FIELD MEASUREMENT OF AIRBORNE SOUND INSULATION BETWEEN ROOMS

Jason Obadiah

Abstract: Airborne sound can be a nuisance and a constant expose to the sound can introduced health problems to the people in the area especially areas where quiet environment is a necessity. The objective of this measurement is to demonstrate the field measurement of the airborne sound insulation properties of interior walls. The measurement was done for determining the sound insulation properties of a partition between two rooms. This measurement will also determine the parameters and source of the problems which are contributing to the airborne sound from the adjacent room. The results are that the volume of the room and the construction of the room (pipe construction and ceiling, etc.) have large effects to the sound transmitted between the rooms.

Keywords: airborne sound, insulation, field measurement, construction, interior

Introduction

Regulatory sound insulation requirements for dwellings have existed since the 1950s in some countries and descriptors for evaluation of sound insulation have existed for nearly as long. However, the descriptors have changed considerably over time, from simple arithmetic averaging of frequency bands in the beginning, to a variety of more complex descriptors developed in different countries and later included in EN ISO 717:1996. As a result, this EN ISO standard provides a large variety of descriptors rather than presenting a more limited number of harmonized descriptors.

The objective of this measurement is to demonstrate the field measurement of the airborne sound insulation properties of interior walls. The measurement was done for determining the sound insulation properties of a partition between two rooms. All the parameters/data to access the airborne sound insulation between two rooms such as level different, D, etc and their weighted values such as

Jason Obadiah adalah staf pengajar dan peneliti pada Program Studi Film, Universitas Multimedia Nusantara, Tangerang.

e-mail: jason.obadiah@umn.ac.id

Dw, etc as stated in ISO 140.4: 2006 will be discuss and present in this report. The rooms are situated in the first floor Faculty of Architecture, Design and Planning, University of Sydney namely as the Design Cognition and Artificial Sky lab and Photometric Lab.

Measurement Rooms

The measurement rooms are situated in the first floor of Faculty Architecture Design and Planning, University of Sydney. The source room is a complex shape room and the receiver room is a rectangular in shape. The receiver room is room 140, Design Cognition and Artificial Sky Laboratory which are not much use nowadays as the laboratory purposes. The decision which room to be decide as source and receiver room is based on the AS ISO 140.4-2006, which stated that 'if the rooms are of different volumes, the larger one should be chosen as source room when the standardized level difference is to be evaluated and no contradictory procedure is agreed upon'. In this measurement, the Photometric Laboratory was chosen as the source room.

Figure 1. Receiver room (Room 140-Design Cognition and Artificial Sky Lab)
(Personal Documentation)

Figure 2. Source room (Room 135 - Photometric Lab)
(Personal Documentation)

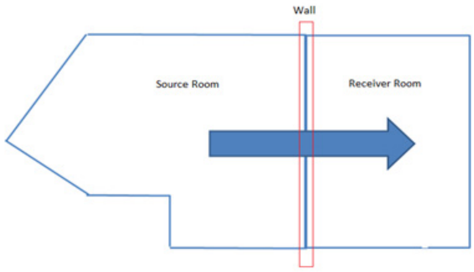

Figure 3. The Measurement Rooms
(Personal Documentation)

Size and Volumes of Measurement Rooms

a. Receiver room

The receiver room has a size as per below:

Length (L) = 6.5 m

Width (W) = 4.8 m

Height (H) = 4 m

Area (A) = 6.5 m x 4.8 m = 31.2 m^2

Volume (V) = 6.5 m x 4.8 m x 4 m = 124.8 m^3

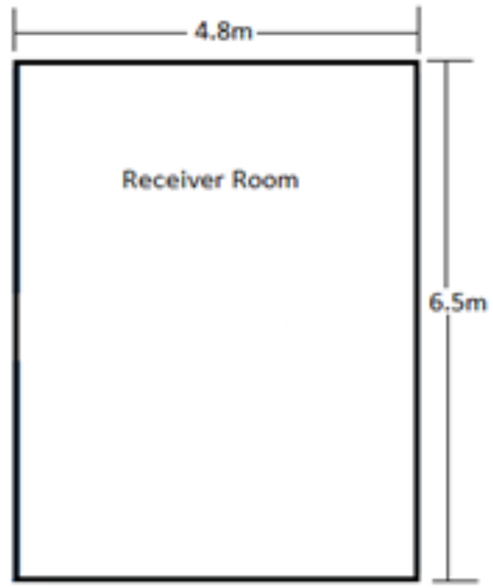

Figure 4. Receiver Room Dimensions
(Personal Documentation)

b. Source room

The source room has a size as per below:

