ACOUSTICAL BEHAVIOR OF LIGHTWEIGHT WALLS

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INTRODUCTION

An experimental investigation of parameters that may affect the transmission loss of lightweight walls is briefly presented. According to the criteria for the sound transmission insulation STC-50 National Building Code in Canada, and the recommended criteria STC-55 by Canada Mortgage and Housing Corporation (CMHC) in condominium buildings, two groups of gypsum board partition walls (coupled walls and uncoupled walls), with or without sound absorbing material in the gap, were examined at the acoustics laboratory of Laval University. The measurements had been carried out using the standard pressure technique with the verification of intensity and vibration techniques in some partitions. The results from measurements and calculations show very strong agreement of the resonance and critical frequencies. The parameters considered in this study include the influence of panel mass, distance of steel studs, absorbing material in the cavity, thickness, multi-leaf panel, symmetric and asymmetric positions, etc. The main goal of this study is to present an acoustical behaviour of lightweight partitions, especially those using traditional materials and an experimental application to the kind of partition made of gypsum board, which could achieve the acceptable criteria STC-50 in Canadian homes and residential buildings, and the recommended criteria STC-55 by CMHC in condominium buildings.

OBJECT OF STUDY

Reviewing the conditions of the last National Building Code STC-45 for party walls and floors separating dwellings established in 1941, one could learn that this criteria was not appropriate to the sound insulation requirement in Canada. A paper, presented to the Canadian Acoustic Association in October 1986 [1], consisted of a collection of complaints investigated by the National Research Council. The compilation contains a relatively small number of complaints about situations in which separation was better than STC-50 and almost none above STC-55. However, the most frequent complaints were in the category from STC-45 to STC-50. The particular aspect of airborne sound insulation was also reported by Bradly [2]. As part of a large survey to relate subjective and objective measures of party walls between adjacent homes, values of several acoustical quantities were obtained in a large number of Canadian homes. Measured STC values ranged from a low of 30 dB to a high of 60 dB. Thus, in spite of efforts to obtain a broad range of STC values, most walls had STC values between 45 and 55 dB. Another research report had been directed by Migneron [3], concerning the acoustic quality of condominiums in the Quebec area. Measured FSTC values show about 38% of the wall partitions achieved STC-55, and 30% of the wall partitions did not achieve STC-50. Unfortunately, 9% of the wall partitions were below STC-45.

Noise reduction of construction elements is a minimum requirement specified in most building codes and, correspondingly, a tool of legal control. Therefore, the prediction of sound transmission properties of building partitions by laboratory testing is of great importance to architects, builders and, consequently, the occupants of the dwelling. In order to achieve the sound insulation criteria STC-50 and the recommended criteria of STC-55 for lightweight walls, academic research concerning the sound reduction index of certain lightweight walls was carried out at the acoustics laboratory. The main objectives were to assess the acoustic parameters of lightweight walls, their sound insulation values, and finally, to investigate the optimum samples in regard to economy, thinness, light weight, and the accepted sound insulation requirements.

METHOD

All sound transmission loss tests were conducted with standard pressure technique in accordance with ASTM 90-70 [4] and ASTM E-413-73 [5]. The sound insulation measurements were performed in the laboratory with two reverberation rooms of 60 m^3 and 200 m^3. Two types of walls, coupled double wall and uncoupled double wall, were chosen for the research. Thirteen test specimens, constructed with gypsum boards and steel studs, were evaluated by various parameters on mass, distance of cavity space, absorption material, stiffness, material orientation, etc. According to the basic transmission loss (TL) theory, there are three important regions for the TL of the wall. When weight restrictions are critical and substantial TL is required, the single wall is generally not adequate. The double wall has greater benefits in middle and high frequencies because it has an airspace. However, for panels and related thin materials (such as plywood, gypsum board etc.) the double wall resonance and coincidence effect are noticeable and they occur in an important part of the frequency range, typically around 1k-4k Hz. (see Figure 1).

