Insulation Performance of Classrooms in Green Building

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Abstract. Physical boundary of object was designed specially to accommodate one requirement for green building. In general, composition of walls are two-panels gypsum combine with half and full-stickered glass of windows and louvered windows were placed in order to optimize daylighting usage and maintain air circulation. According to layout, object position is surrounded by 5 other classrooms. Whenever two or more class were active in the same time, airborne noise were potentially propagate from one classroom to another and vice versa hence it might creates excessive background noise inside it. The purpose of this research is to evaluate insulation performance of vertical structure by in-situ measurement.

1. Introduction

Education may be one of the most significant aspect to change the quality of live and most people are willing to spend around 12-16 years of their youngster time to get it. But good quality of education itself is not easily obtained, the successful rate of education is very dependent to four major factors such as teacher effectiveness, behavior management, time and instructional management or classroom environment [1] and also physical environment [2].

Acoustic as physical component is very important since excessive background noise and high reverberation time could be deterrent for both education achievement and education performance [3] and it has direct impact to verbal task [3], [6]. Background noise itself is might be originated from airborne noise and or structure-borne noise that enter into classroom from certain direction hence arriving energy is dependent to effectiveness of sound insulation from each boundary segment.

Determination of single number that represent quality of insulation can be carried out either by laboratory testing or field testing. The last stated method has been successfully implemented to determine insulation performance of boundary [5] and flanking noise can be identified too [6], good design of acoustic condition is frequently neglected by architect because they put more focused on another components of indoor air quality [7].

There are possibility acoustic factors did not consider as one of objective since philosophy design of object was to meet one concept of green building which is focus on energy consumption. Classrooms borders were designed to have large opening space in order to optimize daylight usage and attached several natural ventilation and fans to maintain indoor air quality. Though, in the 3rd floor has 6 nearly identic classrooms with composition two rows of rooms structure, each row consists of 3 classrooms. The width of corridor between classrooms was around 2 m. Whenever two or more classes were having teaching session in the same time, there were possibilities of
airborne noise to propagate into classes. The purpose of this research is to determine single number (DnTw) that represent the effectiveness of each segment to insulate airborne noise that propagate from outside to inside objects by in-situ measurement. Procedure of measurement comply with EN ISO 16283-1 Acoustics - Field measurement of sound insulation in buildings and of building elements - Part 1: Airborne sound insulation.

1.1. Description of Object
The location of object was in 4th floor of the building. It consisted of 6 classrooms and two unbounded spaces dedicated for student’s waiting room. Space layout of the floor is illustrated at Figure 1. The physical boundary facing East (E), South (S) and West (W) of classroom with number 402 has been selected as an object for this research. Classroom itself has dimension 7.23 x 7.175 x 3.53 m with E and W-facing wall was made of identic material: double panel gypsum while S-facing boundary composed of peculiar materials and specifically designed for airflow circulation. Top section of it were hollow louvered-window while the middle section were made of full-stickered glass window, double panel gypsum and metal-frame full-stickered glass door.

![Figure 1. Building layout](image)

2. Measurement Procedure
Determination of airborne insulation performance follows the procedure as stated in ISO 16283-1:2014. Principally, it requires two rooms, one is dedicated for source room where the loudspeaker was placed and the other has chosen as receiving room. Calculation required physical information obtained from measurement such as background noise, sound pressure level and reverberation time in receiving room.

In this research, measurement equipments were one omnidirectional loudspeaker and fixed microphone moved manually from one position to another. During measurement, loudspeaker was placed only in one position: in the center of source room or it has distance at least 1.0 m from common partition. Speaker was fed by broadband noise signal. Emitted signal was measured in both room, one for sound properties in source room while the other to extract information from transmitted signal through adjacent and flanking element. Acoustical information was captured by microphone in 7 different positions inside receiver room and no positions lied in the same
plane relative to the boundaries at each room. Measurement configuration for each partition is illustrated at Figure 2. Mutual area between source room and receiver room was defined as object evaluation.

![Measurement Configuration](image)

**Figure 2.** Measurement Configuration

Calculation was performed in 1/3 octave from 100 Hz to 3150 Hz. The difference of sound pressure level between source and receiving room is expressed in level difference which stated as follows

\[ D = L_s - L_r \]  

(1)

with \( D \) is a level difference from energy-average from source room \( (L_s) \) and receiving room \( (L_r) \). Below is the equation to calculate average of level energy from measurement points

\[ L_{ave} = 10 \log \left( \frac{1}{n} \sum_{i=1}^{n} 10^{\frac{L_i}{10}} \right) \]  

(2)

where \( L_{ave} \) is average of sound energy in dB and \( L_i \) is pressure level in measurement number \( i \) in dB.

