Sound transmission through gypsum board walls

Warnock, A. C. C.; Quirt, J. D.

SOUND TRANSMISSION THROUGH GYPSUM BOARD WALLS

A.C.C. Warnock and J.D. Quirt

Institute for Research in Construction, National Research Council of Canada, M27 Montreal Road, Ottawa, Ontario, Canada, K1A 0R6

INTRODUCTION.

This paper describes additional findings from a project to study sound transmission through cavity walls constructed from gypsum board using industry-standard details and carefully selected materials[1]. The project was initiated because of increased sound insulation requirements in the 1990 National Building Code of Canada, the removal minimum weight requirements for gypsum board in Standard CAN/CSA-A82.27-M91, and the realization that much of existing published data is obsolete or unsuitable. By making all measurements in a single laboratory, differences among laboratories were avoided and details of specimen construction could be controlled closely. The full report of the study[2], in terms of STC only, provides for builders and regulators a reliable and consistent assembly of sound transmission class (STC) data. About 400 wall systems were tested to examine many parameters but only a few issues can be discussed in this paper. A more detailed report is in preparation.

RÉSUMÉ.

Les principaux facteurs de réduction de la perte de transmission sonore dans les murs creux constitués de feuillets isolés ou liés par un dispositif élastique sont la masse des plaques de plâtre et la largeur de la lame d'air, mais on peut réaliser des gains importants, aux basses fréquences, en déterminant soigneusement l'espacement des poteaux et le type d'absorbant acoustique. Les avantages qu'il y a à utiliser des absorbants phoniques opposant une grande résistance à l'écoulement et possédant une forte masse volumique sont manifestes aux hautes fréquences mais non pas aux basses fréquences, qui déterminent la CTS (classe de transmission sonore) et R'_w. Les absorbants acoustiques testés ont été choisis parmi les matériaux commerciaux servant à garnir les vides de mur ou de plancher. Les données présentées ici indiquent qu'il y a d'autres facteurs à prendre en compte que la résistance à l'écoulement de l'air.

MATERIALS AND STRUCTURES.

Stud systems tested included a single row of 90 mm wood studs (with and without 13 mm resilient metal channels), 65, 90 and 150 mm non-load-bearing steel studs, staggered 90 mm wood studs, a double row of 90 mm wood studs, double rows of 40 and 65 mm steel studs and load-bearing steel studs with 13 mm resilient metal channels. Average properties of the seven sound absorbing materials used are listed in Table 1. In some walls two thicknesses of batts were used. The thickness of sprayed-on cellulose insulation varied with the type of structure being measured.

Table 1: Properties of sound absorbing materials. G and M denote glass and mineral fibre batt materials. C denotes cellulose which was sprayed on to one surface or blown into the cavity.

Code	Thickness mm	Density kg/m^3	Airflow Resistivity mks rayls/m
G1	90	12.2	4800
G1	65	11.7	3600
G1	150	11.2	4300
G2	90	16.4	7900
M1	90	32.6	12700
M1	65	36.7	11400
M2	75	44.2	16600
M2	40	51.9	15000
M3	83	98.1	58800
C1	wet spray	56.3	—
C2	90 (blown)	49.3	33000

Type X fire-rated and conventional gypsum board with thicknesses of 12.7 and 15.9 mm were used. Board density ranged from 7.3 to 11.5 kg/m^2. The average value of Young's modulus was 2.3×10^9 N/m^2.

DEPENDENCE OF STC AND R'W ON MATERIALS AND STRUCTURE.

