inter.noise 2014
MELBOURNE AUSTRALIA
16-19 NOVEMBER

Effects of sample construction, sample size and niche depth on measured sound transmission loss

Robin R. WAREING[1]; John L. Davy[2]; John R. PEARSE[3]

[1,3] University of Canterbury, New Zealand

[2] School of Applied Sciences, RMIT University, Australia

ABSTRACT

Sound transmission loss measurements, performed using a small test facility (1.5 m^2 sample size) are compared with results from full wall sample (11.6 m^2). The effects of sample construction, sample size and niche depth are investigated. Significant changes in the measured sound transmission losses were observed between the samples measured. The variation between the two sample sizes was found to be heavily influenced by the construction of the sample. The variation between the sizes was further confounded by the niches present in both sample arrangements. Individually the contributing factors could be explained using existing theories but the interaction of the different factors was more difficult to predict. The behaviours observed were investigated, including the variations in the pressure at the surface of each panel and the pressure variations throughout the room. The pressure variations within the room were not a major contributor to the variations in transmission loss, whereas the variations across the surface had a small effect on the transmission loss. Finally the appropriateness of using the small transmission loss rig for comparative testing of samples was evaluated. The small test rig was found to be useful for tests in which the construction of the test sample was consistent.

Keywords: Sound Transmission Loss, Sound Reduction, Size, Construction, Niche.
I-INCE Classification of Subjects Number(s): 51.4, 23.9, 33

1. INTRODUCTION

The effects of the sample size, sample construction and facility construction on the sound transmission loss were investigated. These factors have been known to cause variations in the measured sound transmission loss. Research by Guy et al. (1) and Kihlman et al. (2) indicated that the sample size and a number of other physical parameters can have a large influence on the measured sound transmission loss. Other factors found to have a significant influence on the sound transmission loss were the mounting conditions, niche depth and the room sizes (3-5).

Often small samples are utilized for sound transmission loss tests as they require significantly less construction cost and time. The use of smaller sized samples are accounted for in ISO 10140-2 (6); this is intended for the testing of small building elements such as windows. The sound transmission loss tests are undertaken using the intensity method; as described in ISO 15186 (7). The intensity method was well suited to measuring small building elements; due to the directional nature of the intensity measurements. There has been minimal research into the influence of sample size on the sound transmission loss measured when using the intensity method.

This paper presents a qualitative analysis of how several laboratory factors interact and influence the sound transmission loss. The interaction between the wall construction and the sample size was of specific interest. This influence was of interest due to the wide range of different samples that are tested in both the large and small transmission loss rigs.

The results of a range of sound transmission loss tests are presented. Further measurements of the incident sound field and the source room pressure distribution are presented. Finally a qualitative analysis of the behaviour of the different samples is presented, which compares the behaviour of these samples with published data and theories.

---

[1] robin.wareing@pg.canterbury.ac.nz
[2] john.davy@rmit.edu.au
[3] john.pearse@canterbury.ac.nz

2. EXPERIMENTAL ARRANGEMENT AND METHODOLOGY

2.1 TRANSMISSION LOSS FACILITY

The University of Canterbury has two sound transmission loss test facilities. The first is a full size wall system, with outer dimensions of 4800 mm × 2400 mm. The second facility is a small test rig, constructed in a doorway with outer dimensions of 950 mm × 1550 mm. These facilities are used for both commercial testing and research. The reverberation room is common between both facilities but different semi-anechoic rooms are used in each test facility. The layout of the transmission loss facilities are presented in Figure 1. The large sample meets the requirements set out in the standard, the small sample does not.

A white source noise was generated within the reverberation room using a Brüel and Kjær 4295 dodecahedron sound source; the sound pressure level of this signal was measured using five Brüel & Kjær 4189 microphones. These microphones recorded a 30 second linear average of the sound pressure level within the room. The intensity level in the receiving room was measured using a Brüel & Kjær sound intensity probe. For each test five intensity measurements were performed. Each intensity measurement consisted of two individual scans, one horizontal and one vertical. These scans were performed 150 mm from the surface of the sample with a grid spacing of approximately 200 mm. The pressure-intensity index and the repeatability index were calculated for each measurement. If the pressure-intensity index was greater than 10 decibels or the repeatability index was greater than 1 decibel in any one-third octave band the measurement was repeated. The measured sound pressure level was utilized with the sound intensity to calculate the sound transmission loss.

