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THE ACOUSTIC QUALITY OF SEKOLAH ALAM CLASSROOM (CASE: SEKOLAH ALAM IN BANDUNG)

Widyarko [1*], Alya Rizkina [2], Dalhar Susanto [3]
[1] Department of Architecture, Faculty of Engineering, Universitas Indonesia
[2] Student, Department of Architecture, Faculty of Engineering, Universitas Indonesia
[3] Department of Architecture, Faculty of Engineering, Universitas Indonesia, Indonesia
* e-mail: first widyarko.ui@gmail.com

ABSTRACT

Sekolah Alam (The Nature School) is a new concept of school in Indonesia that divide its learning process, both indoor and outdoor. As it needs more outdoor space for learning activity, this type of school has larger yards yet smaller classroom compared to conventional school. As it is still new, no previous study has been done to understand the relation between space dimensions, building material, and surroundings to this school classroom acoustic quality. Therefore, this journal studied acoustic quality by calculating Reverberation Time (RT60) and measuring Background noise value of one typical class of Sekolah Alam in Bandung. Reverberation Time (RT60) was calculated using space dimensions and materials that exist within the studied classroom, while the background noise value was measured using Data Logging Sound Level Meter (SLM). The results indicate that the studied class has an ideal acoustic quality for learning activity. The main factors that affected these results are the classroom has a small size in volume and surrounded by lush trees which work as noise controls.

Keywords: Reverberation Time; Background Noise; Sekolah Alam; Nature School; Classroom; Elementary School

INTRODUCTION

School is an institution established for learning and teaching, to acquire and deliver a lesson. Indirectly, school is expected to support learning process to increase intelligence and to give useful knowledge for children (KBBI, 2019). However, as the city develops, a 'trapped' building in the middle of crowded city negatively affect the students, especially concerning the acoustical comfort. A lot of schools located near the roadway; vehicle noises leads to be the source of noise pollution in school buildings (David Canning, 2015). Based on these typical cases, numerous new schools appear on the edge of the city, some of these schools carry a new concept, the Nature School.

Sekolah Alam (Nature School) first established by Lendo Novo in 1998. In 2019, there are 120 schools registered from Aceh to Papua, which adopting this Nature School concept (School of Universe, 2019), Nature School is different than Conventional School. Based on Indonesia's regulation, the studying activities, theoretically as well as practically, are entirely held in the classrooms or laboratories (Republik Indonesia, 2007). The Nature School uses different methods. This school persuades their students to interact with their surrounding nature directly and utilize nature as the everyday learning media. The learning process is no longer limited to indoor activities only, but the students can also apply their knowledge

directly to their surrounding nature (Kompas, 2009). Although this school has uses an outdoor environment as its primary learning space, indoor classroom still needed in this school. Therefore, like other conventional schools, classes in Nature School still need to have a good quality of acoustic to enhance a conducive learning process.

Acoustic is the science of sound and deals with the origin of sound and its propagation, either in free space, or in pipes and channels, or closed spaces (Kuttruff, 2004). The phenomenon of sound itself occurs when there is a mechanical wave which transmits through gasses, fluids, and solids (Long, 2006). Sounds are sourced by vibrating elastic media, which carries the vibration through the air so that the vibrations could be heard by human's ear (Long, 2006). To prevent the sound from becoming unwanted noise, rooms with specific functions such as classrooms need an excellent acoustic quality.

Both Reverberation Time (RT) and Background noise are some of the crucial aspects that can affect acoustic quality of a classroom thus also affecting student comfort during learning process (Maria Klatte, 2010). With an excellent acoustical quality, background noise can be reduced to prevent disturbance in a learning process. Better acoustic quality also means short reverberation time thus will make the sound distributed by the teacher more clearly for the students. The Nature School is a new concept of education in Indonesia; therefore, its classroom acoustic quality has not been studied before. This study intends to understand the impact of material and design to the room reverberation time and background noise in one of the Nature School classroom located in Bandung City.

METHODS

A. *Sekolah Alam* Bandung (SAB).

The object of the study is an elementary school of *Sekolah Alam Bandung*, which is located in Dago Pojok, Bandung. As a formal school, this school facilitates elementary students from 1st grade to 6th grade. *Sekolah Alam* Bandung assists their students with different kinds of architecture. Each building is a two-story building named '*saung*', and each story consists of one classroom. Each *saung* is typical, has a distance of 5 meters one another. Because of its typical design, this study took place in one classroom, the 3rd grade of elementary school.

