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REVERBERATION TIME IN COMBINED LECTURE ROOMS

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ABSTRACT

The size of the reverberation time is determined by the volume of the room and the type of surface material in the room. Lecture rooms at 701 and 702, Building L, 7th Floor, Bachelor of Architecture Study Program, Tarumanagara University have lecture rooms dominated by glass windows with aluminum frames on both sides of the room and exposed concrete beams and columns. These materials tend to increase reverberation time. Apart from that, the two lecture rooms are also often used simultaneously. Using both lecture rooms simultaneously will increase the volume of the room. The larger the room volume also increases the reverberation time. This research aims to optimize the reverberation time of 2 lecture rooms that are used simultaneously. Lecture rooms and the types of materials forming the rooms were experimented with using Ecotect. Lecture rooms 701 and 702 were used as research samples. The number of occupants in the class was counted as 80 people because not all the tables were filled with students. The research results show that combining 2 lecture rooms causes problems with reverberation time. The reverberation time in existing conditions is 1.11 seconds. To overcome the high reverberation time, it was necessary to replace the ceiling covering from gypsum to acoustic in lecture room 701. After replacing the ceiling, the reverberation time decreased to 0.74 seconds. This value is close to the optimal reverberation time which has a value of 0.77 seconds.

Keywords*: lecture room, material type, reverberation time, room model*

INTRODUCTION

In a lecture room that has optimal reverberation time, it can improve the teaching and learning process because the lecturer's voice can be heard clearly by students. By using an acoustic ceiling and covering the columns and walls with cork, it was possible to reduce the reverberation time of the Tarumanagara University Wastu 1 Architecture lecture room from previously 1.45 seconds to 0.83 seconds (Sabtalistia, 2020:72). The reverberation time of 0.83 seconds is close to the optimal reverberation time of 0.78 seconds. Replacing floor and window materials also has a big effect on reverberation time. Similar to the case study conducted by Sabtalistia (2020), replacing the ceramic floor in the lecture room with carpet, adding a carpet-covered stage at the front of the room, and replacing the single-glazed windows with double-glazed windows and aluminum frames can reduce the reverberation time from 1.45 seconds to 0.95 seconds (Sabtalistia et al., 2020, p. 60).

Performance buildings focus more on visual, acoustic and circulation aspects (Pratiwi et al, 2023). Reverberation time is one of the acoustic criteria for a music concert hall to have optimal sound quality. A room with a larger room volume has a larger optimal reverberation time. Rooms used for music activities have a higher reverberation time than those used for conversation. The optimal reverberation time at the Balai Sarbini Concert Hall is 1.5 seconds to 2.1 seconds (Kurniasih, 2018:91). The reverberation time value when there is an audience is 0.6 seconds and when there is no audience it is 0.7 seconds. This value is lower than the optimal reverberation time. Using too much porous material on walls, ceilings and floors is the cause of decreased reverberation time. A reverberation time that is too low than the optimal reverberation time causes the sound quality of the music in the concert hall to be less good.

The use of the Sabine formula for calculating reverberation time was also carried out in research by Wafa et al. (2020). The results of his research show that the reverberation time of the multi-purpose hall of the Jakarta Teachers' Building is 3.3 seconds. The reverberation time calculations carried out by Wafa et al (2020) were calculated manually using a formula, not using a computer application. The disadvantage of calculating manually is that it takes longer and is more difficult, especially if the room model has a complicated shape.

The reverberation time in an empty classroom and a room filled with desks and chairs has different values. Research by Kusuma et al. (2021), calculated the reverberation time in ITS Physics Department classrooms. The results show that the reverberation time value in an empty classroom is higher than in a classroom filled with desks and chairs. This is because an empty room causes a lot of sound to reflect freely and interference occurs, whereas a classroom filled with desks and chairs causes a lot of sound to be fragmented due to the many surfaces that reflect back (Kusuma et al, 2021: 13).

