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In-situ Measurement of Airborne Sound Insulation at Music Studio

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Abstract

Studio is a specifically room designed for playing music either vocal, instruments or both. One consideration factor in studio is the ability of vertical boundaries to insulate incoming airborne noise from or to outside the object. Boundaries performance is rated with single number represented by Weighted Standardized Level Difference (DnTw). Since noise characteristic may be different in all frequency, it needs some correction at low frequency hence the rating has to adjusted to $D_nT_w + C_{tr}$. Recommendation value for studio music is larger than 50 dB. The volume of research research is around 49 m3 with cubical shape. Based on in-situ evaluation, each insulation rating for each boundary are not larger than 50 dB hence it needs to be redesigned. The solution is taken from mathematical simulation by changing composition of materials, dimension of air gap and thickness of material.

INTRODUCTION

Music studio is a closed-space area that dedicated for musical activities. It may be playing instruments or singing, recording or editing. In acoustic, music studio is categorized as room for music. This room has to be carefully designed in order to accommodate the requirements for musical activities. One consideration factor is the ability of vertical boundaries to insulate the airborne noise into room. As the total energy of incoming noise is quite large, it might be a problem to activities since it causes background noise that may causes sound masking [1].

Acoustic performance of sound insulation may be expressed in transmission loss (R). It illustrates amount of energy loss during transmission through partition between two adjacent rooms. The existence of partition has significant effect to reduce airborne noise from one room to another [2]. The variation of density, composition, thickness, position of materials and partition type has affected the insulation performance [3-4].

TL can be predicted by several methods such as laboratory testing, field measurement or in-situ [5] or using impedance tube [6]. In this research, field measurement is taken field measurement as method to calculate transmission loss (R). This method has some disadvantages and advantages compared to laboratory testing. During measurement, flanking noise from another partition is hard to eliminate [7] and its propagation path is hard to predict [8] but the actual condition of partition structures may be discovered since it has direct impact to insulation performance. Afterward, performance of sound insulation is rated by single number named Weighted Standardized Level Difference (D_nT_w). However, there is correction to improve insulation performance hsence the rating becomes D_nT_w+C_{tr}. The rating value itself is proportional to ability of partition to insulate sound. By comparing D_nT_w+C_{tr} to recommendation value, the insulation quality of wall partitions is examined. Moreover, calculation of rating insulation is also performed by changing partition configuration such as material and thickness in order to improve insulation performance.

OBJECT STUDY

Object study is music studio that located at 2nd floor of building. The studio has dimension 4x3.5x3.5 m with total volume is about 49 m^3. Floor plan of this study is illustrated at Figure 1. Dimension of each vertical partition is shown at Table 1.

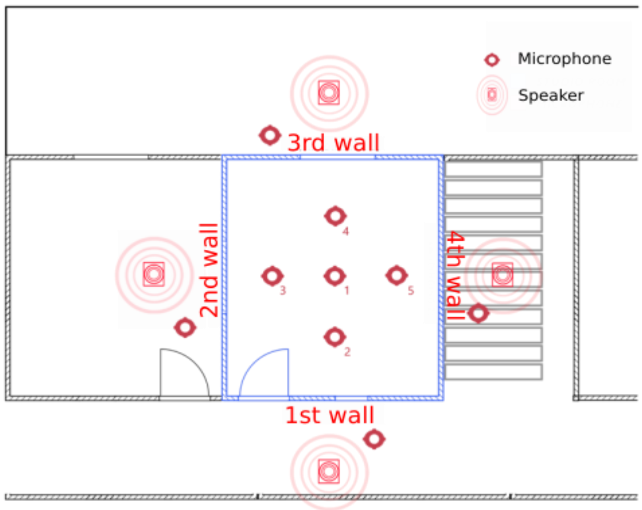


Figure 1. Microphone and speaker position for measurement

Table 1. Partitions dimension

Wall	Area (m^2)	Thickness (cm)
1st	12.25	7
2nd	14	17
3rd	12.25	20
4th	14	10

RESEARCH METHODOLOGY

In this study, partition performance was carried out by field measurement. The procedure to calculate D_nT was comply with

ISO 140-4 Field Measurement of Airborne Sound Insulation. For in-situ measurement, R is defined as Standardized Level Difference (D_nT) expressed in dB. The equation to calculate D_nT for each wall is as follow:

$$D_nT = L_{p_1} - L_{p_2} + 10\ log \frac{RT}{RT_{ref}} \quad (1)$$

where Lp1 and Lp2 is sound pressure level at source room and receiver room (dB), RT is reverberation time at receiver room (s) and RT_{ref} is set to 0.5 s since it is reverberation time reference.