Figure 1. Photo of *Sekolah Alam* classroom building '*saung*'
(Source: Personal documentation)

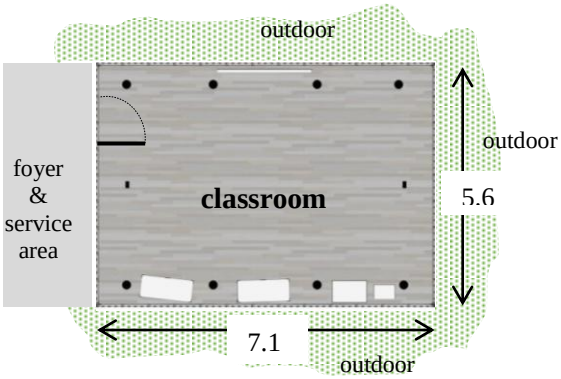

Figure 2. Classroom floor plan
(Source: Personal documentation)

Acoustical quality in the classroom will determine two things that is quality of speech perception and listening comprehension. Methods used to measure both of the qualities are Reverberation Time calculation and Background Noise measurement.

a. Reverberation Time (RT) Calculation

Reverberation Time (RT) is the time taken for the sound energy to decay to silence (Kuttruff, 2004).Long RTs reduces the clarity of the speech and thereby intelligibility. This is because the speech signals reaching a listener are a mixture of direct energy and time-delayed reflections. Also, when RTs are too long, undesired sounds (such as moving chairs or scraping feet) remain longer in the room, and consequently, noise levels increase (Maria Klatte, 2010).

Several methods can be used to calculate reverberation time, but generally, the equation of RT60 is used more often. RT60 is the time taken for sound to decline by 60 dB. This RT60 equation then used as the calculation method in this study. RT60 equation impacted by some factors, that is, frequencies (*f*), sabine (*A*), absorption coefficient (*α*), surface area (*L*), and volume of the room (*V*) (Long, 2006)). The mathematical equation is formulated as follow:

$$\mathrm{RT60} = 0{,}161 \frac{V}{A} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Whereas the mathematical equation for sabine is:

$$A = L_1 \propto_1 + L_2 \propto_2 + L_3 \propto_3 + \cdots + L_n \propto_n \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The value of RT60 depends on the material used in the room. Each material has a different absorption coefficient, which affects the material's ability to reflect or absorb the sound wave. The absorption coefficient of the materials depends on its density and the sound's frequency. Denser material will relatively more reflecting, as the absorption coefficient will get smaller (close to 0). On the contrary, the less dense material will relatively more absorbing, as the absorption coefficient will get close to 1. When the absorption coefficient reached number 1, it showed that the material would fully absorb the sound wave. When the absorption coefficient reached number 0, it showed that the material would entirely reflect the sound wave (Long, 2006). Human on RT60 calculation also considered as a 'material' variable, which will affect the result of RT60. Therefore, RT60 needs to be measured in both occupied and unoccupied conditions.

Figure 3. Photo of Classroom Activities
(Source: Personal documentation)

Figure 4. Photo of unoccupied classroom condition
(Source: Personal documentation)

b. Background Noise Measurement

Background or ambient noise also has an impact on the acoustical quality of a room. Noise itself is unwanted sound heard that could interfere with the desirable sound (Thompson & Fahy, 2015). Background noise is unwanted, and undesirable sound produced other than the monitored sound sources (Long, 2006). Background noise measures the sound of pollution produced both inside and outside the room. The source of noise could be different i.e., unwanted

conversations inside the room, mechanical and electrical sound, sounds of vehicles, etc. The standard unit of background noise is the same as the sound pressure level, which symbolized as decibel (dB). The higher the value, the more it will affect the comfort of the user's hearing capabilities. In other words, to not interfere with human activities and comfort, the level of background noise needs to be controlled effectively. *Sekolah Alam* or where this research takes place, is also no exception. One of the selling points of this school is that it is located far from the main road, so it is assumed that noise pollutions from the road would not disturb the school's activities. This study tries to prove it by measuring the background noise value of the classroom using the Data Logging Sound Level Meter (SLM) *Extech HD600*. SLM is measured when the class is empty, with a measurement interval of 5 minutes. The measuring point is located in the middle of the room, with the height of the instrument as high as 0.60 meters from the floor surface or equivalent to the average position of the head of students in the class while sitting on the floor.

RESULTS AND DISCUSSION

A. Background noise

The learning process in *Sekolah Alam* Bandung starts at 7.30 to 14.30, with break time from 11.00 to 12.30. With this information, background noise measurement was taken at 09.00 to 13.00. Measurement was done on April 24th when it was a sunny day. With the previous method explained in section 2 (Methodology), the result of background noise obtained inside the classroom is in range between 46.6 dB to 50.8 dB, with an average result of 49.2 dB.

