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Analysis of The Level of Acoustic in The Javanese Christian Church Bandung

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A B S T R A C T

In architecture, acoustics are distinguished into two areas of acoustic space: desirable controllable and undesirable or distracting noise. Some variables that can affect the acoustic quality of space include the shape and location of buildings, materials used in building construction, background noise, and also reverberation time. In a large hall used for public speaking or singing, when the hum time exceeds 0.5-1 seconds on a medium frequency ribbon (500-1000 Hz), the room inevitably has a low acoustic quality. (Beranek & Mellow, 2012). The lack of acoustic qualities in buildings that serve as church places of worship is a matter that needs to be discussed. Therefore, the scientific article's writing is intended to analyze the level of acoustic ease in the Bandung Christian church located on Merdeka Street no. 28 using a descriptive method with a quantitative approach called quantitative descriptive. Analysis was made using the auto-desk Ecotect 5.50 by making observation data as the first reference. The results of this study are expected to provide operational information for the building of the Javanese Christian Church Bandung and to be an acoustic quality recommendation for changes in materials used. It is also hoped that the study will inform how the sound and time of good, standardized Spaces can sustain the creation of what is expected to be so that audial information can be distributed to users.

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1. INTRODUCTION

Worship spaces are vital cultural and historical symbols, representing a society's identity and evolving over time to reflect changes in society and architecture, providing insights into the past through their adaptations and modifications [1]. The evolving architecture of religious spaces contrasts with their consistent function, highlighting the importance of auditory perception. During religious services, led by clergy members and attended by congregations, clear sound transmission is essential for understanding the spoken words, as congregants respond at specific points in the ritual. This underscores the significance of sound quality in facilitating effective communication during ceremonies [13].

Acoustics is a science that studies sound that can affect the comfort and safety of its users [2]. In architecture, acoustics can be divided into two, namely the acoustic field of space which is a desired and controllable sound, and noise which is an unwanted and disturbing sound. The nature or material of the space cover can affect the sound quality in a space [2]. The acoustic quality of a space can affect comfort, health, and safety for users of that space. Excessive noise can trigger various problems, such as loss of focus or even mental health problems.

Acoustic quality in places of worship, especially churches, needs to be considered so as not to produce noise that disrupts worship activities. Based on the decision of the Minister of Environment no.48 of 1996, the maximum noise level for places of worship is 55 decibels (dBA) [12].

Some variables that are considered to affect noise include the shape of the building, the location of the building, and ventilation with a wide size. If the location of the church building is near a highway with a very busy traffic volume and is designed with a natural air concept that has many wide openings, the noise transmission process that comes from outside the room can interfere with worship activities [3]. This of course becomes a new problem that needs to be studied.

Another important variable to consider is reverberation time. Reverberation time (RT) is the time it takes for sound in a room to decay over a certain dynamic range [6]. In a large room commonly used for speeches or singing, if the reverberation time exceeds 0.5-1 second in the middle-frequency band (500-1000 Hz), the room certainly has low acoustic quality [9].

In this study, researchers conducted an acoustic study related to the analysis of background noise conditions, reverberation time (RT), and good sound insulation for the Bandung Javanese Christian Church (GKJ) using *Autodesk Ecotect 5.50 software.* This church was chosen because it has a unique shape with an ancient Javanese architectural style and is located near a secondary collector road that is busy with noise. In addition, the church is also designed with the concept of natural ventilation where there are wide openings for ventilation that are at risk of transmitting noise from outside the room.

Especially for acoustic quality analysis, *Ecotect is* not only based on reverberation time (RT) analysis calculations based on Sabine, Eyring, and Millington statistical reverberation formulas but is also equipped with acoustic graphic analysis (acoustic particles) that can be visualized both in 2 dimensions and 3 dimensions. These advantages provide opportunities for acoustic space design to be able to take advantage of the speed and accuracy in visualizing and calculating the results of the analysis, which will certainly be useful to support acoustic space design decisions [4].

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2. METHODOLOGY

2.1 Object of Research

The building chosen as the research object is the Bandung Javanese Christian Church (GKJ) building located at Jalan Merdeka No. 28 Bandung. The building consists of 2 floors with the 2nd floor in the form of a *mezzanine* and oriented towards the west and facing directly to Jalan Merdeka. Details of the building specifications are:

- Building name : Javanese Christian Church (GKJ) Bandung
- Building area/volume : 396.67 m^2/3570 m^3
- Capacity : ± 700 people
- Building orientation : West

(a) **(b)**

Figure 1. Floor plan of the Javanese Christian Church (GKJ) Bandung (**a**) first floor; (b) second floor

Figure 2. Front view of GKJ Bandung

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Figure 3. Inside of GKJ Bandung

Building construction:

a) plastered brick wall
b) ceramic-coated concrete slab floor
c) combination ceiling of *gypsum,* wood, and iron
d) wooden doors, wooden windows with stained glass

3. RESEARCH METHODS

Researchers used literature studies, simulations using *Autodesk Ecotect 5.50 software,* observations, and interviews in the data collection process. Observations and interviews were conducted on November 18, 2022, at the Javanese Christian Church (GKJ) Bandung using a *noise meter* as a *noise* measurement tool in the field. After conducting observations and interviews, researchers conducted simulations using *Autodesk Ecotect 5.50 software* to measure the level of acoustic comfort in the church using observation data as a reference.

