Acoustic Assessment Through Reverberation Time

Case Study: Pembangunan Jaya University Building B Auditorium

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ABSTRACT

Architectural acoustics is a branch of building science that examines sound quality within a building. Each type of space in a building has its own characteristics to create characteristics in harmony with the intended function. This research aims to identify the acoustic characteristics of architectural space with a conversational function which it can be examined based on reverberation time and Articulation loss of consonant (%ALcons) in the auditorium of building B, Universitas Pembangunan Jaya as the case study. The research utilizes software to examine reverberation time through Ecotec software that occurs in existing conditions to calculate %ALcons as a benchmark for speech intelligibility. The final step in this research is to improve the design for the acoustic. The required reverberation time in the built auditorium is 1.39 seconds which is too long for this type of purpose. As for the %ALcons is 9.27% which means it is quite good. It turns out that a design improvisation could improve the acoustic quality of this space by reducing the reverberation time close enough to a suggested number by SNI 03-6368-2000.

Keywords: Architectural Acoustic, Reverberation Time, Articulation Loss of Consonant, Pembangunan Jaya University Auditorium

INTRODUCTION

An Auditorium is a place for the audience to sit to watch and listen to a performer or orator (Latifah, 2015). When it comes to the auditorium we do not talk only about thermal comfort or visual comfort only, yet we also need to understand the importance of the acoustic of the auditorium. One of many functions of the auditorium is functionalized as a space to hold an oration that involves speech and dialogue. In general, the acoustic performance of an auditorium is measured through reverberation time. For a speech auditorium it is recommended that reverberation time does not exceed more than 80ms. Pembangunan Jaya University in Bintaro has two auditoriums in building A and Building B. in the first survey through a balloon popping method observer may hear a reflected sound separated from the original sound in which theese phenomena indicate that there is a sound signature that should not exist in speech auditorium. Thus this journal is has a focus to find the reverberation time of the built auditorium, calculation of the Articulation Loss of

Consonant (%ALcons), and to see what kind of design improvement can be done to increase the acoustic performance of the auditorium.

LITERATURE REVIEW

Reverberation Time

Reverberation time is the time needed by a sound to decay 60dB from its original sound pressure level. The first method to calculate reverberation time is based on Wallace Clement Sabin's formula as seen below:

$$Rt = \frac{0{,}16V}{A}$$

With RT: reverberation time (second); V: volume of the room (m^3) and; A: $\sum$ absorption area of the room

The second method used to calculate reverberation time is a method developed by Noris-Eyring with the formula below

$$Rt = \frac{0{,}161V}{-S\ ln\ (1-aAvg)}$$

Where S: total area of the boundary surface, $aAvg$: average coefficient absorption of the boundary surface, and: ln: normalize logarithm

In general, the reverberation time is very sensitive to the material. Different types of material with different acoustic properties may be resulting a different reverberation time.

Jenis Hunian ----	Tingkat Bunyi Yang Dianjurkan		Waktu Dengung (T) Yang Dianjurkan
	Baik [dBA]	Maksimum [dBA]	[detik]
1	2	3	4
Ruang Kesehatan (P3K)			
Ruang praktek musik	40	45	0,6 – 0,8
Studio musik	40	45	0,7 - 0,9
Ruang kantor	30	35	Kurva 2
Ruang administrasi	40	45	0,4
Ruang seminar	35	40	0,6 –0,8

Image 1. Room Classification (SNI 03-6368-2000, 2000)

For a room functionalized as a speech or seminar function, SNI 03-6368-200 provides a recommendation that reverberation time span from 0,6s and should not exceed 0,8s.

Articulation Loss of Consonant (%ALcons)

One of the measurements used to calculate the performance of the speech auditorium is analyzing the speech intelligibility, and one of them is Articulation Loss of Consonant (%ALcons). %ALcons is highly attached to reverberation time, which the formula as seen below:

$$\%AL_{cons} = \frac{200\ .\ D_2^2 RT_{60}^2 (1+n)}{VQM}$$

Where D2: closest distance to sound source with minimum of 2m, which recommended by ISO3382-1997; RT60: Reverberation time; V: room volume(m3); Q: Directivity factor; M: Sound modifier with assumption number of 1, and; n: the number of the sound sources.

