Evaluation of standards for transmission loss tests

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FG Wilson, a generator set manufacturer in Larne, UK, (part of the CAT Electric Power Division), has an acoustics facility for obtaining noise emission of current products, future developments and research. A wall between a hemi-anechoic chamber and a reverberation room contains an aperture which is used for testing canopy panels to determine their sound transmission loss. Two different standard procedures for transmission loss testing are compared; the J1400, and ISO 15186. Tests were carried out on both to determine which is most feasible for the company to use.
The J1400 is a variation of the ASTM E90 which uses the same method but is specifically for a reverberation room to hemi-anechoic chamber. A known 'limp' material, chosen to be lead, is used to obtain a transmission loss correction. ISO 15186 is based on a sound intensity method. A microphone on the source side recorded the sound pressure levels, and an intensity mapping was done on the receiving side, from which transmission loss was calculated. Two tests were completed; a lead sheet, and a steel plate. Both standards showed an acceptable accuracy in relation to the mass law.

1 Introduction

Built in 2005, the Acoustic Centre of Excellence at FG Wilson in Larne, contains a hemi-anechoic chamber for testing the noise emission of their generator sets, and a reverberation room for measuring the absorption of lining material. There is also an opening between these two rooms which is used for transmission loss of canopy panels and future research. For anticipation of a large number of tests in order to build a database, there is the need for a standard method of transmission loss testing.

Transmission loss is the property of a wall or barrier that defines its effectiveness as an isolator of sound [1]. It is also referred to as the sound reduction index, and is computed from the logarithmic ratio of sound power incident to sound power transmitted, eq (1).

$$TL = 10 \log \frac{SoundPowerIncident}{SoundPowerTransmitted} \quad (1)$$

From recommendations of similar test facilities, and a search through international standards, two of the most relevant methods were the American National Standard for laboratory measurement of the airborne sound barrier performance of automotive materials and assemblies, the SAE J1400, and the International standard for measurement of sound insulation in buildings and of building elements using sound intensity, the ISO 15186. The J1400 is associated with the ASTM E90 International Standard Test Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions and Elements, and is used instead because the ASTM E90 does not cater for a reverberation room to hemi-anechoic chamber.

The first noticeable difference between the two standards is that the J1400 uses microphones to measure sound pressure levels in both rooms, whereas the ISO 15186 uses intensity measurements in the hemi-anechoic chamber to calculate the transmission loss. Another major difference is the use of a reference sample as calibration in the J1400, from which the unknown sample is calculated by inputting a correlation factor.

2 Method

2.1 Theory

Sound transmission loss is the logarithmic ratio of sound power incident to sound power transmitted, eq (1). It can be evaluated from eq (1) that:

$$TL = 10 \log \frac{W_1}{W_2} \quad (2)$$

W_1 incident sound power
W_2 transmitted sound power

For ISO 15186 the sound intensity is measured therefore using power is equal to intensity times area:

$$W_1 = I_1 S \quad (3)$$

$$W_2 = I_2 S_m \quad (4)$$

I_1 incident sound intensity
I_2 transmitted sound intensity
S area of the test specimen
S_m area of the measurement surface, Fig2

Since sound pressure levels are recorded in the reverberation room, the effective intensity in one direction of a diffuse field is [2]:

$$I_1 = \frac{P_1^2}{4\rho c} \quad (5)$$

P_1 is the source sound pressure
ρc is the acoustic impedance

From eq (3) and eq (5)

$$W_1 = \frac{P_1^2 S}{4\rho c} \quad (6)$$

therefore from eq (2), eq (4), and eq (6)

$$TL = 10 \log \frac{P_1^2 S}{4\rho c} \frac{1}{I_2 S_m} \quad (7)$$

$$TL = 10 \log P_1^2 - 10 \log (4\rho c) - 10 \log I_2 + 10 \log \frac{S}{S_m} \quad (8)$$

To convert sound pressure into sound pressure level, and sound intensity to sound intensity level:

$$\begin{aligned} TL &= 10 \log \frac{P_1^2}{P_0} P_0 - 10 \log (4\rho c) \\ &\quad -10 \log \frac{I_2}{I_0} I_0 + 10 \log \frac{S}{S_m} \end{aligned} \quad (9)$$