The sound transmission loss of 10 small samples and 11 large samples were tested, these samples are summarized in Table 1. The large samples with studs were constructed on a timber stud wall with a stud depth of 90 mm and a stud spacing of 600 mm. The wall leaves were screwed onto the studs with a screw spacing of 150 mm, the edges of the panels were sealed, and the joints were taped or glued to minimize leakage. The large unsupported samples had joints taped and glued, and the perimeter was screwed and glued to the outer timber frame with the internal studs removed.

The small samples were clamped into a heavy timber frame which was mounted within a doorway, as shown in Figure 2. The sample was clamped in place via fourteen M8 bolts, torqued to 2 Nm. In order to incorporate double leaf walls into the small transmission loss facility a small stud wall frame was constructed to fit within the test rig. To test the influence of the studs a small frame with studs was also constructed onto; these samples were clamped into the small transmission loss rig. The small stud frame is shown in Figure 3, the stud spacing is 450 mm and the samples were attached using a screw spacing of 150 mm.

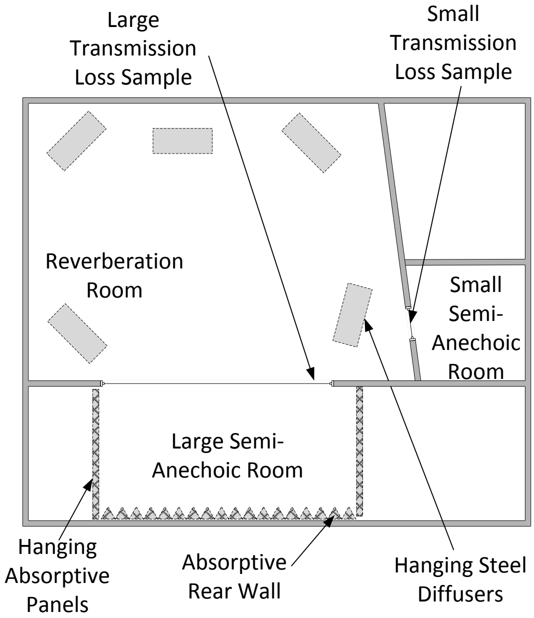

Figure 1 – Layout of transmission loss facility.

Figure 2 – Small transmission loss rig.

Figure 3 – Small stud wall system.

Table 1: Overview of measured samples.

Thickness and Material	Conditions Tested
7 mm & 9 mm Plywood	Single Leaf
12 mm Plywood	Single and Double Leaf
21 mm Plywood	Single and Double Leaf – With and Without Studs
10 mm gypsum plasterboard	Single and Double Leaf
2 kg/m^2 Mass Loaded Barrier	Single Leaf

2.2 ROOM PRESSURE VARIATION

Pressure levels within the reverberation room were measured to investigate if the location of the sample within the room altered the sound pressure level incident on the sample surface. The pressure was measured in a 500 mm × 500 mm × 500 mm array within the room volume using five Brüel & Kjær 4189 microphones on a vertical stand (Figure 4). The sound pressure level was measured using a 30 second linear average at each of the microphone locations.

Figure 4 – Micropohne array for volume pressure measurements.

2.3 SURFACE PRESSURE LEVEL

The pressure level near the surface of both the small and large transmission loss rigs was measured using a microphone array. The large rig was measured 25 mm from the surface using an array of nine microphones, as shown in Figure 5. The small rig was measured at 0 mm and 25 mm from the surface using a panel with holes drilled in it, as shown in Figure 6. The spacing of the large array was 400 mm × 400 mm and the spacing of the small array was 220 mm × 185 mm. A 30 second linear average of the sound pressure level at all of the microphone locations was performed.

Figure 5 – Microphone array for large surface pressure measurements.