Since classroom is closed space then reverberation occured and level difference required to be standardized into

\[ D_{nT} = D + 10 \log \frac{T}{T_0} \]  

(3)

where \( D_{nT} \) is standardized level difference (dB), \( T \) is reverberation time in receiving room (s) and \( T_0 \) is reference reverberation time, 0.5 s. Intersection value between \( D_{nT} \) at 500 Hz and shifted reference curve was value of \( D_{nT_w} \).
3. Result and Discussion

Measured sound pressure level were tabulated at Table 1, 2 and 3 at source room and receiver room. The difference between those parameters described ability of partition to transmit sound energy. Since measured energy have similar magnitude at both room, it demonstrated almost all energy were transmitted from source room to receiver room.

| Table 1. Sound Level at W facing wall |
|---------------------------------------|
| f (Hz) | 100 | 125 | 160 | 200 | 250 | 315 | 400 | 500 |
| \( L_s \) (dB) | 45 | 51 | 59 | 64 | 65 | 64 | 62 | 62 |
| \( L_r \) (dB) | 57 | 57 | 60 | 61 | 62 | 62 | 60 | 58 |
| f (Hz) | 630 | 800 | 1000 | 1250 | 1600 | 2000 | 2500 | 3150 |
| \( L_s \) (dB) | 61 | 61 | 63 | 63 | 63 | 62 | 64 | 62 |
| \( L_r \) (dB) | 58 | 56 | 56 | 55 | 55 | 52 | 53 | 51 |

| Table 2. Sound Level at E facing wall |
|---------------------------------------|
| f (Hz) | 100 | 125 | 160 | 200 | 250 | 315 | 400 | 500 |
| \( L_s \) (dB) | 49 | 55 | 64 | 69 | 69 | 68 | 67 | 65 |
| \( L_r \) (dB) | 58 | 57 | 62 | 65 | 65 | 75 | 63 | 61 |
| f (Hz) | 630 | 800 | 1000 | 1250 | 1600 | 2000 | 2500 | 3150 |
| \( L_s \) (dB) | 65 | 64 | 66 | 66 | 66 | 65 | 68 | 66 |
| \( L_r \) (dB) | 59 | 57 | 57 | 57 | 57 | 55 | 56 | 53 |

| Table 3. Sound Level at S facing wall |
|---------------------------------------|
| f (Hz) | 100 | 125 | 160 | 200 | 250 | 315 | 400 | 500 |
| \( L_s \) (dB) | 55 | 57 | 64 | 70 | 69 | 69 | 68 | 66 |
| \( L_r \) (dB) | 49 | 52 | 57 | 66 | 65 | 64 | 63 | 61 |
| f (Hz) | 630 | 800 | 1000 | 1250 | 1600 | 2000 | 2500 | 3150 |
| \( L_s \) (dB) | 66 | 68 | 69 | 69 | 68 | 68 | 67 | 67 |
| \( L_r \) (dB) | 62 | 62 | 61 | 62 | 62 | 63 | 63 | 62 |

Evaluation of transmission performance for field measurement was ranked by single number named \( D_nT_w \). It was determined at 500 Hz of \( D_nT \) by shifted up or down the reference curve until total error from \( D_nT \) at 1/3 octave did not exceed 32 dB. Performance ranked of these partitions required reference curve to be shifted down more than 37 dB. Value of \( D_nT_w \) for each section of wall was plotted at Figure 3, 4 and 5 with adaptation to A-weighted pink noise.
Based on calculation, $D_n T_w + C$ for W, E and S facing wall were 13.7 + 0 dB, 11.8 -0.01 dB and 10-0.01 dB, respectively.

![Figure 3. $D_n T_w$ of West facing wall.](image3)

![Figure 4. $D_n T_w$ of East facing wall.](image4)

![Figure 5. $D_n T_w$ of South facing wall.](image5)

4. Conclusion
The physical boundary’s insulation performance of classroom in green building has been analyzed. The main feature of green building, especially natural air circulation, seems have significant impact to acoustic insulation performance. Since one segment of partition have hollow part, it provides no insulation effect whenever sound wave propagates through it. Consequently, either flanking noise or direct noise can easily be heard in classroom. In conclusion, these partitions do not have sufficient acoustical performance to insulate airborne noise for classroom application.

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