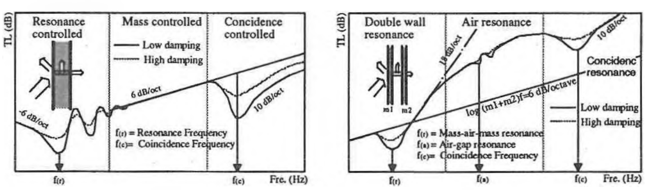

Figure 1. Theory of sound transmission loss

ANALYSIS AND DEVELOPMENT

As shown in Figure 2, the TL increases at low and critical frequencies as the mass of the panel is increased. At middle frequencies (400 Hz to 1600 Hz), TL values experience a small increase, affected by a series of sound coincidence performances which are transmitted by sound bridges in the cavity. There is a significant reduction in TL at the critical frequency. Because the gypsum panels are attached by self-drilled screws, not adhered, the same thickness of gypsum panel has the same coincidence dip at 2562 Hz. Obviously, increasing the mass of the partition can improve STC values. However, with a symmetric orientation such as the N°3 specimen, with two layers of 16 mm gypsum boards on each side, the STC value is less than specimen N°2, since the double-leaf panel resonance is magnified at 82 Hz frequency.

The two TL curves are very different between symmetric partition N°13 and asymmetric partition N°12 (see Figure 3). The results show that the TL can be significantly influenced by the material orientation. For example, the STC value of N°13 is 3 dB lower than N°12, although its internal panel mass per unit area is increased. It can be seen that its mechanical coupling resonance is amplified at 274 Hz. Clearly, using symmetric orientation seems to improve the TL at certain high frequencies, especially at critical frequency (2500 Hz) in this case. However, the vibration and harmonic resonance occur at middle frequencies so that the TL values are significantly reduced in this region.

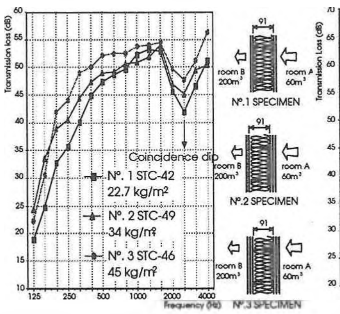

Figure 2. Influence of mass

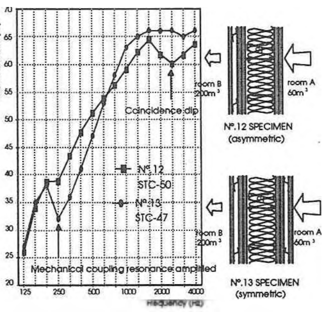

Figure 3. Material orientations

TL of the uncoupled double wall has many benefits at middle and high frequencies (see Figure 4). However, TL was not greatly increased at low frequencies since it is influenced by the resonance of double panel at 105Hz. After the resonance, TL increases about 28 dB per octave until 250 Hz, and 12dB per octave until the air-gap at 798 Hz where the resonance is encountered. It is very important to learn that STC still depends on the TL values at low frequencies. Even though the uncoupled wall has much higher TL values at middle and high frequencies than the coupled wall has, its STC value is improved by only 3 dB.

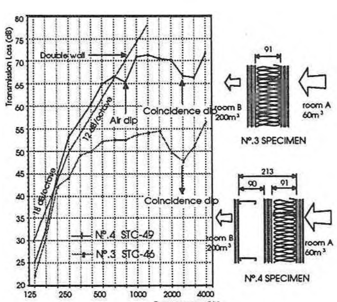

Figure 4. Influence of cavity

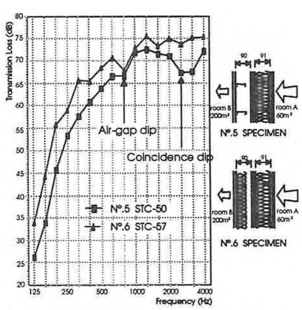

Figure 5. Absorption materials

Figure 5 demonstrates the variation results with and without absorption material in a cavity. The top curve signifies a large TL increase from 5 to 10 dB for all the frequencies except the air-gap frequency. It is interesting to note that the TL value cannot be affected by adding absorption material in the cavity at this frequency. At higher frequencies, the phase of the sound pressure varies with the thickness of the cavity, and the acoustic coupling is weaker. The TL value also significantly increases at the critical frequency 2500Hz. Generally, perimeter absorption has a great effect on TL at most frequencies.