From previous studies it is known that the reverberation time is influenced by the type of material and furniture in the room. Apart from the type of material and furniture, the reverberation time is also influenced by the volume. The larger the volume, the higher the reverberation time. The lecture rooms on the 7th floor, building L, Tarumanagara University are often used together. Two lecture rooms that are often used simultaneously are lecture rooms 701 and 702. Both lecture rooms have room dividers in the form of partition walls that can be folded so they can be opened and closed. The merger of the two lecture halls causes the volume of the room to become larger. Based on the background of this problem, it is necessary to calculate the reverberation time in lecture rooms 701 and 702. If the reverberation time value does not reach optimal, then there needs to be an improvement in the room model in order to achieve the optimal reverberation time.

Reverberation Time (RT) is the time required for a certain sound level to decay to 60 dB or the time required for a sound to no longer be heard after the sound is turned off, calculated in seconds (Templeton, 1997:53). The reverberation time is influenced by the volume of the room, the number of people, and the type of surface material in the room. Reverberation time can be calculated using the Sabine formula (formula 1) and the Norris-Eyring formula (formula 2) (Templeton, 1997: 144).

$$RT_{60} = 0.161\, V/S\bar{\alpha} \tag{1}$$

$$RT_{60} = \frac{0.16\, V}{-S\, log(1-\bar{\alpha}\,)} \tag{2}$$

$$\bar{\alpha} = \frac{\sum_{i=1}^{n} S_i\ \alpha_i}{\sum_{i=1}^{n} S_i} \tag{3}$$

where:

RT_{60}	:	reverberation time (seconds)
V	:	room volume (m³)
α	:	sound absorption coefficient
S	:	Surface area (m²)

According to McMullan, 2007: 225, the reverberation time is influenced by the surface area of the exposed area, the value of the sound absorption coefficient, the distance between various surfaces in a room, and the frequency of the sound source.

The optimal reverberation time for classrooms is 0.6-0.8 seconds (Doelle, 1986:87). The standard reverberation time in a good classroom ranges from 0.6 - 0.8 seconds at the center frequency (500 Hz) (Doelle, 1986:87). This value depends on the volume and condition of the room being used and its furniture (Doelle, 1986:87). The optimal reverberation time can also be calculated using the following equation (McMullan, 2007:225).

$$\mathrm{t} = \mathrm{r}\ (0.0118\ \sqrt[3]{\mathrm{V}} + 0.107) \tag{4}$$

where:

T	:	Optimal reverberation time (second)
V	:	Room volume (m³)
R	:	(4= speech, 5 = orchestra, 6= choir)

Based on formulas 1 and 2, the reverberation time is influenced by the size of the room volume. The larger the room, the higher the reverberation time. This is in line with the optimal reverberation time in the Surakarta jazz music auditorium which has a larger volume than the Surakarta Jazz Club room. The optimal reverberation time in the Surakarta Jazz Auditorium which has a volume of 3821 m^3 is 0.9 seconds, while the reverberation time in the Jazz Club room which has a volume of 585 m^3 is 0.6 seconds (Audryn et al, 2020: 149).

METHODS

The method used is an experimental method with the help of the Autodesk Ecotect Analysis 2011 simulation. According to Groat et al., 2022 research using the experimental method has a cause-and-effect relationship focus. The volume and type of room material are the causes while the reverberation time is the effect. The results of the research are a lecture room model that is able to meet the optimal reverberation time even though both lecture rooms are used simultaneously.

Lecture rooms 701 and 702 are on the 7th floor, Tarumanagara University, Jakarta. These two lecture rooms were used as research samples because they are often used simultaneously (Figure 1). Both rooms have the same model, including floors, windows, doors, ceilings and walls. On both sides of the classrooms there are windows that cover almost the entire wall surface. The window glass material with aluminum frames is a material that has a low α value so it reflects sound very well. The large number of window panes and large room volume due to combining classes tend to cause the RT value to be high.

Lecture rooms 701 and 702 have the same space, length and width. Measurements in the field use measuring instruments in the form of laser meters and manual meters. The floor to ceiling height is 2.96 meters. The number of people sitting on cloth chairs was 80 people. Based on this data, data on the number of occupants sitting on cloth chairs needs

Figure 1. Lecture Rooms 701 and 702
Source: Author’s Documentation, (2023).

to be input to Ecotect. The more people are there, the more the reverberation time can be reduced.