Figure 6 – Microphone array for small surface pressure measurements.

3. RESULTS

3.1 TRANSMISSION LOSS RESULTS

The sound transmission losses of single and double leaf 12 mm plywood wall systems are shown in Figure 7. The small single leaf sample does not have any studs present; all the other samples are constructed on a stud frame. Figure 8 presents the measured sound transmission loss of single leaf 7 mm and 9 mm plywood panels. The large samples are built on the stud frame and the small samples do not have studs present. In all the tested single and double leaf plywood samples the smaller test facility gave significantly higher measurements across the majority of the measured frequency range. Both sample sizes gave similar shaped transmission loss curves, with a similar coincidence dip. The variation between the measured sound transmission losses reached almost 10 decibels in some one third octave frequency bands.

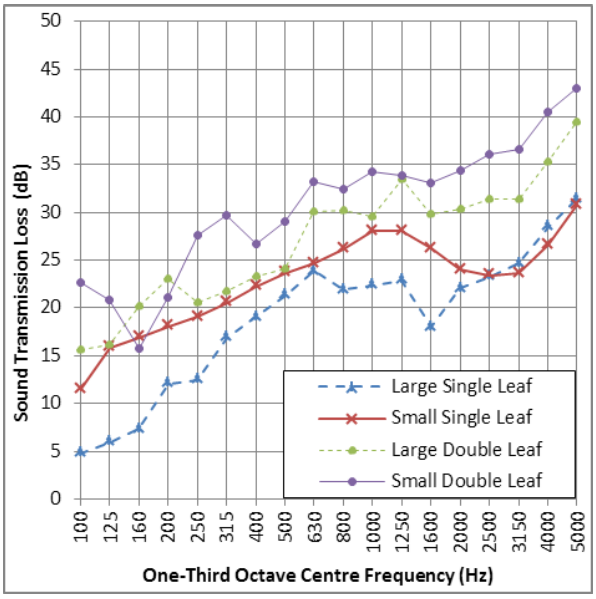

Figure 7 – Measured sound transmission loss of 12 mm plywood panels.

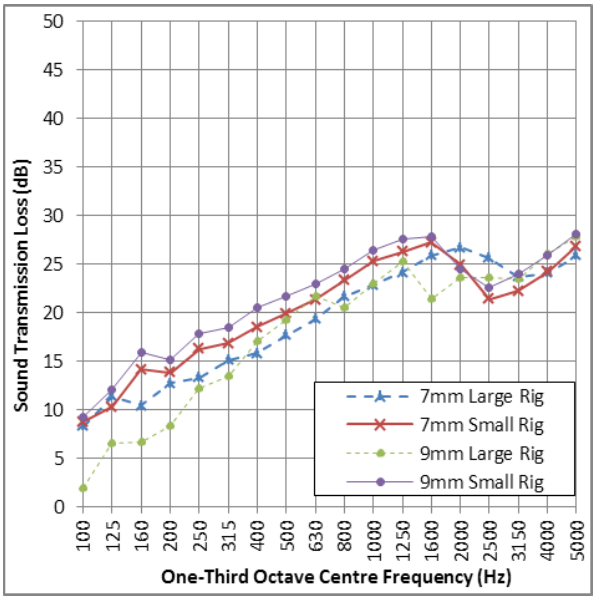

Figure 8 – Measured sound transmission loss of 7 mm and 9 mm single leaf plywood panels.

Four tests were performed using 21 mm plywood panels to assess the effect of both the size of the sample and the presence of studs in the system; the results are presented in Figure 9. As with the other plywood samples the transmission loss measured in the small rig was higher than that measured in the large rig across the majority of the measured frequency range. The removal of studs from the large system caused a reduction in the coincidence frequency by approximately two thirds of an octave. The reduction in the coincidence frequency was likely due to the removal of mass which occurs when the studs are removed. The removal of the studs reduces the bending stiffness of the wall, but this effect is not sufficient to negate the removal of mass from the system.