In this research, all parameters were measured using 1/3-octave filter with no weighting network. MLS signal was emitted from dodecahedron sound source from software through amplifier. There were about 4 different position of sound source with each position was used to calculate insulation performance of facing-walls with flanking noise from another wall was uncontrolled. Distance between sound to the nearest wall was 5 m at minimum. If it was not applicable, gap less than 5 m was allowable too. Decaying sound was captured by microphone as impulse response in certain positions by sensors. Illustration of microphone position is shown at Figure 1. Since volume of the object is less than 100 m^3, there were about 5 different positions of sensors (number 1 to 5) located inside the object. Distance between nearest measurement points was set 1 m and 0.5 m for distance from measurement point to the nearest wall [9 iso]. This was configuration to measure sound pressure level for receiver room or or Lp_2. Average value of sound pressure level for receiver room was calculated using following equation

$$L_{p_2} = 20log \frac{1}{N} \sum_{j=1}^{N} 10^{(L_j 20)} \quad (2)$$

with L_j is sound pressure level (dB) at position j and N is total number of position. Position number 1 was used to measure reverberation time. Microphone located at outside object measured the sound pressure level at source room or Lp_1. Moreover, height of microphone was adjusted so it was equal with human ear while standing.

Before carried out measurement of previous parameters, background noise was measured first. The purpose was to adjust source signal hence it has higher energy rather than background noise about 10 dB at minimum.

Calculation of D_nT were performed after measurement of all required parameters were carried out. Next, D_nT vs frequency was plot in order to predict single number (D_nT_w) that rated the performance of material insulation. Compensation were given to sound source at low frequency hence the rating became D_nT_w+C_{tr}. Every room has specific requirement of insulation performance regarding to activities inside the room. For music studio, rating of recommended D_nT_w +C_{tr} is around 50 dB.

D_nT_w+C_{tr} of each walls were compared with recommendation rating. If it was smaller than 50 dB, it needed to be improved by changing configuration of insulation. Prediction of insulation performance was simulated using two condition: single panel and double panels. Equation to calculate transmission loss (R) for single panel is

$$f > f_c : R = 20log(mf) + 10\log\left[2\eta_{tot}\frac{f}{f_c}\right] - 47 \quad (3)$$

$$f_c = \frac{\sqrt{3}c_0^2}{\pi h}\sqrt{\frac{\rho}{Y}} \quad (4)$$

with f_c and f is frequency critical and frequency in Hz; c_0 is sound velocity (343 m/s), A is cross section area of material (m^2); η_{tot} is total loss factor (N/m^2); ρ is density (kg/m^3); Y is modulus young (N/m^2) and h is panel thickness (m).

If insulation type is double panels with air gap is sandwiched between two materials, R value is calculated by following equation

$$R = \begin{cases} R_{M_1+M_2} & f < f_0 \\ R_1 + R_2 + 20log(f.d) - 29 & f_0 < f < f_d \\ R_1 + R_2 + 6 & f > f_d \end{cases} \quad (5)$$

$$f_0 = 60\sqrt{\frac{m_1+m_2}{m_1 m_2 d}} \quad (6)$$

$$f_d = \frac{55}{d} \quad (7)$$

where f, f_0 and f_d is frequency, resonance frequency of air gap, resonance structure of panel (Hz). d is for distance between panel (m); m_1 and m_2 is ratio between mass and area panel (kg/m^2), R_1 and R_2 is transmission loss for each panel (dB) and R_{m1}+R_{m2} indicates that R has to be calculated from both mass panels. R and D_nT is a symbol to express transmission loss for laboratory and field measurement.

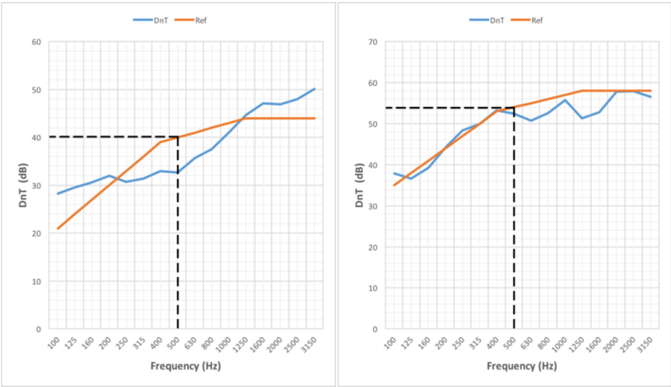
In this step, insulation performance is simulated by changing configuration of insulation (single and double panels) and combination of both materials and geometry of insulation. Partition geometry is set therefore the thickness is equal or lesser than actual condition.