Rooms 701 and 702 are 29 meters long and 9.6 meters wide (Figure 2). There are 10 protruding structural columns and quite large windows. On the left side, the classroom is limited by a display room for mock-up and panel exhibitions as well as a corridor that connects to the Architecture Study Program Secretariat room (Figure 3). On the right side, it is directly adjacent to the outside of the building (Figure 3). The α values in lecture rooms 701 and 702 are shown in table 1. The α values for gypsum walls and plywood doors with hollow frames have high α values.

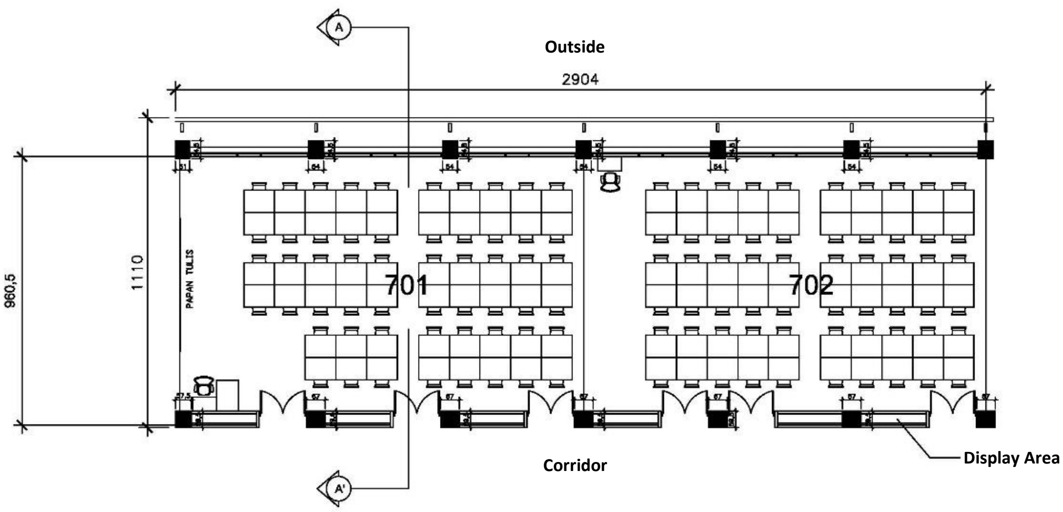

Figure 2. Room Plans *(Not to Scale)*
Source: Author's Documentation, (2023).

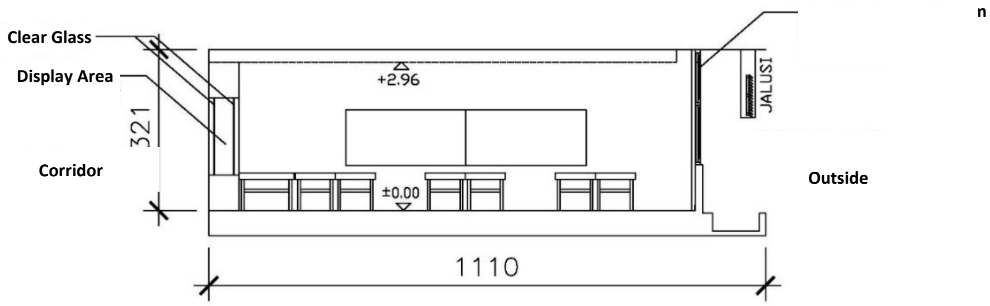

Figure 3. Section A-A'
Source: Author's Documentation, (2023).

Table 1. Sound Absorption Coefficient (α) on Surface Elements on Lecture Halls 701 and 702

No	Element	Material Type	Layer	Sound Absorption Coefficient (α) at a Frequency of 500 Hz
1	Corridor Divider Wall	Gypsum wall with hollow frame (Framed Plaster board)	80mm framed wall as air gap, with 10mm plaster board either side.	0,1