The major factors that control sound transmission through walls have long been known. This project revealed the significance of other factors that had not been considered very important. To provide an overview, multiple regression analyses were made for the single number ratings STC[3] and R'_w[4] as dependent variables and factors such as mass, cavity depth, airflow resistance as independent variables. Only 360 walls, those with a single cavity containing sound absorbing material and having the two layers independent or resiliently connected, were included in the analyses. For STC and R'_w the regression equations found were

$$STC = -69.8 + 33.5 \log_{10} M_g + 32.2 \log_{10} d - 7 \times 10^{-4} R$$
$$+0.017 S_{oc}, \quad r^2 = .903$$

and

$$R'_w = -60.3 + 29.5 \log_{10} M_g + 32.2 \log_{10} d - 2.1 \times 10^{-4} R$$
$$+9.2 \times 10^{-3} S_{oc}, \quad r^2 = 0.924$$

Here M_g is the total mass per unit area of the gypsum board layers (kg/m^2), d is the cavity depth (mm), R is the flow resistance of the sound absorbing material (mks rayls), and S_{oc} is the stud spacing (mm). The standard errors of the estimates are 2.0 and 1.6 dB respectively. Below 500 Hz, these factors accounted for most of the variance. Above 500 Hz, stud spacing was not significant. Simple multiple correlation with these variables failed at higher frequencies because of gypsum board stiffness effects and other factors. This is of little importance if only STC or R'_w are considered. Transmission loss (TL) contours for common cavity walls using lightweight materials are such that ratings are controlled by TLs at frequencies below 500 Hz.

Dependence of TL on weight and cavity depth were expected. Some dependence on stud spacing, discussed in the next section, was also expected from the earlier work in this project where pronounced resonances were seen when gypsum board was directly attached to wood studs. What is surprising in the equations above, is the negative dependence on the flow resistance of the sound-absorbing material. For a 90 mm material thickness, using the minimum and maximum values of flow resistance in Table 1, the expected change in STC is about 3; for R'_w, it is about 1. The reason for this is discussed below.

EFFECTS OF STUD SPACING.

Attaching gypsum board to studs creates smaller sub-panels with a width determined by the stud spacing. The edge conditions and the effective radiating area for these sub-panels will depend on stud properties and the spacing of the screws attaching the gypsum board. Figure 1 shows improvements for three systems with different combinations of 16 mm gypsum board on each face. The curve labeled SS90 shows the mean improvement for 90 mm steel

NRCC-39272

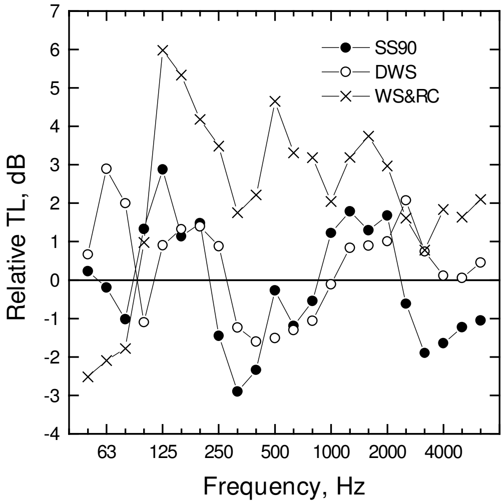

Figure 1: Improvements in transmission loss due to changes in stud or resilient metal channel spacing.

stud walls when the stud spacing is changed from 400 to 600 mm. The curve labeled DWS shows the improvement with double wood stud walls for the same change in stud spacing. The curve labeled WS&RC shows the improvement when both wood stud and resilient metal channel spacings are changed from 400 to 600 mm. Resonance effects are pronounced around 125 and at 200 Hz. Similar results were found for other types of gypsum board. STC and R'_w are often controlled by TL values around 125 Hz, so increased stud and channel spacings can lead to dramatic rating increases. In general, the greater the distance between studs or resilient metal channels, the greater the TL at the lower frequencies. Even with resilient steel studs and double wood studs, there is a benefit to having larger stud separations.

EFFECTS OF SOUND ABSORBING MATERIAL.