Height (H) = 4 m

Area (A) = 25.35 m2 + 9.96 m2 + 3.15 m2 + 3.72 m2 = 42.18 m^2

Volume (V) = 42.18 m2 x 4 m = 168.76 m^3

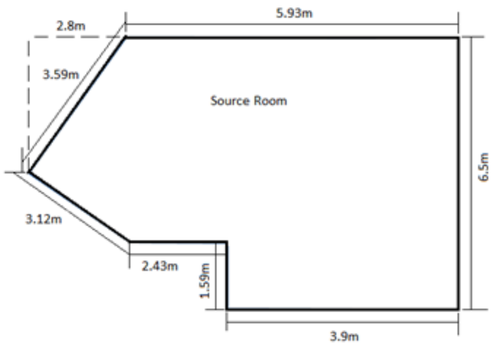

Figure 5. Source Room Dimensions
(Personal Documentation)

c. Partition

The partition has a size as per below:

Length (L) = 6.5 m

Height (H) = 4 m

Area (A) = 6.5 m x 4 m = 26 m^2

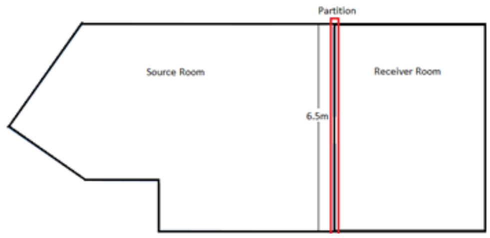

Figure 6. Partition Dimensions
(Personal Documentation)

Test Standards

Test standards applicable for the measurement and determination of reverberation times, sound insulation and background noise are as follows:

a. AS ISO 140.4: 2006 Acoustics-Measurement of sound insulation in buildings and of building elements, Part 4: Field measurements of airborne sound insulation between rooms.

b. AS/NZS ISO 717.1: 2004 Acoustics- Rating of sound insulation in buildings and of building elements, Part 1: Airborne sound insulation.

c. AS/NZS 2460: 2002 Acoustics-Measurement of the reverberation time in rooms

Definition from ISO 140-3

The definitions given below abstracted from ISO 140-3 apply.

a. average sound pressure level in a room, L

b. level difference, D

c. normalized level difference, Dn

d. standardized level difference, DnT

e. apparent sound reduction index, R'

f. Spectrum adaption terms, C and Ctr

Types of Measurement

Insulation is the principal method of controlling both airborne sound and impact sound in buildings. The overall sound insulation of a structure depends upon its performance in reducing the airborne and impact sound transferred by all sound paths, direct and indirect. The airborne sound insulation is the insulation against noise originating in air, e.g. voices, music, motor traffic, wind. In airborne sound insulation measurement, there are three types of measurement need to be done as per AS ISO 140.4: 2006. The three measurements are:

a. Sound pressure level

b. Background noise level

c. Reverberation time

The receiving and the source room have different type of measurement need to be done.

Figure 7 below depicts the types of measurement for receiving and source room.

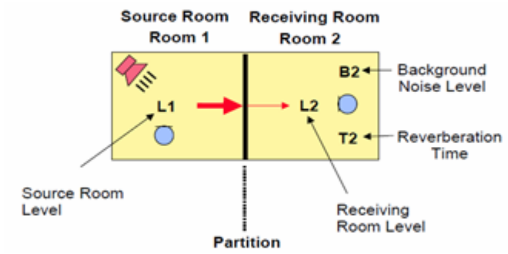

Figure 7. Types of Measurement for Receiving and Source Room in Airborne Sound Insulation (Personal Documentation)

Test Instrumentation

The following test instrumentation was used in the measurement:

a. Sound Source

Brüel & Kjær 4292 OmniPower Sound Source

The speaker has a cluster of 12 speakers in a dodecahedral configuration that radiates sound evenly with a spherical distribution. This type of speaker was used in the source room to generate the noise from the power amplifier.

b. Sound Level Meter

Brüel & Kjær Type 2250 Sound Level Meter

The sound level meter was used to measure the background noise level, sound pressure level and reverberation time. This sound level meter is capable of calculating in one-third-octave and octave bands.

c. Power Amplifier

Brüel & Kjær Type 225

The power amplifier was used to generate the noise during the measurement.

d. Computer Analyzer

Dell Laptop with Audobe Audition and Aurora plug-in

The computer analyzer was used with the Adobe Audition equipped with Aurora plug-in to generate the noise to the power amplifier hence to the speaker.

