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The Attenuation of Aircraft Noise by Wood Stud Walls

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Abstract

In North America, both single-unit and multiple housing is frequently built using wood stud construction. The overall sound insulation of many common wood stud walls is limited by excess low frequency sound transmission and indoor aircraft noise levels are dominated by low frequency sound. A study to develop improved methods for determining the sound insulation of buildings against aircraft noise has included laboratory sound insulation measurements of 41 wood stud wall constructions. The results highlight the importance of low frequency resonanaces on the overall sound insulation ratings. Although the sound insulation of a wall with brick cladding is often cited as an ideal goal, other wall designs produced higher sound insulation. In some cases less material produced a better and more cost-effective solution.

1. Introduction

This paper presents analyses of the laboratory measurements of the sound transmission loss of a series of exterior wood stud walls. The effects of: the mass of surface layers, stud size and spacing, structural breaks, and cavity insulation are considered. The walls are representative of contemporary constructions used in parts of North America where significant thermal insulation is required. Modern energy conservation requirements have generally led to more air tight and thicker walls with greater thermal insulation. This investigation of the acoustical properties of such modern wall constructions is part of a larger project to measure exterior building façade components and to develop a computer based procedure for the design of the sound insulation of buildings exposed to aircraft noise. The measured sound transmission loss values of over 100 constructions have been published [1].

Measurements were made according to the ASTM E90 procedure [2] but with the frequency range of measurements extended from 50 to 5k Hz. The overall performance of the walls was rated using the Outdoor-Indoor Transmission Class (OITC) [3], which is an overall A-weighted level reduction to a standard source spectrum representative of typical outdoor noises. It is not appropriate to use ratings such as the STC for exterior walls exposed to sounds with significant low frequency sound energy.

2. Key acoustical characteristics of wood stud walls

Figure 1 illustrates the measured sound transmission loss (TL) versus frequency for two walls that illustrate the important characteristics that are key to understanding the parameters that most influence their overall sound insulation. One wall was the base wall from which many of the comparisons in this study were based. It consisted of a single 13 mm layer of directly attached gypsum board on the interior of 140 mm wood studs at a 406 mm spacing and with glass fibre thermal insulation filling the stud cavities. The exterior surface was vinyl siding on Oriented Strand Board (OSB) sheathing. The other wall was similar except that the interior surface was a double layer of gypsum board mounted on resilient channels. These results show the obvious improvements due to the addition of the structural break created by the use of resilient channels.

For the results of both walls shown in Figure 1 the dip in the 2.5k to 3.1k Hz region is the well-known coincidence dip. It is due to the coincidence between the velocity of the incident sound and the bending waves in the gypsum board and OSB panels. However, the low frequency dips are more important because they more severely limit the overall performance of the walls. For the base wall, without resilient channels, the dip at 125 Hz is the primary structural resonance of the ribbed panel system formed by the surface layers rigidly attached to the stud system [4]. When resilient channels are added to create a structural break, this primary structural resonance no longer exists. However, the two surface layers are then effectively coupled by the stiffness of the air cavity and a mass-air-mass resonance occurs in the 63 Hz band for this wall. The frequency of this resonance is determined by the masses of the surface layers and the stiffness of the contained air and is further modified by the additional stiffness of the resilient channels [5]. Both of these resonances limit the overall performance of the walls and have the greatest influence on the A-weighted indoor aircraft noise levels.

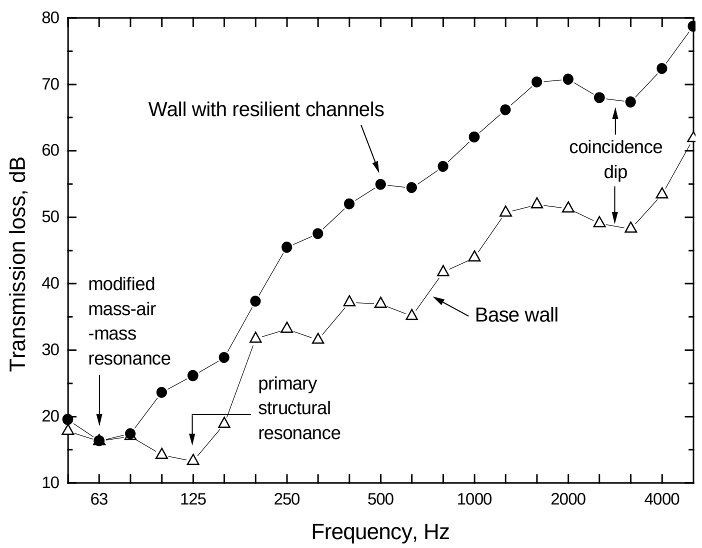

Figure 1. Key characteristics influencing the sound insulation of wood stud walls.