RESULT AND DISCUSSION

Measurement result for average background noise and reverberation time is 53.21 dB and 1.15 s in all frequency. By using reverberation time value from measurement, DnT is calculated on using equation (1). The result of D_nT is plotted as shown at Figure 2 and Figure 3. Afterward, D_nT_w is obtained by adjusting reference curve with condition as follow gap between reference curve and D_nT curve in all frequency is not large than 32 dB. Allowable maximum different in single frequency is 8 dB. D_nT_w rating is shown at Figure 2 & Figure 3 too.

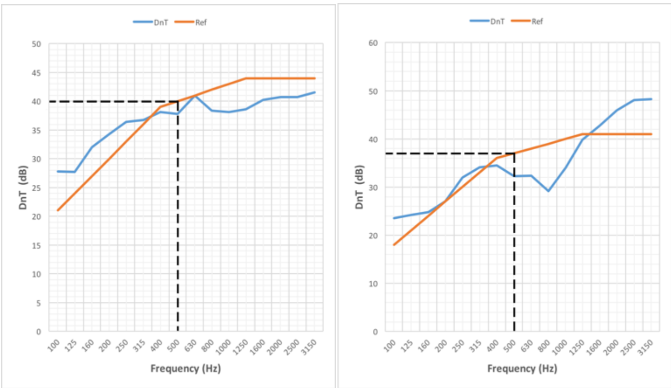
Since it might be external noise, D_nT_w needs to be corrected by adding compensation at low frequency. Therefore, insulation performance becomes D_nT_w+C_{tr}. Calculation result of D_nT_w+C_{tr} is shown at Table 2. According to it, D_nT_w+C_{tr} of each wall does not have sufficient quality to be used as partitions for music studio. It requires to be enhanced by modifying material or else.

In this stage, partition properties are modified in order to get insulation with prediction of D_nT_w+C_{tr} is larger than 50 dB. Properties to be modified involves material density, material thickness and air gap. Table 3 shows the property of material for simulation. Partition with and without air gap is named as double and single panel. Total thickness of partitions is not larger than maximum dimension of actual wall. There are 12 different conditions of partition to be predicted insulation performance.



(a) (b)

Figure 2. DnTw for a) 1st wall and b) 2nd wall



(c) (d)

Figure 3. DnTw for c)3rd wall and d) 4th wall

Table 2. DnTw for all partitions

Wall	DnTw (dB)
1st	36
2nd	49
3rd	38
4th	33

Material	Density (kg/m^3)	Modulus Young (N/m^2)	Total *Loss Factor*
Gypsum Board	740	2,013 x 10^9	0.01
Cement Board	1250	6,9 x 10^9	0.01
Concrete	2300	26 x 10^9	3,92

By applying equation (3-7) then compensate it with C_{tr}, $D_nT_w+C_{tr}$ is obtained. Insulation performance of each modified partitions is shown at Table 3. Most of combination properties do not have sufficient quality to insulate airborne noise at music studio even though the thickness of both panel is already set to maximum thickness. Only three combination have $D_nT_w+C_{tr}$ value larger than 50 dB. It occurs for double panel partition with combination material of high and low density material: cement board, gypsum and concrete. Also, addition of air gap between panels have positive effect for sound insulation application. The air gap between those can not be reduced since $D_nT_w+C_{tr}$ might be drop.

Table 3. Prediction of $D_nT_w+C_{tr}$ for modified partitions

Material		Thickness (cm)		Air gap (cm)	DnTw+Ctr (dB)
1	2	1	2		
Concrete	-	7	-	-	29
Gypsum board	Gypsum board	1	1	5	29
Gypsum board	Gypsum board	4	6	10	35
Cement board	Cement board	1	1	5	38
Concrete	-	10	-	-	39
Cement board	Cement board	2	6	9	43
Gypsum board	Gypsum board	2	5	10	43
Cement board	Cement board	1.25	1.5	7.25	45
Cement board	Cement board	4	6	10	48
Cement board	Concrete	1.5	4	10	51
Gypsum board	Cement board	4	6	10	52
Cement board	Concrete	3	4	10	53

CONCLUSSION

Evaluation of sound insulation has been performed by in-situ measurement. Every boundaries of object study do not have sufficient quality to insulate airborne noise since $D_nT_w+C_{tr}$ value for each wall is 36 dB, 49 dB, 38 dB and 33 dB since recommendation value is larger than 50 dB.

Improvement of insulation performance has been carried out by simulation. There are several combination of modified partition properties to be predicted airborne insulation performance. Only 3 combinations have qualified the recommendation value. Therefore, boundaries of music studio might be chosen from one of those combination since it has $D_nT_w+C_{tr}$ value larger than 50 dB.

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