Test Procedure

a. General

1. Frequency range of measurement

The field measurement of airborne sound insulation was measured in one-third-octave band having the following center frequencies, in hertz:

Table 1. One-third Octave Bands

100	125	160	200	250	315
400	500	630	800	1000	1250
1600	2000	2500	3150	4000	5000

In order to obtain additional information, the frequency range of the measurement was enlarged with 4000 Hz and 5000 Hz one-third-octave band centre frequencies. These frequencies were used to measure the background noise level, sound pressure level and reverberation time measurement.

2. Generation of sound field

A dodecahedron loudspeaker was used in the measurement which having more than one loudspeaker operating simultaneously in phase which having a radiation that is uniform and omnidirectional. For the sound pressure level measurement, the sound was generated in the source room and the sound power must be sufficiently high for the sound pressure level in the receiving room to be at least 10 dB higher than the background noise level in any frequency band. The loudspeaker was positioned in the corners of the source room.

Background Noise Measurement

The background noise of the receiver room was measured over a five minutes period in one-third-octave band center frequencies. The background noise was measured using the sound level meter to get the Leq values. Table 3 in Appendix Results tabulates the results of the background noise measurement in the receiver room.

Reverberation Time Measurement

Reverberation Time (RT) is crucial for describing the acoustic quality of a room or space. It is the most important parameter for describing sound levels, speech intelligibility and the perception of music and is used to correct or normalize building acoustics and sound power measurements. RT is the time for a 60 dB drop in the sound level after the excitation stops. This decay is usually measured over the first 10, 20 or 30 dB and then extrapolated to the full 60 dB range. The measurement of the reverberation time in the receiver room was based on AS/NZS 2460:2002 Acoustics – Measurement of the reverberation time in rooms. The test sound source was the white noise to generate the noise as omnidirectional as possible.

The measurement spacing for the microphone (here we were using sound level meter) where the minimum distance was calculated by using the formula dmin = 0.3V1/3. Interrupted noise method was used in this measurement which using a power amplifier and loudspeaker sound source where the sound level meter with reverberation time software turned it's noise generator on and off, and then measured and displayed the RT spectrum and decays.

The measurement was conducted in one-third-octave frequency range. At first the measurement was conducted using the microphone and the Aurora plug-ins software instead of using the sound level meter, but since the Aurora plug-ins did not have measurement value in one-third-octave frequency range, the measurement was conducted using the sound level meter. Measurements for the assessment of the amount of room absorption for noise control purposes, including field measurement of sound reduction index, or assessment of the reverberation time for sound system calculations are generally made at a relatively small number of positions. Apart from that, since the reverberation time varies between positions in a room, so it is usually measured at several positions. In this measurement, we measured the reverberation time at four different positions. The average for all positions gives an overall assessment, since reverberation time is conceived of as characteristics of a room. Table 2 in Appendix Results tabulates the results of the average reverberation time measurement (T30) in the receiver room.

Sound Pressure Level Measurement

The sound level pressure measurement was done at both source and the receiver room. The measurement was conducted using the sound level meter instead of the microphone. In this sub topic report, the microphone will be referred to the sound level meter.

a. Microphone position

The following are minimum separating distances:

1. 0.7 m between microphone positions;
2. 0.5 m between any microphone position any microphone position and the sound source;
3. 1.0 m between any microphone position and the sound source.

b. Fixed microphone position

A minimum of five fixed microphone positions shall been used to evenly distributed within the space permitted for measurement in the room. However, six different positions have been used during the measurement.

c. Sound source position

The sound source location was located in the corner of the source room and the distance between the room boundaries and the source centre should not be less than 0.5 m.

d. Using a multiple sound source operating simultaneously

As stated in 8.12, the type of the sound source used in this measurement is a dodecahedron loudspeaker which using a multiple sound source operating simultaneously. The minimum number of measurements using fixed microphone position is five.