No	Element	Material Type	Layer	Sound Absorption Coefficient (α) at a Frequency of 500 Hz
2	External Building Walls, Toilets and Stairs	Brick Plaster	110mm brick v 10mm plaster eit side.	0,02
3	Floor	Ceramic floor (ConcFlr_Tiles_Suspended)	100mm thick suspen concrete floor p ceramic tiles and pla ceiling underneath.	0,02
4	Ceiling	Gypsum ceiling with concrete top (SuspendedConcreteCeiling)	-	0,02
5	Exterior Window	Windows with clear glass and aluminum frames (SingleGlazed_AlumFrame)	Single pane of glass with aluminium frame (no thermal break).	0,03
6	Corridor Divider Glass	6 mm clear glass	6mm clear glass.	0,01
7	Column	Concrete column (ConcBlockPlaster)	110mm concrete block with 10mm plaster either side.	0,01
8	Beam	Concrete beam (ConcBlockPlaster)	110mm concrete block with 10mm plaster either side.	0,01
9	White board	Clear Glass	6mm clear glass.	0,01
10	Door	Plywood door with hollow frame (Hollow Core_Plywood)	40mm thick hollow core plywood door.	0,25

Source: Ecotect, (2023).

RESULT AND DISCUSSION

If the 2 lecture rooms are combined (rooms 701 and 702) then the volume of the room becomes 810.20 m³. The lecture room model if 2 lecture rooms are combined is shown in Figure 4. The number of students is assumed to be 80 people (sitting on cloth chairs). By calculating using Ecotect, it is known that the optimal reverberation time is 0.77 seconds. Meanwhile, the reverberation time if 2 lecture rooms are combined is known to be 1.11 seconds at a frequency of 500 Hz (Table 2 and Figure 5). There is a difference between the reverberation time of 0.34 seconds and the optimal reverberation time. The difference in reverberation time is quite large, so improvements need to be made.

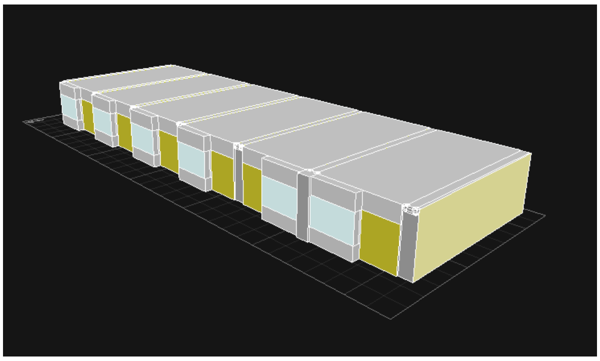

Figure 4. Model of 2 Lecture Rooms Combined into One (Visualize)
Source: Ecotect, (2023).

Table 2. RT Value (seconds) in 2 Combined Lecture Rooms in Existing Conditions

Frequency	Sabine (seconds)	Nor-Er (seconds)	Mil-Se (seconds)
63 Hz	0.21	0.12	0.19
125 Hz	0.26	0.14	0.25
250 Hz	0.32	0.19	0.31
500 Hz	1.11	0.43	1.09
1 kHz	1.09	0.54	1.07
2 kHz	0.99	0.54	0.98
4 kHz	0.68	0.42	0.67
8 kHz	0.75	0.4	0.74
16 kHz	0.6	0.32	0.59

Source: Ecotect, (2023).

