Partition Sound Insulation of 51 STC for the Jordan Gate Project

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ABSTRACT

A double-leaf gypsum board partition was tested under laboratory conditions to investigate if it meets the Hilton Hotels criterion for sound insulation between bedrooms of 51 STC. According to American Gypsum, this partition should provide sound insulation of 50 STC (Gypsum Association, 2003). Testing revealed that only 45 STC was achieved. Additional horizontal studs were used to increase the stiffness of the partition and a third layer was added on one face to overcome the resulting coincidence effect. This yielded a partition with insulation of 51 STC, which meets the Hilton Hotels criterion.

Keyword: Sound Transmission Class, Transmission Loss (SLD), Normalized level difference (DnT).

1. INTRODUCTION

This paper describes laboratory sound-insulation testing of a double-leaf gypsum board partition. According to American Gypsum, (Gypsum Association, 2003) this should provide sound insulation of 50 STC. The contractor of a 40-story building as part of a twin tower of Jordan Gate project, to minimize the dead load of the building, suggests this partition. The partition was tested in the laboratory of the Faculty of Engineering and Technology, Jordan University, but failed to meet the Hilton Hotels criterion of 51 STC or the recommended STC insulation by the Gypsum Company.

We added elements to improve the insulation and obtained a partition that meets the criterion of Hilton Hotels.

2. BACKGROUND

The insulation provided by a double-leaf partition with an air gap of thickness \( d \) is described by the equation: (Balilah, 1987)

\[
2\log_{10}\left[1 + \frac{\omega m_1}{\rho c} \cos^2 \theta \left( \cos \beta - \frac{\omega m_2}{2 \rho c} \cos \theta \sin \beta \right)^2 \right]
\]

Where: \( \beta = kd \cos \theta \);

\( k = \frac{2 \pi}{\lambda} \); \( \theta \) is the incident angle for sound wave;

\( m_1 \) and \( m_2 \) represent the density of the two layers \([\text{kg/m}^3]\);

\( \omega \) is the angular frequency;

\( \rho c \): is the characteristic impedance;

And \( \lambda \) is the wavelength of the sound wave \([\text{m}]\).

When the sound wave is incident in all directions, i.e., a diffuse field, the transmission loss (TL) is calculated according to: (Beranek, 1960)

\[
10 \log_{10} \left[ \frac{1}{2 \cos^4 \theta} \left( \frac{1}{2} \right) \frac{1}{\sin \theta} \right] \quad \text{dB}
\]

If \( \theta = 78^\circ \), the equation becomes:

\[
\text{TL} = \text{TL}_{\theta} - 28 \quad \text{dB}
\]

This is valid when the two layers are of the same material, the incident waves are less than the critical wave, and the mass law is valid. (Hammad, 2006)

For practical use, the above equation can be simplified to: (Ginn, 1978)

\[
\text{TL} = 20 \log_{10} \left( m_1 + m_2 \right) + 20 \log_{10} f \left[ 1 + 0.3d \right] - k \quad \text{dB}
\]

Where \( k \) varies between 26 and 41, depending on the connection elements between the two layers.

3. DESCRIPTION OF THE PARTITION

The partition is described by the Gypsum Association as two layers of type X gypsum board applied parallel to each face. Each layer is 12.5 mm thick with 125-mm steel studs (600 mm o.c.) with 25-mm type S drywall screws (300 mm o.c.). A 50-mm mineral wool fiber of 80 kg/m\(^3\).
in density is placed in the stud spaces.

The partition was constructed in a window between two reverberant rooms in the laboratory and tested according to international criteria.

### 4. MEASUREMENT PROCEDURE

The test procedure was conducted according to BS EN ISO 140:1998. (Ginn, 1978; NBS, 2004)

The test specimen was constructed in a window between the source and receiving rooms. The source room is a reverberant room of 200 m³ in volume, with specially constructed walls and floor. It is constructed as a shell within a shell, and the walls are constructed above a resilient material to isolate the two rooms from outside impacts and vibrations. The walls are not parallel and reflectors ensure that sound is distributed uniformly on the test specimen. The walls, ceiling and floor are hard and the reverberation time is very high (9–3 s). The window between the two rooms is completely separated by a steel frame and the two walls between the two rooms are completely separate. The walls of the two rooms are each of 200 mm and made of solid lime blocks, with an intervening space of 100 mm. The receiving room is approximately 28 m³ in volume, with hard surfaces and a high reverberation time (3–2 s).