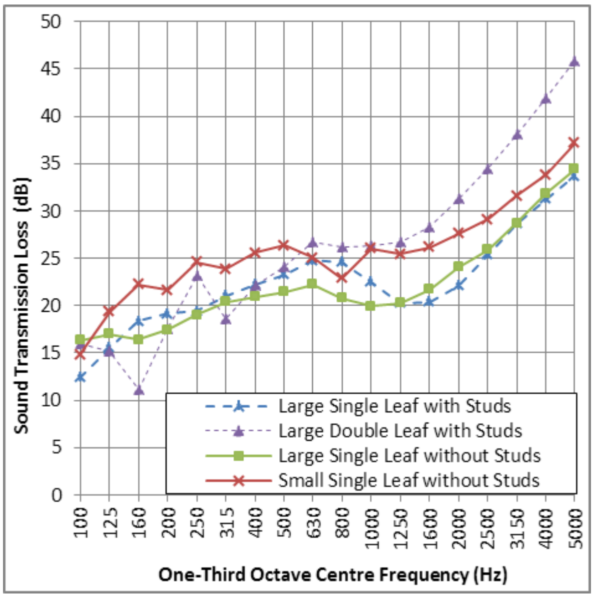

Figure 9 – Measured sound transmission loss of 21 mm plywood panels.

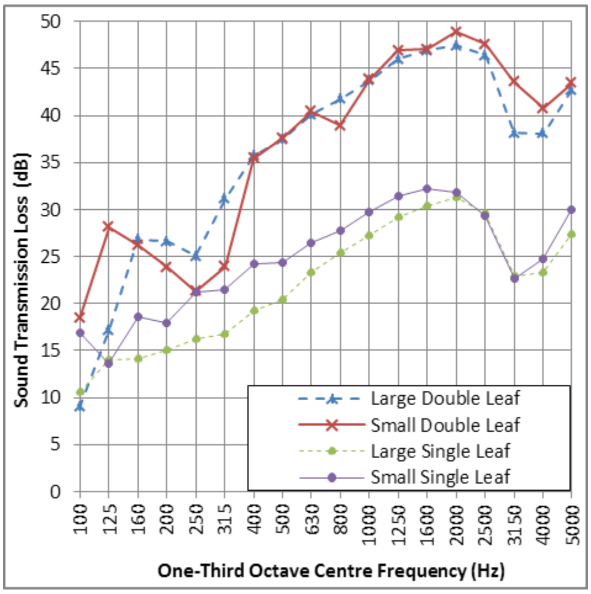

Figure 10 – Measured sound transmission loss of 10 mm gypsum plasterboard.

The sound transmission loss of a single and double leaf gypsum plasterboard wall is presented in Figure 10. The small single leaf sample does not have studs present; all the other samples are constructed on a stud frame. The small sample has a higher sound transmission loss above and below the coincidence frequency in the case of the single leaf samples, with a convergence occurring between the two sample sizes at the coincidence frequency. There was some variation between the measured sound transmission loss of the double leaf samples but it was not as consistent as the variation seen in the single leaf samples. It should be noted that the double leaf gypsum walls both had absorption in the cavity.

Finally the sound transmission loss of an unsupported 2kg/m^2 mass loaded barrier is presented in Figure 11. The same trends are seen in this sample with the small sample having a significantly higher sound transmission loss across the entire measured frequency range. There is no appreciable convergence seen in the coincidence region. Both these samples were unsupported and the large sample was clamped and glued onto the surrounding frame.