The previous paper[1] reported a positive correlation between airflow resistance and TL from 500 to 2000 Hz. The reason for the negative correlation found here between STC and R'_w and airflow resistance can be found by examining Figures 2 and 3. The plots show differences in TL as a function of airflow resistance relative to the case where the cavity contained 90 mm of sound absorbing material G1. A set of differences was calculated for a single stud and gypsum board arrangement with different sound absorbing materials. The figures combine several sets of differences. By referring to a standard absorption condition for each construction type, differences in TL should be due only to the sound absorbing material. Reference to Table 1 shows that different locations on the flow resistance axis correspond to different materials, especially at the right hand side of the plots. Clumps of points are identified in Figure 2 for mineral fibre and cellulose fibre. Figure 2 shows that the mineral fibre and cellulose fibre materials tend to give lower TL values at 125 Hz. Similar relationships are found for other low frequencies. This leads to lower STC and R'_w ratings. For some of these materials as flow resistance increased, so did density and rigidity and there might well have been transmission through the structure of the material. Thick layers of sprayed-on cellulose or the very dense M3 material might even have increased the rigidity of the non-load-bearing steel studs.

At higher frequencies transmission loss increases with increasing flow resistance as found in the previous work[1]. Figure 3, for 2 kHz, marks sets of differences with different symbols and shows some outliers (open circles) in the upper left corner. These outliers come from measurements made on double wood stud systems and show clear, consistent trends at the higher frequencies with improvements due to increasing airflow resistance significantly higher than for other systems. Double wood stud systems are physically connected only around the edges of the specimen through the mounting frame. In all other wall systems, there is coupling through resilient metal studs or channels. These paths may allow significant sound energy to bypass the airborne path through the sound absorbing material and reduce its effectiveness. This needs further investigation.

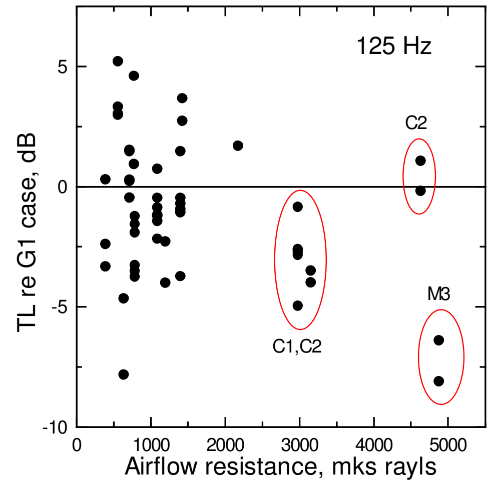

Figure 2: Transmission loss at 125 Hz relative to a cavity containing 90 mm of G1.

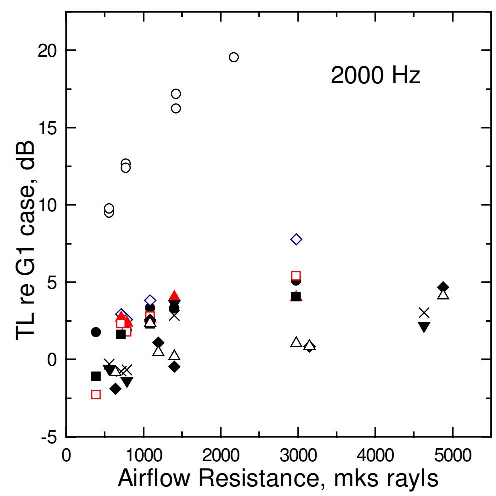

Figure 3: Transmission loss at 2000 Hz relative to a cavity containing 90 mm of G1.

SUMMARY

While the most important factors controlling TL in cavity walls constructed with isolated or resiliently coupled leaves are the gypsum board mass and the depth of the cavity, there are some important gains to be made at the lower frequencies by carefully selecting stud spacing and the type of sound absorbing material. The benefits available from using sound absorbing materials with higher flow resistivity and density are evident at the higher frequencies but not at the low frequencies that determine STC and R'_w. The sound absorbing materials tested were selected from commercial materials sold for use in wall and floor cavities. The data presented here suggest that there are factors other than airflow resistance to be considered.

REFERENCES

1. J.D. Quirt and A.C.C. Warnock, INCE 93, p971, 1993.
2. "Final Report for the Gypsum Board Wall Consortium." Internal IRC report
3. ASTM E413
4. ISO 717