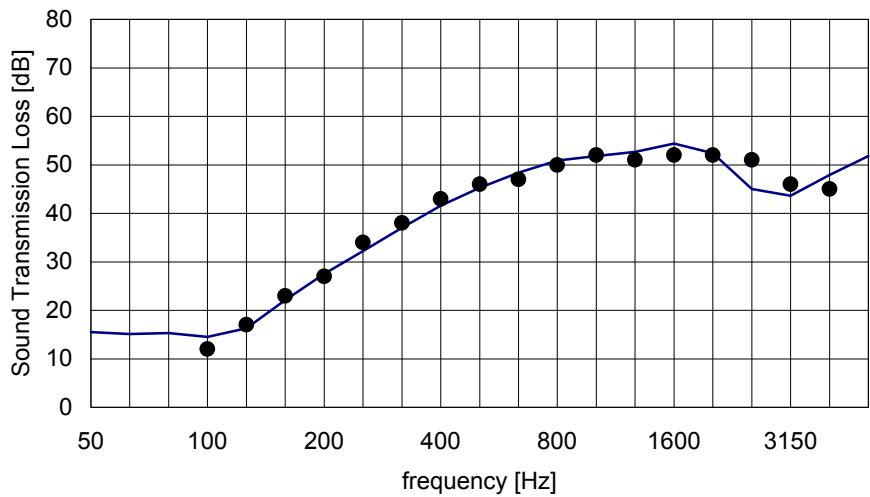


Fig. 7: Sound insulation of steel stud wall consisting of 1 layer of 10mm gypsum board screwed to each side of 64mm studs, with a 75mm fibreglass blanket in the cavity (— predicted, • measured)

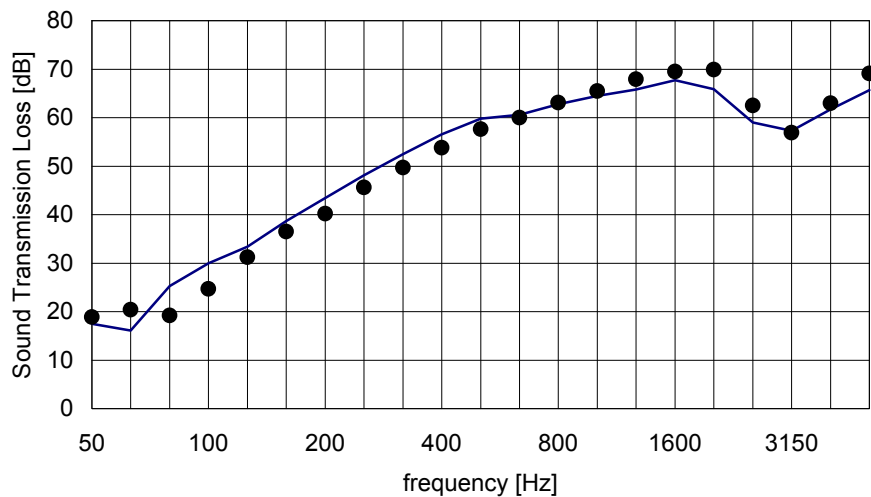


Fig. 8: Sound insulation of timber stud wall with a neoprene resilient isolators fixed to one side of the studs with 2 layers of 13mm gypsum board fixed to each side, with a 75mm fibreglass blanket in the cavity (— predicted, • measured)

3.4 Overall Accuracy

The agreement shown in the figs above is generally very good, but this is a very limited set of comparisons. In order to quantify the accuracy over a wide range of constructions a large number of comparisons were made between theory and measurements. National Research Council (NRC) in Canada has published measurements on more than 240 walls and floors [7,8]. Predictions were made for each construction using the published properties of the materials and the descriptions of the constructions. The mean difference in STC/R_w between measurement and theory was less than 0.5 dB and 90% of results were found to lie within ± 2.5 dB.

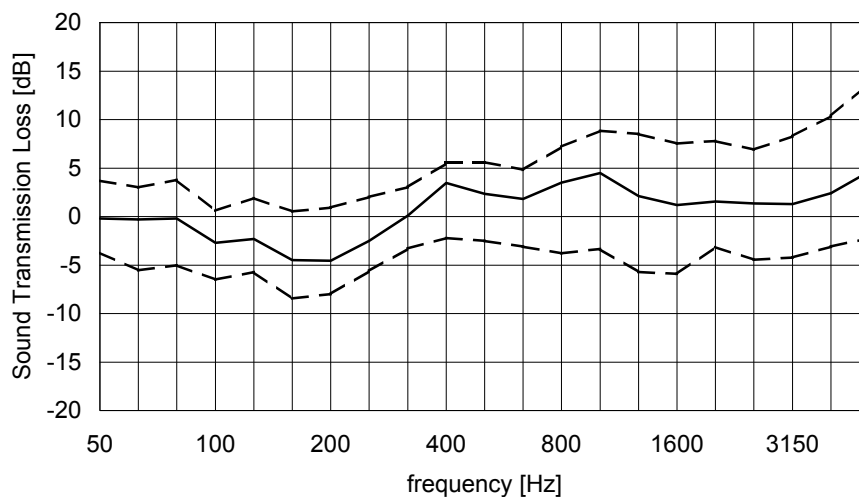


Fig. 9: Measured less predicted for 132 floors from ref [8] (--- 10% and 90% limits, — median error)

This is acceptable accuracy given that measurement repeatability and reproducibility between laboratories is probably no better than ± 1.5 -2 dB. The difference between theory and measurement as a function of frequency is shown in Figure 9 and 10. It can be seen that the variations are smallest at low frequency and tend to increase with frequency. The floors have only a small median

error over the whole frequency range while the models for walls tends to under predict by about 5 dB at mid frequencies.

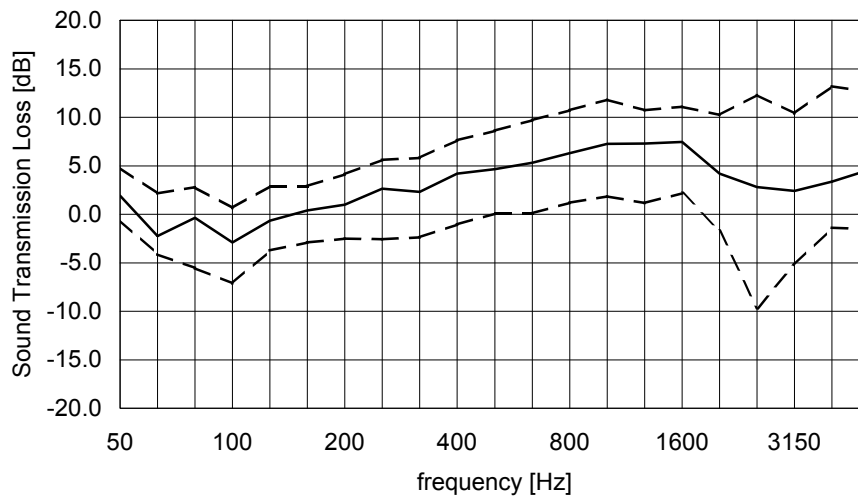


Fig. 10: Measured less predicted for 112 walls from ref [7] (--- 10% and 90% limits, — median error)

4 CONCLUSIONS

The sound insulation of typical building constructions using either masonry or lightweight cavity construction can be predicted with acceptable engineering accuracy over the frequency range 50-5,000 Hz using simple and readily available expressions.

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