3. Influence of the mass of the surface layers

Figure 2 illustrates examples of the effects of varied surface mass for walls without structural breaks. Replacing the vinyl siding of the base wall with acrylic stucco (EIF) or cement stucco increases the mass of the surfaces and increases the TL over a wide range of frequencies. The increase in OITC rating is approximately 10 times the logarithm of the ratio of the surface masses. (see Table 1). For the wall with brick cladding the increase is greater than expected from the added mass because there was a 16 mm gap between the exterior sheathing and the brick with only occasional ties between the brick and the sheathing. In spite of the brick, Figure 2 shows the overall sound insulation is still limited by the presence of the primary structural resonance of the wood stud wall to which the bricks were attached.

Material and thickness	**Surface density kg/m^2**
Vinyl siding, 1 mm	0.4
Aluminum siding, 0.6 mm	0.4
Oriented Strand Board (OSB), 11 mm	6.9
Wood fibre board, 13 mm	3.5
Acrylic stucco (EIF), 6 mm	10.2
Cement stucco, 9.5 mm	15.6
Brick, 89 mm	132.0
Gypsum board, 13 mm (regular)	8.1

Table 1. Surface densities of the various materials used in these test walls.

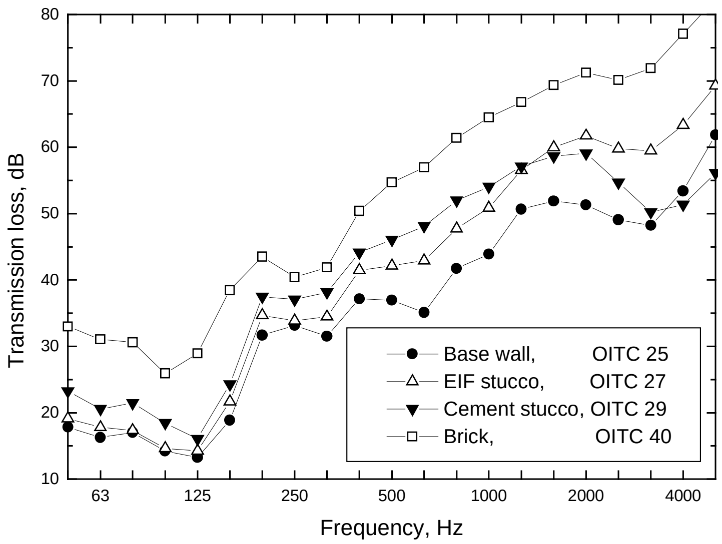

Figure 2. Effects of adding heavier surface layers to the base wall.

4. Influence of stud size and spacing

Increasing the stud spacing and increasing the stud size both lower the frequency of the primary structural resonance and hence improve the overall sound insulation of the walls. The effect of stud size is most significant for larger stud spacings. This is illustrated by the results in Figure 3 for the four combinations of 140 mm and 89 mm stud sizes and 406 and 610 mm stud spacings. Increasing stud size (from solid to open symbols) has a smaller effect than increasing the stud spacing (from circles to square symbols). Other results confirmed that this trend continued for a smaller stud spacing of 305 mm. Decreasing the stud spacing from 610 to 406 and to 305 mm increased the frequency of the resonance dip from 80 to 125 and to 200 Hz. Although the magnitude of the TL at this resonance does not change much, when shifted to lower frequencies, it has less effect on the A-weighted indoor sound levels. Above about 250 Hz, the transmission loss values are not greatly changed by the variations in stud size and stud spacing.