However, in this measurement, six fixed microphone position was used.

e. Averaging time

At each individual microphone position, the averaging time shall be at least 6 s at each frequency band. In thus measurement, the average averaging time was used is at 10 s.

Figure 8 and 9 below shows the measurement setup of the source and microphone position at both source and receiver room.

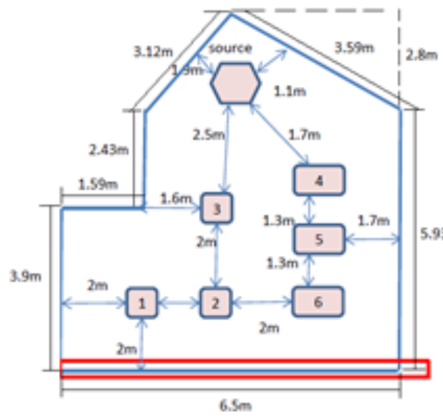

Figure 8. The Position of Microphone and The Loudspeaker in The Source Room
(Personal Documentation)

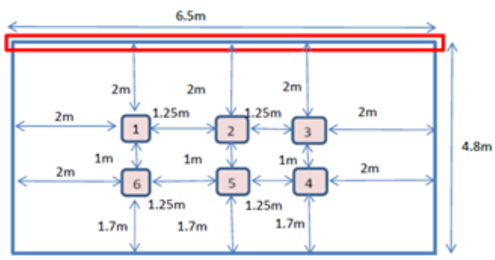

Figure 9. The Position of The Microphone in The Receiver Room
(Personal Documentation)

f. Measurement

Sound pressure level measurements were undertaken in accordance to ISO 140-4:2006. The tests involved generation of a diffused sound field in a source room to the receiver test room. A dodecahedron loudspeaker was used in the measurement which having more than one loudspeaker operating simultaneously in phase which having a radiation that is uniform and omnidirectional. Broadband noise (white noise) was used in the measurement that was generated from the source room. The sound power of the broadband noise must be sufficiently high for the sound pressure level in the receiving room to be at least 10 dB higher than the background noise level in any frequency band. Sound pressure levels were then measured in the source room, and the resulting transmitted sound perceived in the receiver room measured accordingly. Measurements were undertaken in one-third-octave frequencies. Table 1 and 4 in Appendix Results tabulates the results of the average sound pressure level at the receiver room and the source room respectively measured at six different microphone positions. The average sound pressure level can be obtained by using the formula in equation (1) of the ISO 140-4:2006.

Results

All the parameters as stated in ISO 140-4:2006 were used to tabulate the results for this measurement. The results are in one-third-octave band frequencies from 100 Hz to 3150 Hz. The level difference, D, the normalized level difference, Dn, the standardized level difference, DnT, and apparent sound reduction index, R' is tabulated in Appendix Results in this report. D can be obtained from equation (2) while Dn can be obtained from equation (3). DnT can be obtained from equation (4) while equation (6) was used to calculate the R'. Table 5, 6, 7 and 8 tabulates the results for D, Dn, DnT and R' respectively.

The above values can be converted to a single number rating of weighted level difference, Dw, weighted normalized level difference Dnw, weighted standardized level difference, DnTw and weighted apparent sound reduction index, R'w. This weighting is done by shifting a standard curve up in unit steps until the sum of unfavourable deviations is as large as possible but not more than 32 dB. The single number rating is then read from the 500 Hz value of the curve. An unfavourable deviation at a particular frequency occurs when the results of measurement are less than the reference value. Only the unfavourable deviations were taken into account. The weighted values were determined in one-third-octave band frequencies.