This is relevant to the researcher's goal to emphasize the analysis of numerical data, where the process of analyzing and verifying field data is carried out to determine the condition of background noise, Reverberation Time (RT), and good sound insulation for the Javanese Christian Church (GKJ) Bandung.

4. RESULTS AND DISCUSSION

4.1 Noise Measurements

Measurement of *noise* and sound source strength using a *noise meter* at the Javanese Christian Church (GKJ) Bandung was carried out by determining the points to be measured. Noise level measurement at the Javanese Christian Church (GKJ) Bandung was carried out on Saturday, November 18, 2022, when there were no worship activities starting from 09.00 - 10.00 WIB. Measurements were made at 3 different points, 2 points inside the church on the ground floor and 1 point outside the church. The measurement points are carried out in the field of floors and *paving* blocks. The existing condition of the floor uses ceramic tiles measuring 20 x 20 with a thickness of 11 mm.

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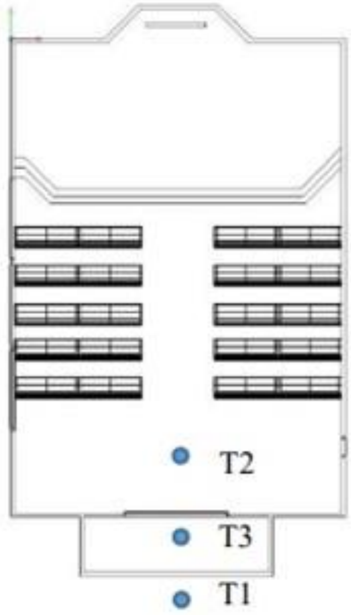

Figure 4. Background noise measurement points

Table 1. Noise Measurement inside and outside the Church

Point Measurement	Max. (dB)	Min. (dB)	Average (dB)
T1	74,9	33,4	58,9
T2	74,3	33,4	58,7
T3	74,3	33,4	58,3

In the indoor measurement table, it can be seen that the noise level generated is above 55 dB. The highest noise level produced was 74.9 dB with an average of 58.9 dB and the lowest noise level was 33.4 dB with the lowest average of 58.3 dB. These results show that the noise level cannot be suppressed because it exceeds the noise limit of 30-35 dB(A) [11]. This can be caused by the location of the church adjacent to the highway with busy traffic, which is only 12 meters away from Jalan Merdeka. Another factor that affects the noise in the church is that the building construction materials used are not able to reduce the noise. As a result, the noise received exceeds the standard limits that have been set.

The noise problem can be reduced by using plants as natural *barriers* by combining them with existing *barriers* to reduce noise. Another way that can be done to reduce noise is by combining glass doors with doors following the architectural style that is in line with the architectural style of GKJ Bandung. Glass doors are considered to be able to keep the noise level entering the place of worship low but also still maximize the visual connection between the people on the terrace and the worship activities in the church. [7]. To get clearer results about the acoustic quality at GKJ Bandung, the next step is verification by analyzing the *reverberation time (RT)* with the help of *Autodesk Ecotect 5.50 software.*

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4.2 Acoustic Quality

(a) (b)

Figure 5. Loudspeakers positions (a) first floor; (b) second floor.

The Christian Javanese Church has 6 loudspeakers as sound sources. In the simulation conducted using Ecotect, the delay time value at the first reflection at a frequency of 1kHz is 16.5 ms - 35 ms at the audience's listening point. That means that the sound heard by the audience is not uniform, and there are even some spots that get mediocre or unclear sound [13].