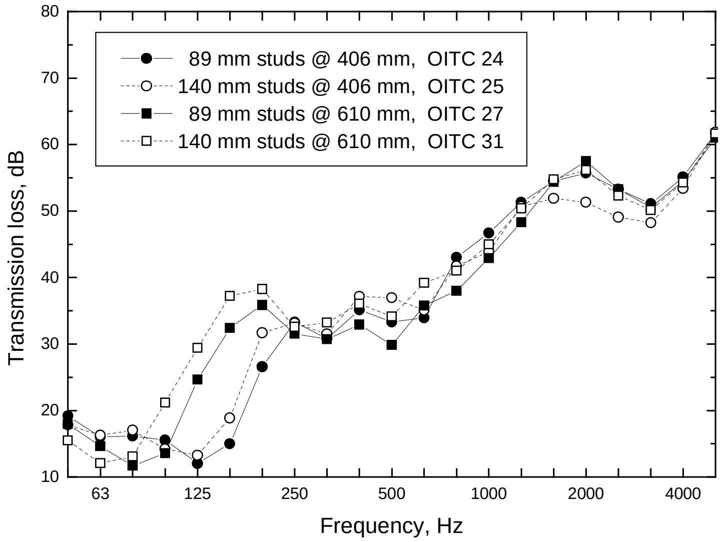

Figure 3. Effects of stud size and stud spacing on measured transmission loss (TL).

5. Influence of structural breaks

Structural breaks were achieved by either attaching the gypsum board using resilient channels or by using staggered stud constructions. The results in Figure 4 compare the TL values for walls with resilient channels with the results for the base wall (without resilient channels). As discussed with respect to Figure 1, adding resilient channels creates a break in the ribbed panel system formed by the base wall and eliminates the primary structural resonance at about 125 Hz. For the walls with resilient channels the modified mass-air-mass resonance limits the low frequency sound insulation. Adding mass to the surfaces of the walls with resilient channels is seen to further improve the TL values. The combination of cement stucco on the outer surface and a double layer of gypsum board on the interior surface gave an OITC rating of 41 which is slightly better than the OITC of 40 for the wall with brick cladding.

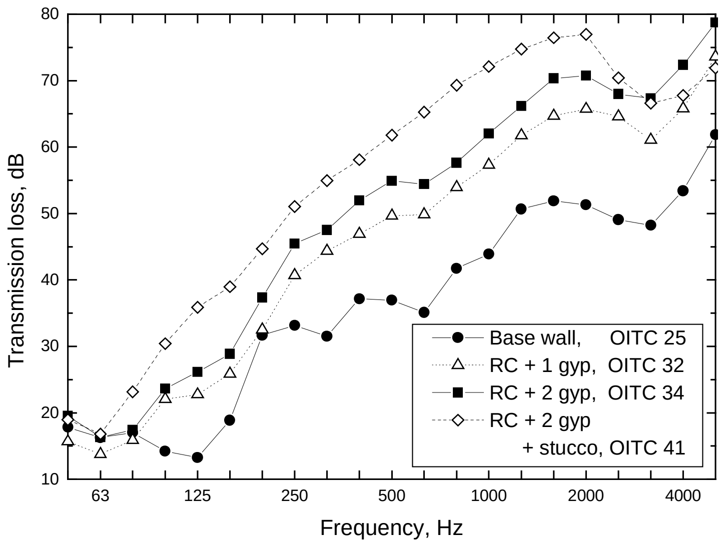

Figure. 4. Comparison of results for walls with resilient channels (RC) with the base wall.

Staggered stud walls consisted of two sets of 89 mm wood studs between a 140 mm header and footer and with each outer surface attached to a separate set of studs. The results in Figure 5 show that these walls can be more effective at the important lower frequencies. Adding mass to the surface layers systematically lowers the mass-air-mass resonance and improves the overall OITC rating for these walls. Surprisingly the increased surface mass had only small effects above about 400 Hz and presumably sound transmission in this region is limited by flanking paths via the connecting header and footer. Figure 6 shows that when resilient channels were added to staggered stud walls, the TL values below 400 Hz remained unchanged but increased considerably above this frequency. When results were repeated for a different stud spacing, there were only small changes and the OITC ratings stayed the same. Stud spacing is not usually an important factor in walls where there is a structural break.