P_0 is the reference sound pressure ($2 \times 10^{-5} Pa$)
I_0 is the reference sound intensity ($10^{-12} W/m^2$)

Eq (9) becomes:

$$TL = L_{P1} + 10\log P_0 - 10\log(4\rho c) - L_{In} - 10\log I_0 + 10\log\frac{S}{S_m} \quad (10)$$

L_{P1} average source sound pressure level
L_{In} average transmitted sound intensity level

Substituting the values for the constants eq (10) becomes:

$$TL = L_{P1} - 6 - [L_{In} + 10\log\frac{S}{S_m}] \quad (11)$$

Eq (11) is used to calculate the transmission loss for the international standard ISO 15186.

In comparison the J1400 evaluates the TL from eq (12)

$$TL = MNR(unknown) - CF \quad (12)$$

$MNR(unknown)$ measured noise reduction of the unknown sample
CF correlation factor, eq (13)

$$CF = MNR(reference) - TL(reference) \quad (13)$$

$MNR(reference)$ measured noise reduction of the limp material
$TL(reference)$ mass law of limp material, eq (14)

$$TL(reference) = 20\log W + 20\log f - 47.2 \quad (14)$$

W surface density, kg/m^2
f centre frequency of the third octave band

The measured noise reduction is calculated from eq (1) where TL now becomes:

$$TL = 10\log\frac{P_i^2}{P_t^2} \quad (15)$$

P_i incident sound pressure
P_t transmitted sound pressure

Eq (15) is converted to sound pressure levels as before

$$TL = 10\log\frac{P_i^2}{P_0^2} - 10\log\frac{P_t^2}{P_0^2} \quad (16)$$

$$TL = 20\log\frac{P_i}{P_0} - 20\log\frac{P_t}{P_0} \quad (17)$$

$$TL = L_{P1} - L_{P2} \quad (18)$$

L_{P1} average sound pressure level in source room
L_{P2} average sound pressure level in receiving room

Eq (18) is used to calculate the measured noise reduction (MNR) as stated in the standard J1400. It can be compared to eq (11) for ISO 15186 as there is similarity in transmission loss calculation since L_{P1} is the source sound pressure level, i.e. the same for both, however eq (11) converts this to intensity with the 6dB difference and the inclusion of the test specimen area S. Because eq (11) calculates transmission loss as the difference between sound intensity levels it is recognised from eq (18) that L_{P2} corresponds to the sound intensity level L_{In} and the measurement surface area S_m.

2.2 Setup

Equipment required for both include the reverberation room setup containing two speakers and a diffuse field microphone on a rotating boom. Other items are coaxial cables, networks leads, microphone calibrator, data acquisition unit, and a computer with the relevant software. J1400 states the number and spacing of microphone positions required in each room depends on the statistical precision desired, but from prior work to determine the accuracy of measurements, the selected number of microphones was three, spaced at the positions stated in table 1.

Microphone	Height from floor (m)	Distance from LHS (m)
1	2.11	0.61
2	2.91	1.18
3	2.38	1.75

Table 1: Microphone positions in hemianechoic chamber

Fig1 shows the microphone positions in relation to the test piece. They are mounted on rods and fixed in tripods at a distance of 22inches from the sample. In comparison only one tripod is needed for the intensity probe, but this is not at a fixed position and moves over a box grid as shown in Fig2 and Fig3.

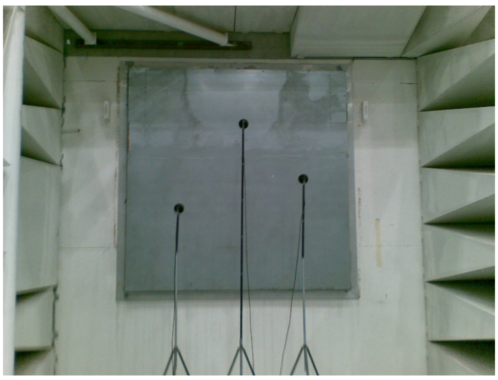

Figure 1: Three microphone positions for the J1400 tests.

2.3 Software

Pulse LabShop, produced by Brüel and Kjær, is designed for the type of tests required, and provides ease of use through pre-programmed applications.