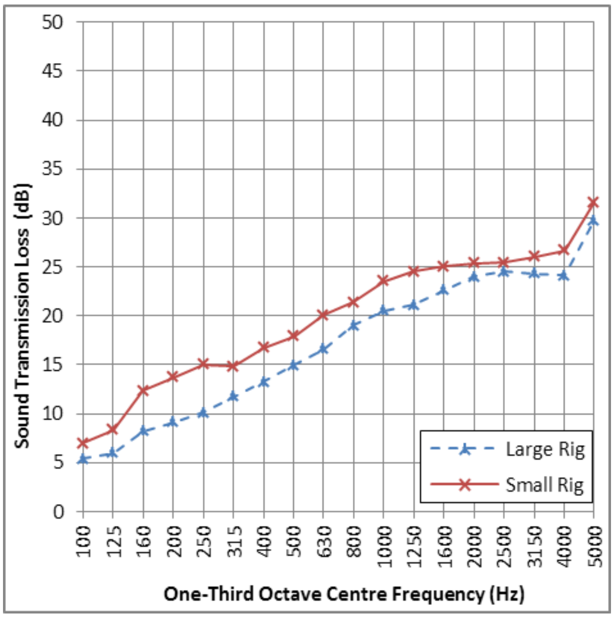

Figure 11 – Measured sound transmission loss of 2 kg/m^2 mass loaded barrier.

3.2 ROOM PRESSURE VARIATION

The average sound pressure level throughout the reverberation room is presented in Figure 12; in addition to with the average sound pressure level near the small and large samples. The measurements near the samples were within 500 mm of the sample surface. These tests were performed to assess if the small sample was "shadowed" due to its location within the reverberation room. It was clear that the pressure levels near both samples were very similar across the frequency range measured.

Figure 13 provides an example of the pressure variation throughout the room. This was typical of the pressure variation across the frequency range measured. The large sample was located at the same locations as identified in Figure 1. The variation in the sound pressure level throughout the reverberation room is small, with exception of locations close to the sound source which have a significantly higher sound pressure level as expected.

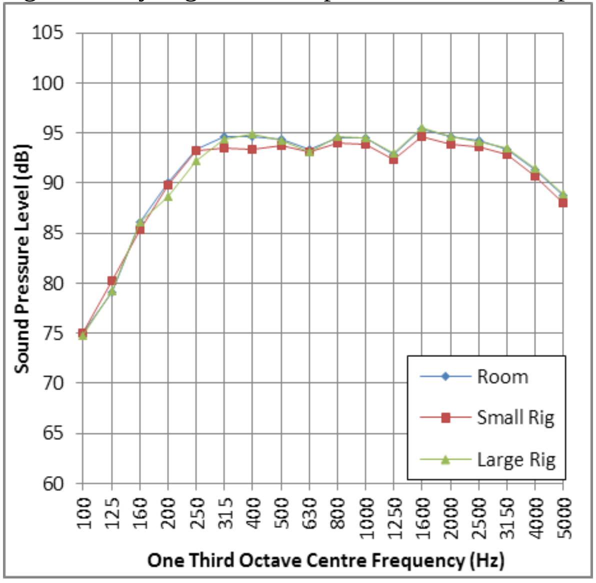

Figure 12 – Average pressure throughout room volume compared to measurement points within 500 mm of samples.

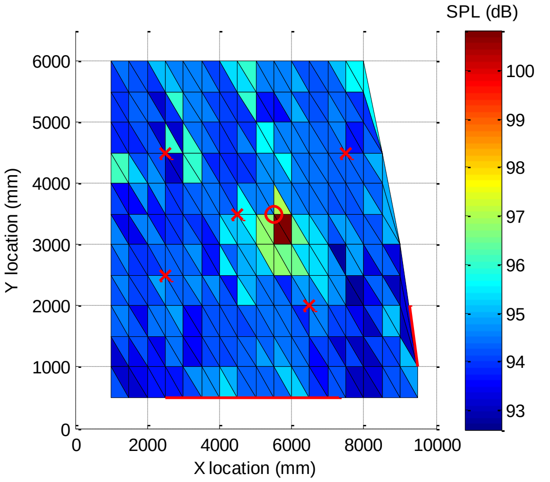

Figure 13 – Pressure level throughout room at 400 Hz and a height of 1000 mm. The crosses represent the normal microphone locations, the circle is the location of the source, and the lines are the locations of the samples.

3.3 SURFACE PRESSURE VARIATION

The average surface pressure levels are presented in Figure 14. The large sample has a higher sound pressure 25 mm from the surface of the panel, this variation peaks at approximately four decibels around the 1000 Hz frequency band. The flush (0 mm) measurements of the pressure level show a significant increase at higher frequencies (greater than 1000 Hz) due to doubling of pressure at the surface of the panel.