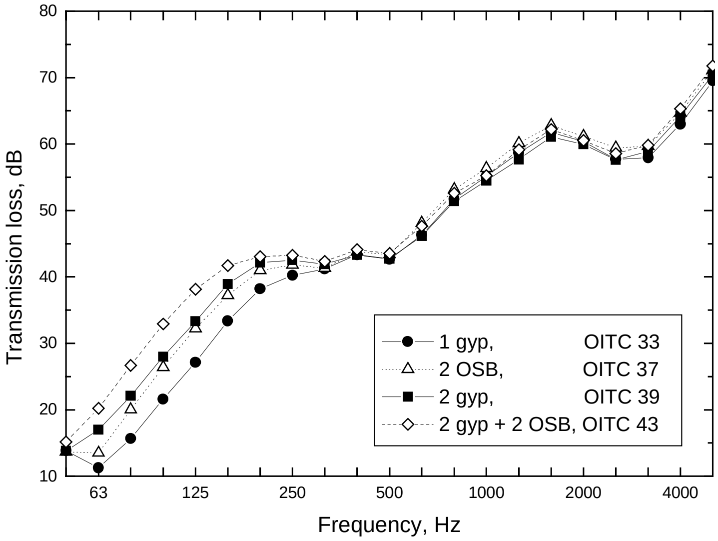

Figure 5. Effects of various surface layers on staggered stud walls.

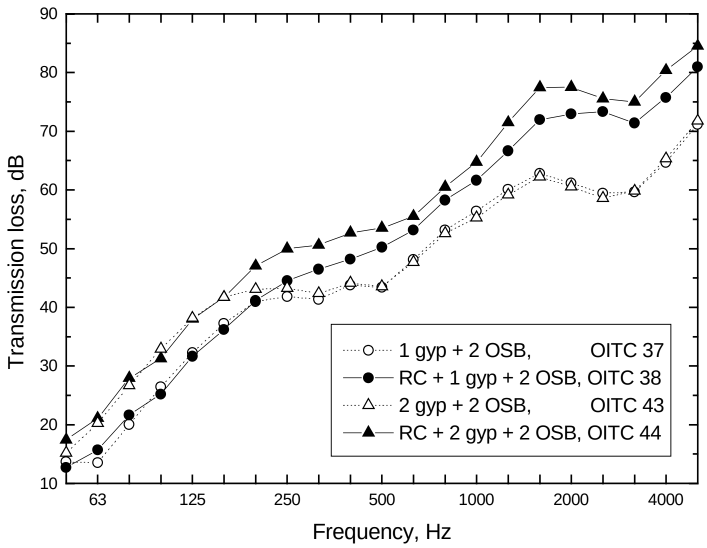

Figure 6. Comparison of results for staggered stud walls with and without resilient channels.

6. Influence of cavity thermal insulation

The effects of three types of thermal insulation in the stud space were compared. These were glass fibre, rock fibre and dry blown in cellulose fibre. They were tested in a wall having vinyl siding and OSB sheathing on the exterior and with two layers of gypsum board attached with resilient channels as the interior surface. This type of wall construction was expected to best show the expected small effects of different thermal cavity insulation materials.

Changing from the glass fibre, used in the base wall, to cellulose fibre increased the OITC rating by 1 point and using rock fibre by a further one point. These increases were partially due to the rounding up of the values to integers in the OITC procedure. The effects were small because the important limiting low frequency transmission loss did not greatly change and would be smaller in walls without structural breaks.

Conclusions

The overall sound insulation of wood stud exterior walls is limited by poor performance at the low frequencies. It is therefore very important to concentrate on improving the low frequency sound transmission loss to achieve better overall sound insulation.

The low frequency sound transmission loss is limited by two types of low frequency resonances that increase the transmitted sound energy. For walls without a structural break between the outer surface layers, the primary structural resonance that occurs at about 125 Hz for a 406 mm stud spacing limits the overall performance. Using a larger stud spacing (i.e. fewer studs) lowers the resonance frequency and improves the overall sound insulation.

For walls with a structural beak between the two outer surfaces, the low frequency performance is limited by the mass-air-mass resonance due to the mass of the surface layers and the stiffness of the air in the stud cavity. Increasing the mass of the surface layers and the depth of the air space can lower the frequency of this resonance and improve the overall sound insulation rating. However, where the structural break is achieved by using resilient channels, the possible shift of this resonance is limited by the presence of the additional stiffness of the resilient channels [5]. For staggered stud walls, increasing the mass of the surface layers more effectively improves the overall sound insulation rating.

Although only a small number of 89 mm wood stud walls were tested, they provided somewhat inferior performance to the corresponding walls built with 140 mm wood studs.

Acknowledgements

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