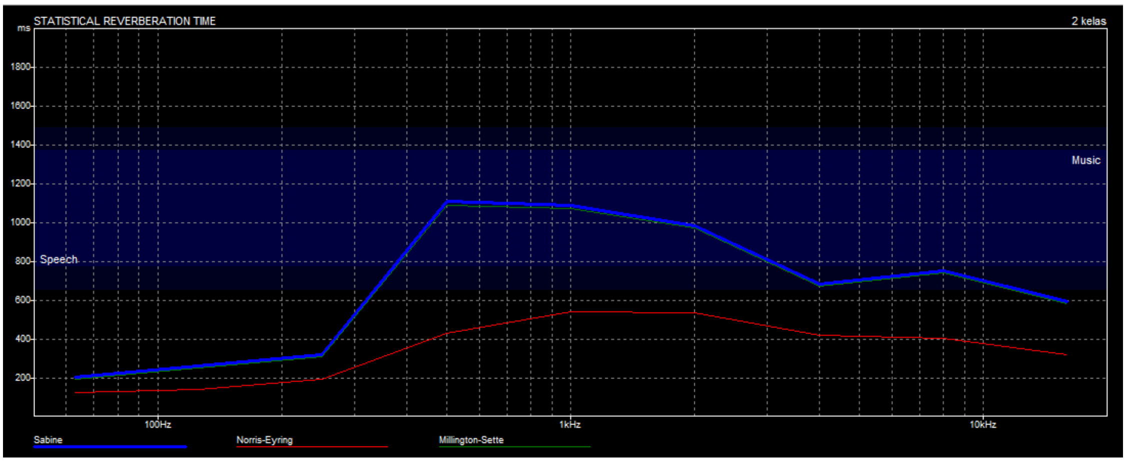

Figure 5. Graph of Reverberation Time in 2 Combined Lecture Rooms
Source: Ecotect, (2023).

Improvements to the reverberation time of 2 lecture rooms that are combined can be done by replacing the gypsum ceiling with an acoustic ceiling in room 701 while the ceiling in room 702 remains in the existing condition, namely with a gypsum ceiling (Figure 6). The ceiling in class 702 was left to use a gypsum ceiling because the price of acoustic ceilings is quite expensive on the market. Apart from that, if the ceiling of the two lecture rooms is replaced with an acoustic ceiling, it will cause the reverberation time to decrease too much, making it further away from the optimal reverberation time. The α

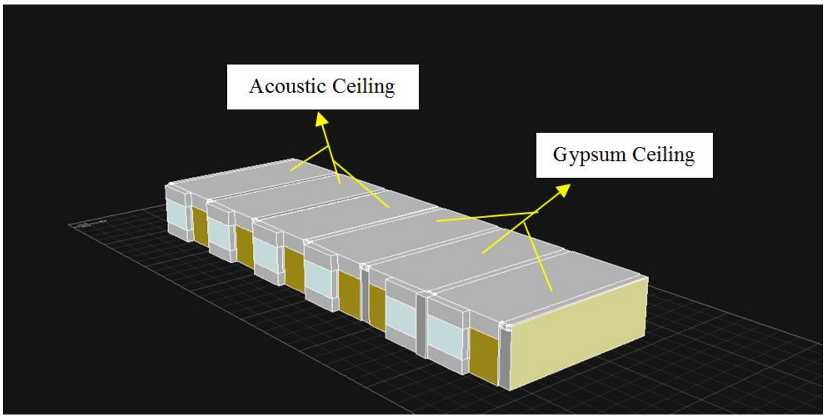

Figure 6. Improved Reverberation Time in 2 Combined Lecture Rooms
Source: Ecotect, (2023).

Table 3. RT value (seconds) in 2 lecture rooms whose reverberation time has been corrected

Frequency	Sabine (seconds)	Nor-Er (seconds)	Mil-Se (seconds)
63 Hz	0.19	0.12	0.17
125 Hz	0.24	0.14	0.23
250 Hz	0.3	0.19	0.29
500 Hz	0.74	0.37	0.65
1 kHz	0.58	0.38	0.32
2 kHz	0.54	0.37	0.27
4 kHz	0.46	0.33	0.35
8 kHz	0.53	0.33	0.4
16 kHz	0.44	0.27	0.36

Source: Ecotect, (2023)

value in concrete covered by a gypsum ceiling (Suspended Concrete Ceiling) is 0.02 at a frequency of 500 Hz. Meanwhile, the α value for the acoustic ceiling (Acoustic Tile Suspended) has an α value of 0.47 at a frequency of 500 Hz. Increasing the α value causes a decrease in the reverberation time. The results show a decrease in reverberation time from 1.11 seconds in existing conditions to 0.74 seconds (Table 3). This value is close to the optimal reverberation time which has a value of 0.77 seconds.

CONCLUSION

The merger of lecture rooms causes an increase in room volume. Based on Sabine's formula, volume is directly proportional to reverberation time. Therefore, combining lecture rooms risks increasing the reverberation time. When combining two lecture rooms, namely: rooms 701 and 702, the results show an increase in reverberation time. To overcome this, replacing the ceiling from gypsum to an acoustic ceiling in room 701 can be an effective solution because there is no need to replace other materials, such as window glass, floors and walls. Replacing the ceiling can reduce the reverberation time so that it approaches optimal.

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