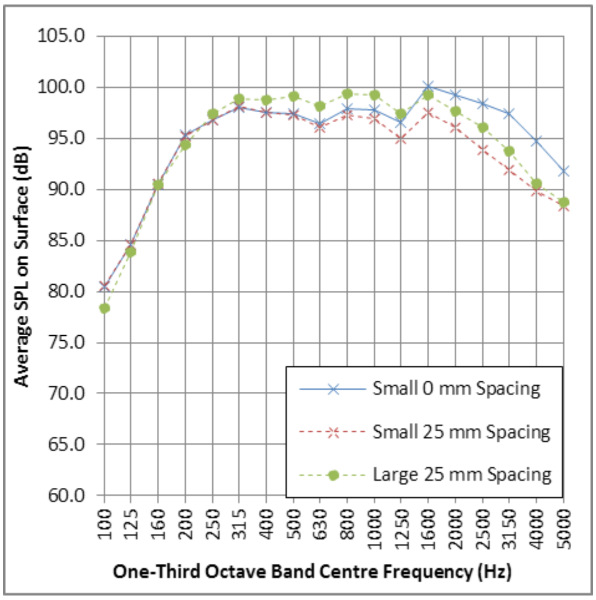

Figure 14 – Average sound pressure level at surface of samples. The large sample was measured with a fiberboard filler wall in place.

Figure 15 shows the pressure variation across the surface of the small transmission loss sample at 100 Hz. There was some level of modal behaviour evident in the measurement, this is typical of the sample in the frequency range below 500 Hz. Above this frequency the small panel shows no obvious modal behaviour across the surface, as shown by Figure 16, which is a typical of the high frequency response (4000 Hz).

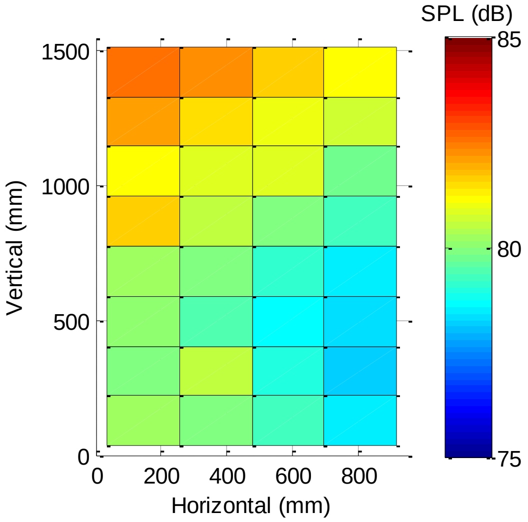

Figure 15 – Pressure variation 25 mm from surface of small sample at 100 Hz.

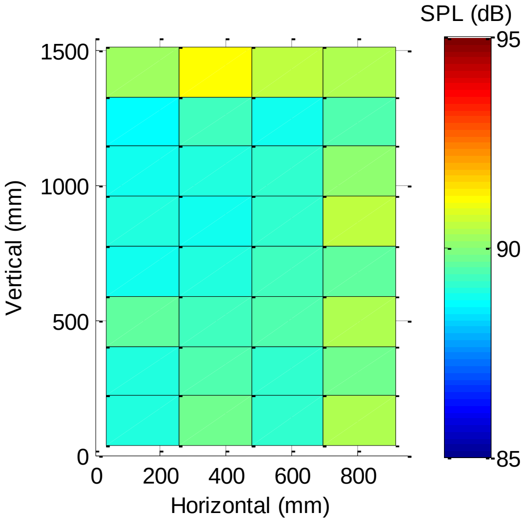

Figure 16 – Pressure variation 25 mm from surface of small sample at 4000 Hz.

The larger sample does not show the same modal behaviour as the small panel in any of the frequency range evaluated. There was still a reasonably large variation in the pressure level across the surface throughout the entire frequency range evaluated. Figure 17 and Figure 18 show the variation in pressure level 25 mm from the surface of the panel. Some of the variation in the lower frequency example may be due to modal behaviour, but this was unclear based on the measurements performed.