Based on the observation during measurement, noise comes from some sound sources like animals, plants, and vehicles. Maximum background noise (50.8 dB) comes from pass over vehicles on the road near the class, while the minimum noise (46.6 dB) comes from the wind or tree leaves. Lush trees also become a shelter for animals so that the other dominant noise comes from insects and birds.

Sound level intensity heard by human are between 0 to 120 dB (Kuttruff, 2004). But human could listen to comfortably at the level of 65 dB (Long, 2006). The maximum sound level also has an exception as the sound generated in a more prolonged period can raise the level limit of human’s hearing to 80 dB (Doelle, 1993). Based on these theories, the classroom average and maximum background noise value reached 49.2 dB and 50.8 dB, are below the references explained. This result is intriguing because the classroom only located 10 meters from the road that actively used by the peoples to ride vehicles.

Moreover, only half of the walls are covered by solid walls. The rest of the wall only use ventilation frame so that external noise could easily entered the classroom. The previous study determined that sound and noise generated by vehicles has an intensity of 70 dB, measured from the range of 7.5 to 8.0 meters (IAC, 2019). Deviation between the previous study and the measurements indicate that the space between the road and the class contains something that work as a noise control mechanism. Based on the site investigation, it can be concluded that trees and lush plants around the class work as a noise control mechanism that reduces noise coming from the passing vehicles.

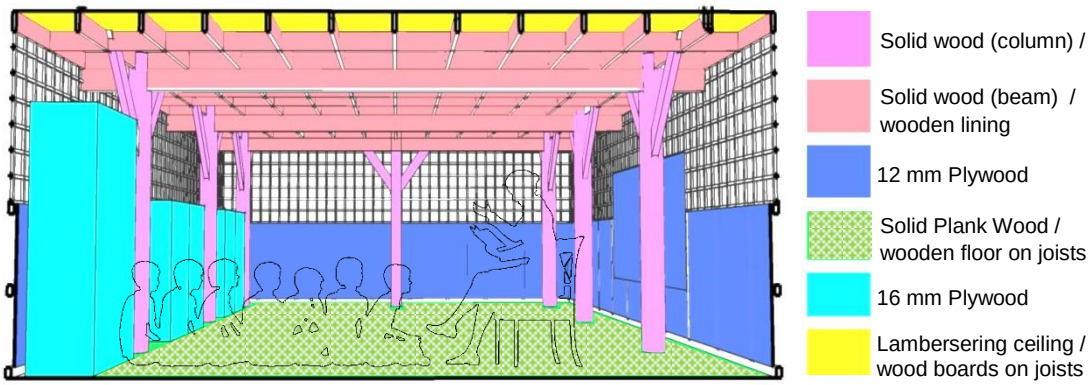

Figure 5. Classroom material mapping
(Source: Personal documentation)

B. REVERBERATION TIME

500 Hz is a frequency generally used as a reference for RT60 calculations. This frequency is part of the mid-frequency level but located near the value of low-frequency level (below 250 Hz); this makes this frequency also accommodate the characteristics of low-frequency sounds (Long, 2006). Room measurement and material identification both on the surfaces and the furniture were done before conducting the calculation of RT60. Based on the measurement, the class has a floor plan dimension of 5.50 x 7.00 m2 and 2 meters of ceiling's height.

Wood or processed wood is the dominant material found in this classroom, both as floors, walls, and ceilings. However, the solid wood walls only built 1 meter from the floor, with the remaining 1 meter only covered by a wood ventilation frame. Based on the observations, the furniture in the class consists of 3 cupboards, single whiteboard, and 17 folding tables, which also made using wood. The classroom was designed for 26 students, with a minimum of 2 teachers. But as the observation processed, the specified class only occupied of 15 students. If linked to the absorption coefficient value (α) listed by Long (2006), there are six types of woods used; therefore, the absorption coefficient will be different, as seen in Table 1.

The result shows that the classroom's RT60, when it is unoccupied, is 0.54 seconds, and for the occupied one is 0.44 seconds (see table 1). Hopkins (2003) states that for human speech to be easily articulated or translated, a room with a volume of 50-100 m3 requires an RT60 value in a range of between 0.40-0.70 s. But the hearing and language articulation ability possessed by elementary students is still below the adult. Therefore, Hopkins (2003) also formulated different standards for elementary schools, where school classrooms need to have RTs below 0.60 s (see table 2). The RT60 value of the *Sekolah Alam* classrooms that were the object of this research (0.54 s and 0.44 s) was, in fact, still in accordance with general and specific standards (elementary school).

The results of this research are quite perplexing because the dominant material used in this school was wood or processed wood. Based on the sound absorption coefficient value issued by Long (2006), this material is a material that tends to work as a sound reflector, so the room RT60 should be high. But apparently, the volume of space had the most impact on making the value of RT60 to be low. As a classroom, *Sekolah Alam* has a dimension of floor-plan (5.50 x 7.00 m2) and a ceiling height (2 m) that is much lower than other conventional schools.