The results are very similar using different cavity space (118 mm, 141 mm, and 166 mm). It seems that to change the space distance in the cavity can vary their STC values a small amount. In addition, the effect of partition stiffness was also measured by reducing the distance of steel studs from 600 mm to 400 mm, and STC improved 1 dB only. On the other hand, the intensity method was used to verify the reliability of STC values in which the TL demonstrated a small difference at certain high and low frequencies. Furthermore, the vibration method was used to identify the frequency of mass-air-mass resonance, air-gap resonance, coincidence effect, etc. Table 1 outlines the information and measured results of thirteen samples [6].

Table 1. Measured results

Sample N°	1	2	3	4	5	6	7	8	9	10	11	12	13
Thick mm	125	140	158	260	260	260	292	317	342	358	184	180	202
Mass kg/m²	22.7	34.1	45.5	53.9	53.9	53.9	56.9	56.9	56.9	68.2	56.9	53.9	62.3
STC dB	42	49	46	49	50	57	62	62	63	66	50	50	47
$/m²*	25.6	29.1	32.6	41.9	42.3	53.9	54.9	54.9	54.9	58.4	37.6	36.9	41.1

* the price valued in 1992

CONCLUSIONS

For coupled walls: They have a high level of agreement between measurements and theoretical calculations in three controlled regions. Adding layers of gypsum board increases STC, but not for the symmetric orientation samples. The TL increases 16 to 18 dB/octave after resonance frequency, 6 to 10 dB/octave at the mass controlled region. The TL increases 2 to 5 dB/octave at middle and high frequencies (400 to 2k Hz) by adding one gypsum panel. The coincidence resonance can be reduced by increasing the mass. The TL increases 15 dB/octave after coincidence frequency. The mechanical coupling resonance is significantly amplified with symmetric position. The coincidence dip can be minimised by using different thickness of gypsum boards and asymmetric position.

For uncoupled walls: They have great benefits at the middle and high frequencies. The TL increases 28 dB/octave after resonance frequency, 12 dB/octave until the first air-gap resonance, 5 dB/octave in the general air-gap resonance region. Adding absorption material to the cavity space increases STC to 7 dB, and considerable improvement occurs at the low and critical frequency bands. The STC values do not show a large difference when placing steel studs 600 mm or 400 mm away from each other, or changing the air-gap space distance from 118 mm to 166 mm.

Finally, specimen N°2 (STC-49) nearly achieved STC-50. It should reach more than STC-50 with the following developed construction model. Specimen N°6 (STC-57) is optimum an ideal STC-55 wall: thin, lightweight, and economical.(see Figure 6).

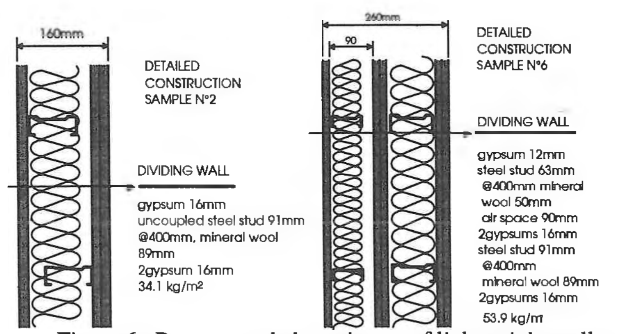

Figure 6. Recommended specimens of lightweight walls

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[3] MIGNERON, J,-G., et MARTEL, C.: *Qualité acoustique, insolation et intimité des immeubles d'habitation en copropriétés.* 325p. Rapport CRAD/SCHL, contrat 6585/M12-4, Université Laval, 1989

[4] American Society for Testing and Materials ASTM Standard E-90-70 (Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions)

[5] American Society for Testing and Materials ASTM Standard E-413-73 (Determination of Sound Transmission Class)

[6] WU, Weixiong: *Airborne Sound Transmission Loss of Lightweight Walls.* Master's thesis, Université Laval, 1994