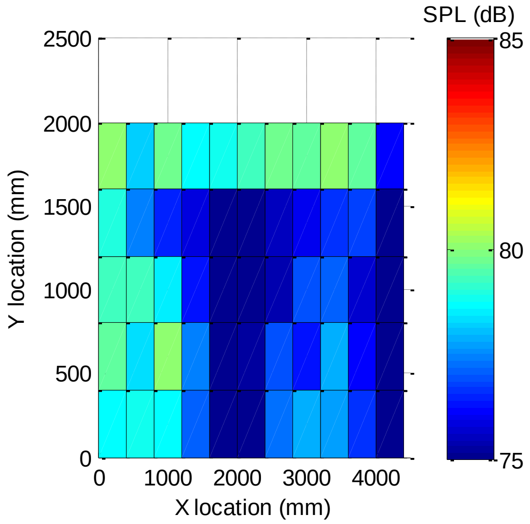

Figure 17 – Pressure 25 mm from surface of the large sample at 100 Hz.

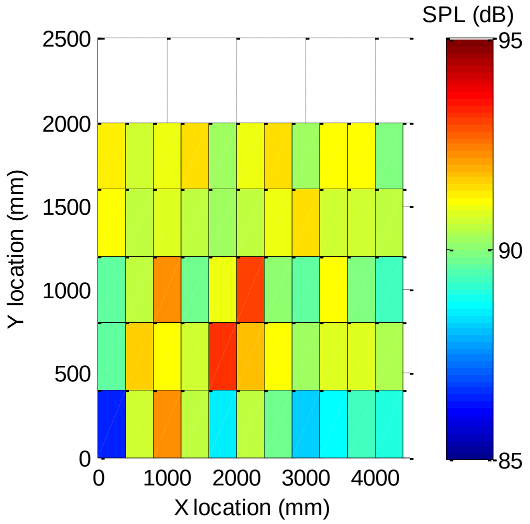

Figure 18 – Pressure 25 mm from surface of the large sample at 4000 Hz.

4. DISCUSSION

4.1 FACTORS INFLUENCING THE SOUND TRANSMISSION LOSS

There has been significant research into the effects of sample size on the measured sound transmission loss. The sample size is predicted to have a large influence on the sound transmission loss. This effect is due to the varying importance of resonant and forced transmission paths, as well as the reduction in effective maximum angle of incidence.

Above the coincidence frequency the sound transmission is dominated by resonant transmission in both finite and infinite panels. In the case of an infinite panel the sound transmission below the critical frequency is controlled by the forced waves, whereas the sound transmission in finite panels is governed by both forced and resonant contributions. Sewell (8) developed an early expression for the sound transmission loss, which incorporated the effects of the panel size on the predicted sound transmission loss.

There are varying theories related to the predicted influence of the sample size on the transmission loss (9, 10). Altering the sample size changes a number of important factors including the edge ratio, the wall to area ratio, and the maximum angle of incidence. Changes in sample size will also amplify the influence of low frequency modal behaviour on the sound transmission loss. The measurements performed in this research used intensity and as such are less influenced by other factors such as the wall percentage and baffle construction. The use of intensity also reduced the influence of the receiving room parameters on the measured sound transmission loss.

The niche effect is influenced by the length of the mounting "tunnel", the location of the sample within this tunnel and the size of the sample. The niche effect becomes more pronounced as the sample size decreases (11). The maximum angle of incidence that the panel is exposed to decreases as the ratio between niche depth and maximum sample dimension increases. Numerous authors have highlighted the importance of the angle of incidence on the sound transmission loss, reducing the maximum angle of incidence will increase the measured sound transmission loss. Compounding the niche effect is a tunnelling effect which has been shown (12) to increase the transmission loss as the tunnel depth is increased, and is dependent on the sample location within the tunnel. The small facility has a source room niche of 350 mm for both the single and double leaf samples. The large facility has a source room niche depth of 70 mm for double leaf samples and 160 mm for single leaf samples. The smaller sample was influenced by the niche depth to a greater extent.