Table 1. RT_{60} Calculation Table

Material	**Absorption Coefficient** (Long, 2006)	**Area/ Volume (m^2)**	***Sabine***	**Volume (m^3)**	**RT (Occupied) (s)**	**RT (Non-Occupied) (s)**
	500 Hz		500 Hz		500 Hz	500 Hz
Ceiling				75.70	0.44	0.54
Wood boards on on joists or battens	0.10	35.50	3.85			
Ceiling beams (Wooden lining)	0.22	23.51	5.17			
Walls						
Wood Frame (Wooden lining)	0.22	22.60	4.97			
Wood wall (12mm plywood)	0.04	25.00	1.00			
Square profile column (Solid wood)	0.10	2.72	0.27			
Round Profile wall (Plywood Panelling)	0.10	5.00	0.50			
Floor						
Floorboard (Wooden floor on joists)	0.10	38.50	3.85			
Furniture						
Cupboard (12mm plywood)	0.04	5.23	0.21			
Table (Wooden lining)	0.22	12.96	2.85			
Man						
Children, standing (per child) in m2 units	0.37	15.00	5.55			
Teacher (Adults per person standing)	0.42	2.00	0.88			

Table 2. RT_{60} for 500 Hz in a School. Source: (Carl Hopkins, 2003)

Room Type		**RT limit (s)**
Nursery school playroom		< 0,6
Elementary School		< 0,6
Junior high school (SMP)		< 0,8
Open Plan School	Learning area	< 0,8
	Source area	< 1,0
Small lecture room		< 0,8
Large lecture room		< 1,0

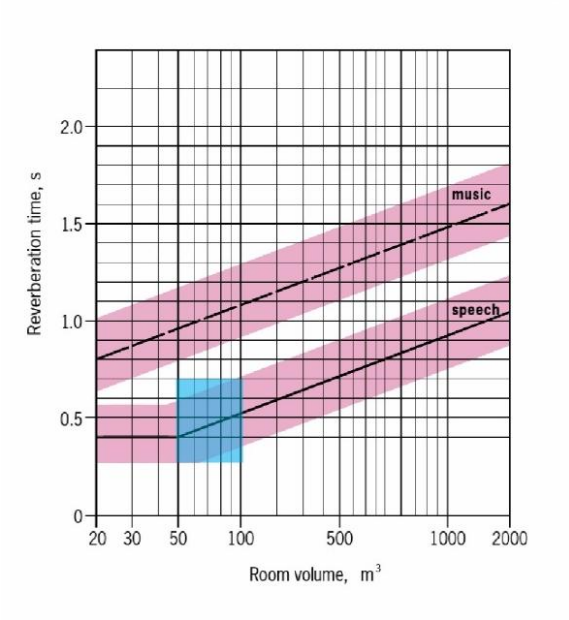

Figure 2. Chart of RT to Room's Volume and SAB's RT
(Source: adapted from (Carl Hopkins, 2003))

The dimension of *Sekolah Alam* is much smaller than conventional school. The government has set the regulation for class capacity allocation, which is 3.3 m2 for each student (Republik Indonesia, 2007). However, the observed classroom of *Sekolah Alam* had only 2.9 m2 for each student, smaller than the national standard. In *Sekolah Alam*, student learning process involves directly with nature such as gardening, farming, or raising animal utilizing any learning media on surroundings (Kompas, 2009). So that the smaller class compensated to the large schoolyard because most of the activities are done outdoor, this observation proves that smaller class, lush, and big schoolyard balance itself to the defying factors such as the noise reflector material and the noise that comes from nearby road. Yet, all of the factors collaborate to create *Sekolah Alam* until it reaches the number of RT60 and a low noise background so that it has a proper acoustic quality for learning process.

CONCLUSION AND RECOMMENDATION

Both Reverberation Time (RT) and Background noise value are some of the crucial aspects that can affect the acoustic quality of a classroom, thus also affecting student comfort during learning process. This study proves that *Sekolah Alam* (Nature School), has a low Reverberation Time (RT) value and Background noise value or is in accordance with the needs of the classroom. The measurement results were influenced by several factors, namely the dimensions of the class volume that are smaller than other general classes and the presence of noise control in the form of trees and lush plants around the building. It is essential to know that this study cannot yet be used to validate that the Nature School classrooms will have better acoustic quality than school classrooms in general. The Nature School is a new concept of school in Indonesia that does not yet have a certain classroom standard, for that study needs to be continued by understanding the typology of Nature School classrooms more profoundly and its effect on acoustic quality.

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