The %ALcons score spans in percentage. Bellow 10%, it can be considered a room with very good performance. %Alcons 10%-15% considered as a good performers. Whereas %ALcons exceeding 15% are considered as a room with bad speech intelligibility (Baikhaqi, 2015). Usually, consonants take place at a frequencies from 500Hz to 4kHz (DPA Microphones, 2021)

METHODOLOGY

The first method is to analyze reverberation time with the help of **Autodesk Ecotec**. Firstly we need to have the documentation of the dimension of the built auditorium. We also need to acknowledge the material in the built environment to apply the absorption coefficient of the material used in the built environment.

The third step is to measure the articulation loss of consonants (%ALcons). %ALcons is measured on 125Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz, and 8kHz. This is because humans may speak not only specific to a perticular frequency only.
The last step of the process is to apply design changes in terms of the auditorium form. We also used new material with a better sound absorption coefficient. Once we've done that, we repeat the first and the second step to see whether the improvement may affect the performance of the auditorium.

RESULT & DISCUSSION

Reverberation Time Calculation

Once we have the model of the built auditorium, we could proceed to calculate the reverberation time of the built auditorium. The formula used to analyze the Reverberation time in this research is based on the Norris-Eyring formula. ISO 3387-1997 stated that measurement for large volume room take the reference at 500Hz or 1kHz. For this research, we referred to the result within 500Hz

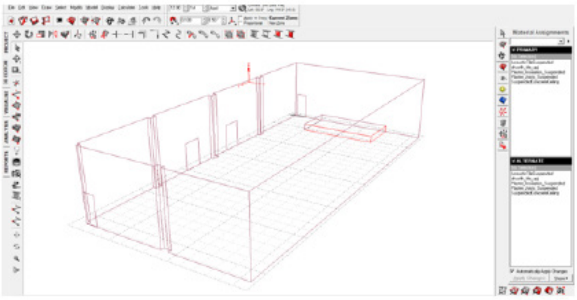
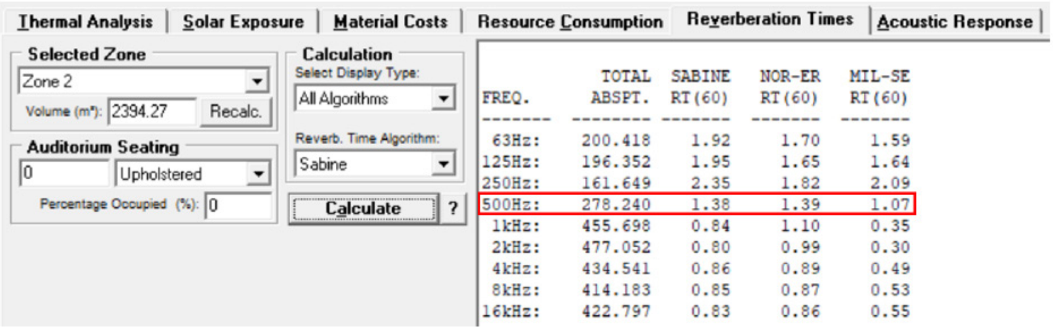


Image 2. Model of the built auditorium (Rahardjo, 2022)

Table 1. Table of Absorption Coefficient In The Built Auditorium (Rahardjo, 2022)

Material	**Absortioon Coefficient (Hz)**							
	63	125	250	500	1000	2000	4000	8000
Gypsum	0,28	0,28	0,1	0,05	0,04	0,07	0,09	0,15
Floor tile	0,01	0,01	0,01	0,01	0,02	0,03	0,07	0,07
Painted Concrete	0,02	0,02	0,03	0,03	0,03	0,04	0,07	0,07
Acoustic ceilling	0.06	0.06	0.13	0.47	0.91	0.94	0.78	0.74
Carpet on Wood	0,07	0,11	0,24	0,5	0,68	0,75	0,79	0,78
Curtain	0,43	0.05	0.06	0.39	0.63	0.7	0.73	0.73
Hollow wood Door	0,44	0,41	0,35	0,25	0,20	0,15	0,14	0,13



FREQ.	TOTAL ABSPT.	SABINE RT(60)	NOR-ER RT(60)	MIL-SE RT(60)
63Hz:	200.418	1.92	1.70	1.59
125Hz:	196.352	1.95	1.65	1.64
250Hz:	161.649	2.35	1.82	2.09
500Hz:	278.240	1.38	1.39	1.07
1kHz:	455.698	0.84	1.10	0.35
2kHz:	477.052	0.80	0.99	0.30
4kHz:	434.541	0.86	0.89	0.49
8kHz:	414.183	0.85	0.87	0.53
16kHz:	422.797	0.83	0.86	0.55

Image 3. Reverberation Time of The Built Auditorium Result (Rahardjo, 2022)

Within the data shown, we can see that it is still exceeds 0,8s which is suggested by SNI 03-6368-2000. Thus this reverberation characteristic is still far from the optimum number.