The mounting conditions have also been shown to affect the measured sound transmission loss (13, 14). Panels that are more rigidly mounted within the frame will give a lower sound transmission loss. This reduction is due to that "clamped" edges has greater radiation efficiency than simply supported panels (15). It was assumed in this research that both panels have similar mounting conditions.

4.2 CONSTRUCTION INFLUENCE

The sample construction had a significant effect on the influence of sample size on the measured sound transmission loss. The variation between small and large test samples was significantly reduced in the double leaf system. It was believed that the introduction of the second leaf increases the importance of the structure borne transmission path which in turn causes the studs to radiate more efficiently, narrowing the difference between the radiation efficiency of both panels. Furthermore the introduction of the second leaf decreases the effective niche depth on one side of the sample. The introduction or removal of studs had a minor effect on the variation between the two samples. The sample material also has an influence on the size effects. The sound transmission loss is seen to converge closely above the coincidence frequency in the single leaf plasterboard sample. The intrinsic inhomogeneity in the plywood may have also contributed to the variations seen in the measurements.

5. CONCLUSIONS

An experimental analysis of a range of test parameters of the sound transmission loss measured using the intensity technique has been presented. The sample size was found to alter the sound transmission loss by more than of five decibels in some one-third octave bands. It has been shown that the construction of the sample has a large influence on how the size alters the measured sound transmission loss. The sample location and arrangement on the incident pressure was assessed as having a minimal influence.

REFERENCES

1. Guy R, De Mey A, Sauer P. The effect of some physical parameters upon the laboratory measurements of sound transmission loss. Appl Acoust. 1985;18(2):81-98.
2. Kihlman T, Nilsson AC. The effects of some laboratory designs and mounting conditions on reduction index measurements. J Sound Vib. 1972;24(3):349-64.
3. Sakuma T, Adachi K, Yasuda Y, editors. Numerical investigation of the niche effect in sound insulation measurement. INTER-NOISE and NOISE-CON Congress and Conference Proceedings; 2011: Institute of Noise Control Engineering.
4. Warnock A. Influence of specimen frame on sound transmission loss measurement. Appl Acoust. 1982;15(4):307-14.
5. Bhattacharya M, Guy R. The influence of the measuring facility on the measured sound insulating property of a panel. Acta Acust united Ac. 1972;26(6):344-8.
6. ISO 10140-2:2010; Acoustics -- Laboratory measurement of sound insulation of building elements -- Part 2: Measurement of airborne sound insulation
7. ISO 15186-1:2000; Acoustics -- Measurement of sound insulation in buildings and of building elements using sound intensity -- Part 1: Laboratory
8. Sewell E. Transmission of reverberant sound through a single-leaf partition surrounded by an infinite rigid baffle. J Sound Vib. 1970;12(1):21-32.
9. Hansen CH, editor Effect of size on the sound transmission loss of both heavily and lightly damped orthotropic panels. INTER-NOISE Conference Proceedings; 1991: Institute of Noise Control Engineering.
10. Michelsen N. Effect of size on measurements of the sound reduction index of a window or a pane. Appl Acoust. 1983;16(3):215-34.
11. Vinokur R. Mechanism and calculation of the niche effect in airborne sound transmission. The Journal of

the Acoustical Society of America. 2006;119(4):2211-9.

12. Kim B-K, Kang H-J, Kim J-S, Kim H-S, Kim S-R. Tunneling effect in sound transmission loss determination: Theoretical approach. The Journal of the Acoustical Society of America. 2004;115(5):2100-9.
13. Nilsson A. Reduction index and boundary conditions for a wall between two rectangular rooms. Part I: Theoretical results. Acta Acust united Ac. 1972;26(1):1-18.
14. Nilsson A. Reduction index and boundary conditions for a wall between two rectangular rooms. Part II: Experimental results. Acta Acust united Ac. 1972;26(1):19-23.
15. Leppington F, Broadbent E, Heron K. Acoustic radiation from rectangular panels with constrained edges. Proceedings of the Royal Society of London A Mathematical and Physical Sciences. 1984;393(1804):67-84.