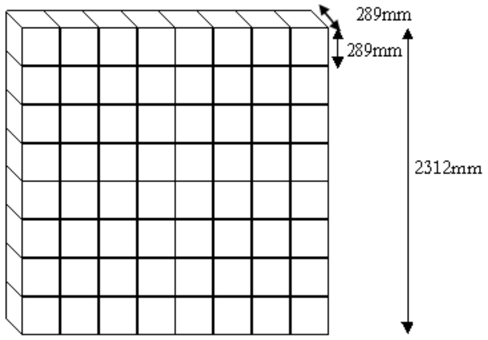

Figure 2: Measurement grid for the ISO 15186

Figure 3: Intensity probe used for the ISO 15186 tests

The initial step is to detect all connections to the software, this includes the speakers as outputs, the diffuse microphone as an input and for the J1400 the three microphones as the other inputs, but for the ISO 15186 the intensity probe is the input. For both tests the signal generated for the reverberation room through the speakers is sourced from the software with white noise through one speaker and pink noise through the other. The diffuse field microphone in the reverberation room is set on a rotating boom with a 64 second cycle.

After calibration of recording equipment the background sound levels are recorded in both rooms for a check to be carried out later. The next step is to use the graphics equaliser to adjust the source sound levels in the reverberation room. When this is complete the transmitted sound can be recorded. For the J1400 this is carried out with an average of three readings. Each reading consists of the average of the three microphones captured as 128s linear averages. The ISO 15186 test is setup differently with 18 second averages recorded for each grid point. There are 96 points to measure, and they are averaged according to the standard.

Measurements are exported from the Pulse software to a spreadsheet where calculations are carried out. Also exported are the calibration data and background levels to complete the necessary checks.

3 Results

The correlation factor for the J1400 was calculated from the transmission loss measured from the average of the three recorded values over the frequency spectrum. Fig4 shows the difference between the recorded data and the mass law, this difference is the correlation factor eq (13).

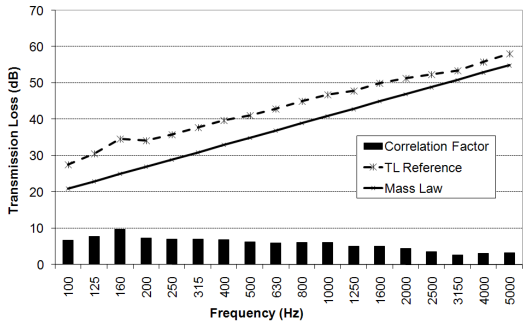

Figure 4: Calculated correlation factor from the reference sample.

Repeating the test of the lead sheet with a steel plate, the transmission loss for this unknown sample is found, Fig5. This is done by subtracting the correlation factor from any measured transmission loss using the J1400 method to predict the actual transmission loss as stated in eq (12)

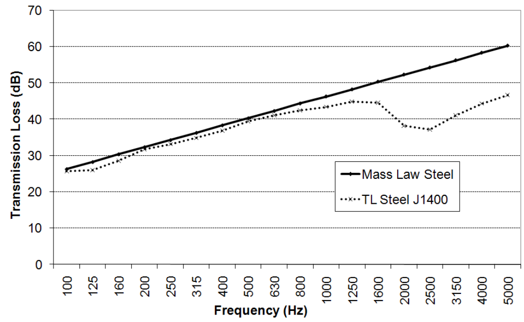

Figure 5: Transmission loss of steel using the J1400.

Fig6 shows the transmission loss of steel for ISO 15186, calculated using eq (11). From this graph it is observed that there is very good correlation for the frequency range 100Hz to 1250Hz. The large differences at the higher and lower frequencies can be accounted for by stiffness and damping.

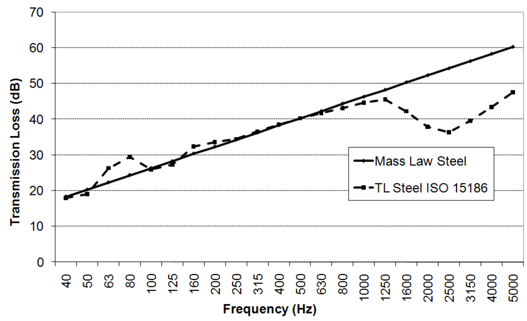

Figure 6: Transmission loss of steel using the ISO 15186.