Articulation Loss of Consonant (%ALcons)

The %ALcons is measured on the red spot with the distance of 5,338m from the yellow spot, which is the sound source. The %ALcons measurement uses the reverberation time on the previous step.

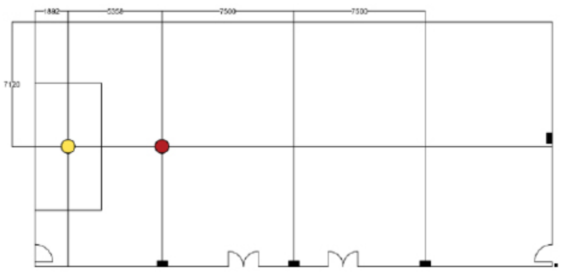


Image 4. Location of The Measurement (Rahardjo, 2022)

$$\%AL_{cons}\ 125Hz = \frac{200\ .\ 5.358m^2 1.65^2(1+1)}{2394.27\ (1)(1)} = 13{,}06\%$$

$$\%AL_{cons}\ 250Hz = \frac{200\ .\ 5.358m^2 1.82^2(1+1)}{2394.27\ (1)(1)} = 15.89\%$$

$$\%AL_{cons}\ 500Hz = \frac{200\ .\ 5.358m^2 1.39^2(1+1)}{2394.27\ (1)(1)} = 9{,}27\%$$

$$\%AL_{cons}\ 1000Hz = \frac{200\ .\ 5.358m^2 1.1^2(1+1)}{2394.27\ (1)(1)} = 5{,}80\%$$

$$\%AL_{cons}\ 2000Hz = \frac{200\ .\ 5.358m^2 0.99^2(1+1)}{2394.27\ (1)(1)} = 4{,}70\%$$

$$\%AL_{cons}\ 4000Hz = \frac{200\ .\ 5.358m^2 0.89^2(1+1)}{2394.27\ (1)(1)} = 3{,}78\%$$

$$\%AL_{cons}\ 8000Hz = \frac{200\ .\ 5.358m^2 0.87^2(1+1)}{2394.27\ (1)(1)} = 3{,}63\%$$

Within the frequency range of 500Hz-4kHz of humankind, the %ALcons can still be considered safe within a good range below 10%.

Design Changes

The final step is to implement design changes that implement reflector ceiling and changes of material that could be seen below:

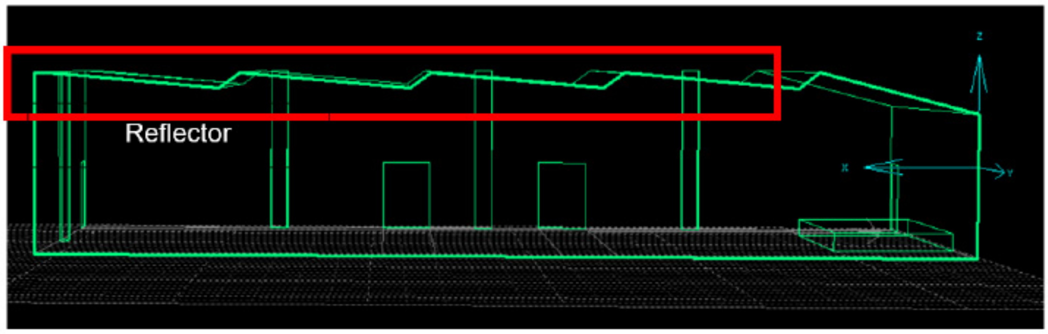


Image 5. Design Changes (Rahardjo, 2022)

Table 2. New Material Used On Auditorium With Design Improvement

Material	Absorption Coefficient (Hz)							
	63	125	250	500	1000	2000	4000	8000
Perforated Gypsum	0,28	0,3	0,69	1	0,81	0,66	0,62	0,09
Cotton Carpet	0,07	0,07	0,31	0,49	0,89	0,66	0,54	0,48
Painted Concrete	0,02	0,02	0,03	0,03	0,03	0,04	0,07	0,07
Acoustic Ceilling	0.06	0.06	0.13	0.47	0.91	0.94	0.78	0.74
Reflector plasterboard	0,06	0,2	0,15	0,1	0,08	0,04	0,02	
Carpet on Wood	0,07	0,11	0,24	0,5	0,68	0,75	0,79	0,78
Curtain	0,43	0.05	0.06	0.39	0.63	0.7	0.73	0.73
Solid Wood Door	0,44	0,41	0,35	0,25	0,20	0,15	0,14	0,13