Furthermore, two spectrum adaption terms were calculated based on two typical spectra within the frequency range of one-third-octave band. The two spectrum adaption terms were not been included as one-single number quantity but have been included as separate numbers. The set of reference values used for comparison with measurement results and the set of sound spectra to calculate the spectrum adaption terms for airborne sound in one-third-octave bands are as per below:

Table 2. Reverence Values and Measurement Results

Frequency, Hz	Reference values, dB	Spectrum No.1 to calculate C	Spectrum No.2 to calculate C_{tr}
100	33	-29	-20
125	36	-26	-20
160	39	-23	-18
200	42	-21	-16
250	45	-19	-15
315	48	-17	-14
400	51	-15	-13
500	52	-13	-12
630	53	-12	-11
800	54	-11	-9
1000	55	-10	-8
1250	56	-9	-9
1600	56	-9	-10
2000	56	-9	-11
2500	56	-9	-13
3150	56	-9	-15

Table 9, 10, 11 and 12 of Appendix Results tabulates the results of single number quantity for airborne sound insulation (R'w, Dw, DnW and DnTw respectively) of the reference curve at 500 Hz after shifting it accordance with the method specified in ISO 717.1:2004. The spectrum adaptation term values were also added to the single number rating to take account of the characteristics of particular sound spectra. The spectrum adaptation terms C can be obtained from equation (7) while the spectrum adaptation terms Ctr can be obtained from equation (8). These values were at frequency range from 100 Hz to 3150 Hz although the measurement was done from 100 Hz to 5000 Hz.

Discussion

The Rw of building elements concern only the sound which only transferred through particular elements such as doors, windows, etc. The flanking noise which is transferred through adjacent areas; e.g. the side walls, floors, ceilings, etc are not taken into consideration. The inverted commas indicate that this value also takes account of the flanking noise through the joints, interfaces, etc. The R'w is the field measurement value that is called the apparent sound reduction index. Flanking that is the sound that may be transmitted via many paths, not just via a common partition. From figure 10, it is clear that there was an air conditioning ducting that penetrates the partition under measurement from the receiver room to the source room. This is the major flanking contribution. Although we did calculate and evaluate the R'w in this report, this means that R'w might not be useful because of the flanking from the ducting system. Level difference is still meaningful, and perhaps more so than the apparent sound reduction index in field measurement. In Building Code of Australia (BCA), the minimum rating for partition/interface is Dnt,w + Ctr 45 dB. It shows that Dnt,w is more important than the R'w in BCA for field measurement.

During the measurement, the volume of the amplifier was set to maximum in order to get the sound power sufficiently high so that at the receiver room, the sound pressure level in the receiving room to be at least 10 dB higher than the background noise level in any frequency band. From the measurement, at all frequency bands, the sound pressure level was having more than 10 dB higher than the background noise. It probably because the partition is not having a 'proper insulation' indeed there was a source of flanking noise from the ducting system.

Figure 10. Air Conditioning Ducting Inside The Receiver Room
(Personal Documentation)

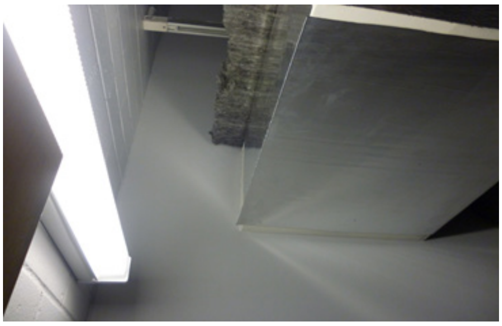

Figure 11. Air Conditioning Ducting Penetrate The Partition from The Receiver Room to The Source Room
(Personal Documentation)

Conclusions

In field measurement of sound insulation, it introduces some complications. One problem is whether a diffuse field truly exists in the source and receiving rooms. When applied to residential rooms, the room volumes are often too small to satisfy diffuse field requirements. Furnished domestics rooms usually have short reverberation times and are far from diffuse.

Another problem is background noise. The receiving room may subject may be subject to environment noise, which could influence the measurement. The noise floor should be more than 10 dB below the received sound level.

In this measurement, we did experience some of the noise that occurs during the measurement such as air conditioning hum, etc.

Flanking that is the sound transmitted via many paths, not just via a common partition also one of the problems in field measurement. This means that apparent sound reduction index might not be measurable. This problem did occur in our measurement and although we did calculate the apparent sound reduction index, the value might not be useful.

Another problem is regarding the receiving room volume. Sometimes the volume might not be easy to define, meaning that the normalized level difference might not be measurable. In most situations, the reverberation time is measurable, and so the standardized level difference can be used. Since the receiving room is rectangle in shape, we did not have a problem to determine the size and volume of the room.

Acknowledgement

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