Another comparison is the lead sheet tested using the ISO 15186 to compare its accuracy with the mass law for lead. Fig7 shows great correlation for the 100Hz to 1250Hz, which was the same as the steel. The issues arising due to the stiffness and damping are observed again, but are not as large due to lead being a limp material.

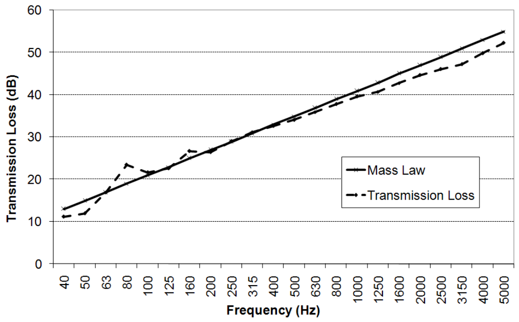

Figure 7: Transmission loss of lead using ISO 15186.

The overall comparison for both standards with the mass law for steel is observed in Fig8. It can be seen how accurate the standards are to the mass law, but also how well the two standards correlate with each other. Fig9 shows the difference between the ISO 15186 and the J1400. As can be seen the difference lies within 2dB with two outlying third octave bands at 160Hz and 1600Hz.

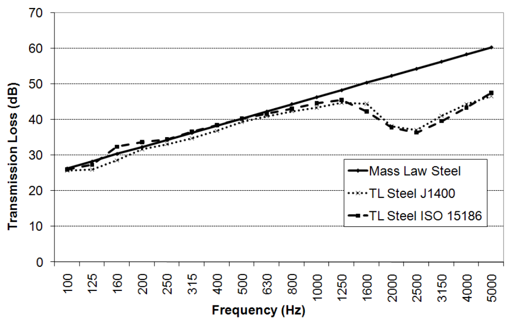

Figure 8: Comparison of the J1400 and ISO 15186 with the mass law for the steel.

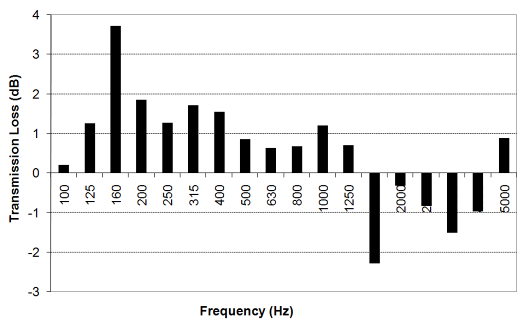

Figure 9: The difference between the transmission loss using the J1400 and ISO 15186 for steel.

4 Discussion

As an accurate measure of sound transmission loss both the standards correspond well to the mass law as shown in Fig8, there are however inaccuracies at frequencies below 100Hz, and above 1250Hz. These can be accounted for due to resonances at low frequencies and coincidence effect at high frequencies causing a deviation from the mass law.

The most important comparison is represented by Fig9 which compares the standards. From this graph it can be said that both the J1400 and the ISO 15186 predict the same sound transmission loss. This shows that both are suitable for testing noise reduction of a partition, but this study has been carried out to find the most appropriate method for FG Wilson to use.

A method of recording sound using microphones is easier from the setup and testing technique. However there is one major disadvantage using the J1400, this is the need to have a reference material tested first before testing the unknown. As a result this is not the most suitable for FG Wilson due to the setup of replacing the test piece each time being very time consuming, therefore requiring a whole day for one test.

The alternative is to use the intensity method, although the setup takes longer and the probe must be positioned manually, the test takes only two hours to complete. This favours the ISO 15186 as being the method to use since there is very little difference in actual results.

5 Conclusion

For FG Wilson the test method to find transmission loss will be the international standard ISO 15186 which utilises the sound intensity method. It has been shown from this research that the measurements used to predict the sound transmission loss result in very close correlation, so it is the actual facilities setup and availability of equipment that determine which method to use.

6 Acknowledgments

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References

[1] B. J. Smith, R. J. Peters, S. Owen, "Acoustics and Noise Control", Second Edition *Addison Wesley Longman Limited*, 151 (1996)

[2] David A. Bies, Colin H. Hansen,"Engineering Noise Control", Third Edition *Spon Press*, 287 (2003)