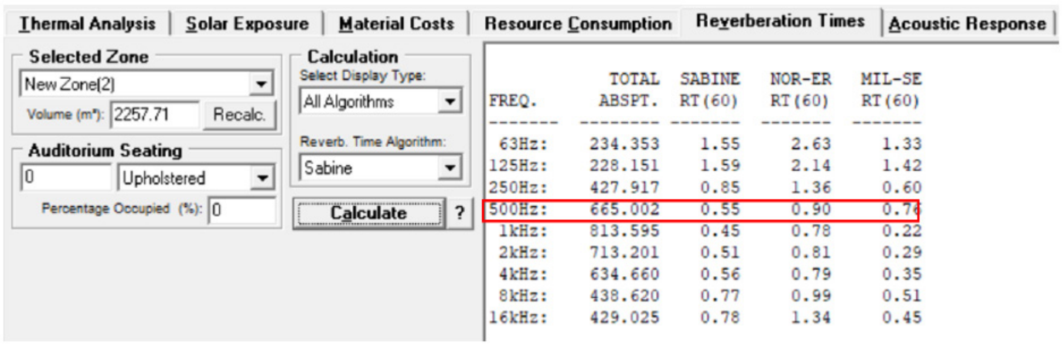


Image 6. Reverberation Time Result of The Improved Auditorium Design

Like the previous calculation, this reverberation calculation is also oriented on the Norris-Eyring formula on a frequency of 500Hz. The resulted reverberation time from design improvement is 0,9s which is reduced by 0,49s from the original auditorium state. From the data above, we could say that with the implementation of the reflector on the ceiling and material changes, we've shortened the the reverberation time close enough to the reverberation time suggested by the SNI 03-6368-2000, which suggested that for the seminar-type room should have reverberation time with the span from 0,6s to 0,8s.

With the improvement of the reverberation time, we also encountered an improvement on %ALcons as well which could be seen below:

$$\%AL_{cons\ 125Hz} = \frac{200\ .\ 5.358m^2 2.14^2(1+1)}{2257.71\ (1)(1)} = 23.29\%$$

$$\%AL_{cons\ 250Hz} = \frac{200\ .\ 5.358m^2 1.36^2(1+1)}{2257.71\ (1)(1)} = 9.41\%$$

$$\%AL_{cons\ 500Hz} = \frac{200\ .\ 5.358m^2 0.9^2(1+1)}{2257.71(1)(1)} = 4.12\%$$

$$\%AL_{cons\ 1000Hz} = \frac{200\ .\ 5.358m^2 0.78^2(1+1)}{2257.71\ (1)(1)} = 3.10\%$$

$$\%AL_{cons\ 2000Hz} = \frac{200\ .\ 5.358m^2 0.81^2(1+1)}{2257.71\ (1)(1)} = 3.34\%$$

$$\%AL_{cons\ 4000Hz} = \frac{200\ .\ 5.358m^2 0.79^2(1+1)}{2257.71\ (1)(1)} = 3.17\%$$

$$\%AL_{cons\ 8000Hz} = \frac{200\ .\ 5.358m^2 0.99^2(1+1)}{2257.71(1)(1)} = 4.98\%$$

CONCLUSION

From the data resulting from the reverberation time of the built auditorium, the result from the Autodesk Ecotec is 1,39s, a deviation of 0,59s from the suggested number by SNI 03-6368-2000 that shall not exceed 0,8s. Hence, the built auditorium still doesn’t have the characteristic of the seminar auditorium.

As for speech intelligibility measured through articulation loss of consonant, we see a different conclusion. Within the speech region between 500Hz to 4kHz we could say the built auditorium perform quite well where the result are below 10%. When we implement the design improvement by changing the form and some of the material used with better acoustic properties, we can conclude that design improvement indeed could produce a better acoustic performance. With the design improvement, we can reduce the reverberation time to 0,9s, or only 0,1s slower than the suggested number by SNI’s. Since we see reduction in overall reverberation time number, it also reduced the articulation loss of consonant at 500Hz reduced from 9,27% all the way to just 4,12%.

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