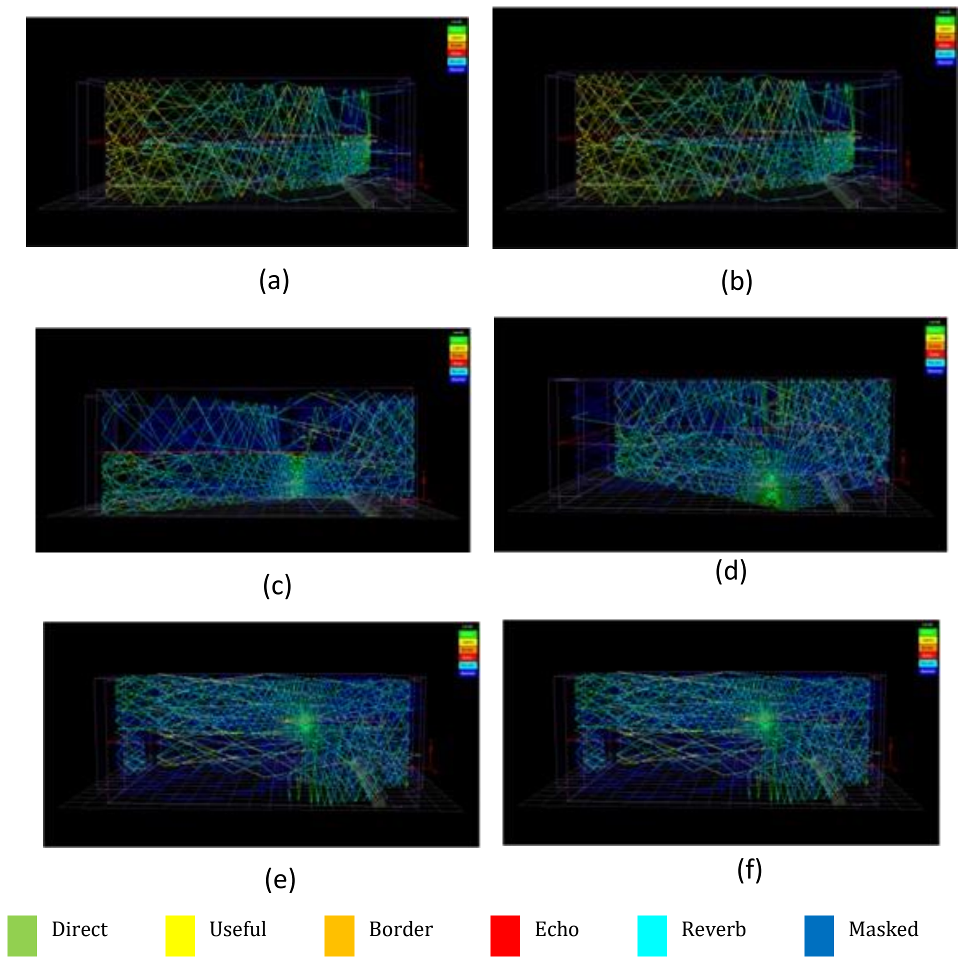

Figure 6. (a) Sound Spread Loudspeaker 1; (b) Sound Spread Loudspeaker 2; (c) Sound Spread Loudspeaker 3; (d) Sound Spread Loudspeaker 4; (e) Sound Spread Loudspeaker 5; (f) Sound Spread Loudspeaker 6.

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Figures 6(a), 6(b), 6(c), 6(d), 6(e), and 6(f) show the spread of sound by six loudspeakers facing the main room, namely loudspeakers 1, 2, 3, 4, 5 and 6 with the setting of generate rays using a circular pattern, angular increment of 5.0°, and bounces as many as 10 bounces.

Table 2. element of interior furniture in the church

No.	Object	Materials	Number
1.	Walls	Brick plastered + paint	
2.	Floor	- Ceramic 20 x 20 cm white - Rug	
3.	Ceiling	- Gypsum board - Wooden Frame - Iron	
4.	Column	Concrete + paint	17
5.	Door	Wood + polintur	8
6.	Window	Wooden frame + carved glass	38
7.	Pulpit Table	Wood + polintur	1
8.	Pulpit Chair	Wood + polintur	1
9.	Table of the Word of	Wood + polintur	1
10.	Congregational chairs	Wood + polintur	94
11.	Speaker	Speaker	6
12.	Musical instruments	Mic, keyboard, etc.	1

Table 3. Sound absorption coefficient based on Satwiko & Doelle

No.	Materials	Sound Absorption Coefficient				
		125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz
1.	Brick wall with plaster	0.01	0.02	0.02	0.03	0.04
2.	Inner room carpet	0.01	0.05	0.10	0.20	0.45
3.	Concrete block, painted	0.10	0.05	0.06	0.07	0.09
4.	Glass, weight (widt)	0.18	0.06	0.04	0.03	0.02
5.	Glass, regular window	0.35	0.25	0.18	0.12	0.07
6.	Gypsum board 1 layer, 5/8" thick	0.55	0.14	0.08	0.04	0.12
7.	¼" thick wood	0.42	0.21	0.10	0.08	0.06