A B&K type 4224 source with different sound spectra, including 1/3 octave bands, was used. The source is stable and can deliver high sound levels that are much greater than any ambient sounds near the room. The source is set to propagate on white noise, and sound is measured using a microphone boom that rotates at one rotation every 32 s on average. A B&K type 4165 microphone is connected to a B&K type 4418 building acoustic analyzer with a 1/3 octave band from 100 to 8000 Hz. The analyzer has two channels for receiving and source room measurements store all readings in memory.

Using the above procedure, the standardized level difference (SLD) was calculated using the formula (Ginn, 1978):

\[
\text{SLD} = L_1 - L_2 + 10 \log \left( \frac{t}{0.5} \right) \text{dB},
\]

Where \( L_1 \) and \( L_2 \) represent the sound pressure level [dB} in the source and receiving rooms, respectively, in the 1/3 octave band from 100 to 8000 Hz; \( t \) is the reverberation time [s] in seconds, in the receiving room for each octave band; and 0.5 is the reference reverberation time [s].

Sound transmission class (STC) (Sound Transmission Class Ratings) curves are compared with the SLD and one parameter, DnT, should meet the following criteria: the maximum deviation in any single 1/3 octave band should not exceed 8 dB and the total negative deviation from the STC in the frequency range 100–3150 Hz should not exceed 32 dB. (Bruel and Kjaer, 2004)

### 5. RESULT AND DISCUSSION

The insulation provided by the partition was first measured, since the company predicted an insulation of 50–54 STC. The partition was constructed according to the manufacturer’s recommendations and was tested according to BS EN ISO 140:1998.

Fig. (1) shows the insulation measured for the partition and the 45 STC curve. It is clear that the partition does not provide the insulation suggested by the manufacturer. Moreover, the partition is affected by resonance at low frequencies and by the coincidence effect at high frequencies.

![Fig.1. TL provided by the partition and the 45 STC curve.](image-url)
The second step was to increase the stiffness of the partition. Therefore, additional horizontal metal studs were connected to the vertical studs. This should decrease the effect of resonance at low frequencies and shift the coincidence effect to higher frequencies.

The sound insulation of the partition was measured under the same sound conditions as for the previous case. The results are shown in Fig. (2).

It is clear from Fig. (2) that the resonance effect was eliminated and the insulation reached 47 STC. The coincidence effect was much less than for the previous case.
However, the partition does not meet the insulation criterion of Hilton Hotels and further development is needed.

In the third stage of the work, an additional 12.5-mm gypsum board was added to one face using the same configuration as for the second stage (with horizontal studs fixed to the vertical studs), as shown in Fig. (3).

Fig. (4) shows that the final insulation measured for the partition was 51 STC, which meets the Hilton Hotel criterion.

![Fig. 4 SLD and STC for the partition with horizontal studs and an additional layer of 12.5-mm gypsum board.](image)

The insulation of this partition is compared with the theoretical value in Fig. (5). It is clear that the insulation measured for the partition is close to the theoretical value in the mid-frequency range, with less agreement at low and high frequencies. This can be attributed to resonance at low frequencies and the coincidence effect at high frequencies.

![Fig. 5. Theoretical and actual insulation provided by the partition.](image)

6. CONCLUSIONS

The partition recommended by American Gypsum only provided insulation of 45 STC, while the company suggested 50–54 STC insulation. To provide the insulation required by Hilton Hotels, we suggest an increase in stiffness of the partition, which can be achieved by adding horizontal studs. These studs increase the stiffness and thus reduce the effect of resonance in the partition. This approach only increased the insulation to 47 STC. A third layer of 12.5-mm gypsum board was added to the partition, which increased the insulation to 51 STC, thus meeting the Hilton Hotels criterion. This insulation is comparable to the theoretical value for a double-leaf partition, and the result compares well for the mid-frequency range.
REFERENCES


DnT, SLD, STC