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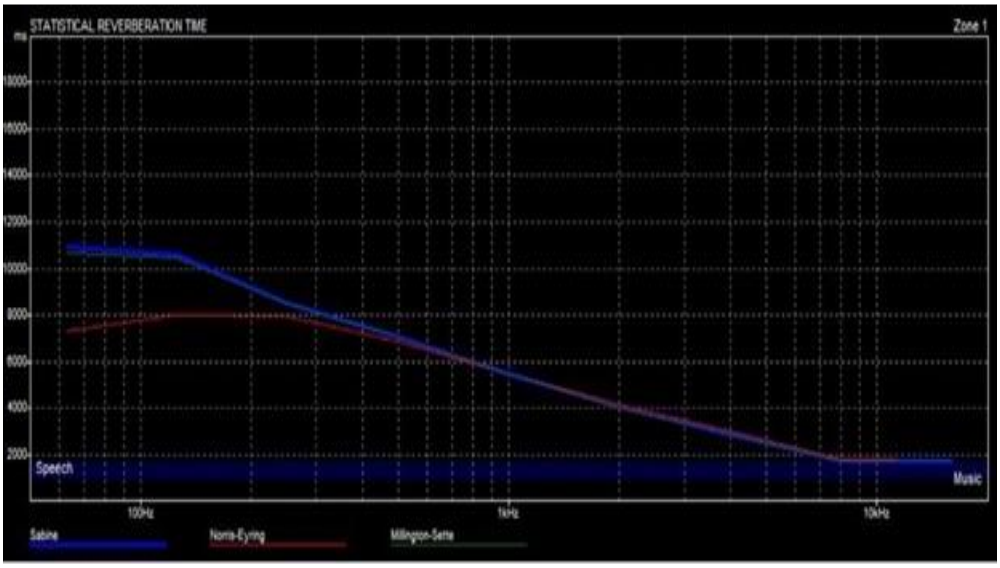

Figure 5. Reverberation Time (RT) Simulation Graph using Ecotect Software

Figure 5 shows the graphic of reverberation time simulation using ecotect software and sabine algorithm for 700 audiences capacity with 0% occupied and using a hard-backed chair in the church. The simulation result shows that the optimum RT for speech in 500 Hz frequency is 0.82s, and the optimum RT for music in 500 Hz frequency is 1.44s.

Table 4. Ecotect Reverberation Time (RT) Simulation Result Data for GKJ Bandung.

Frequency	Total Absorbtion	Sabine RT (60)	NOR-ER RT (60)	MIL-SE RT (60)
63 Hz	25.168	10.93	7.32	10.66
125 Hz	17.626	10.59	7.99	10.46
250 Hz	10.307	8.53	7.95	8.51
500 Hz	7.793	7.08	6.87	7.07
1 kHz	10.558	5.47	5.46	5.46
2 kHz	13.323	4.05	4.12	4.05

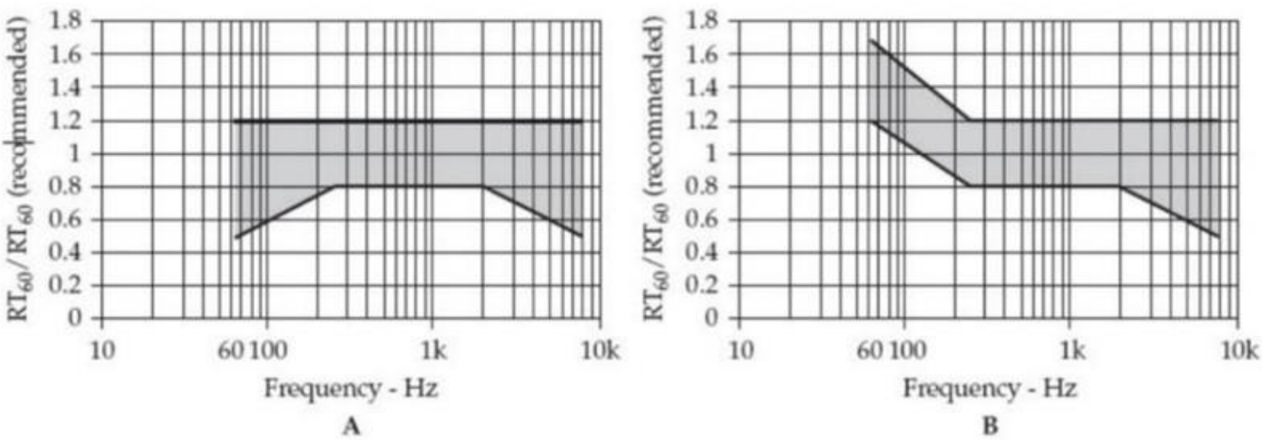

Figure 6 (A) & (B). RT Speech and Music Standards

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From the simulation results, it can be seen that the *Reverberation Time (RT)* value at the Bandung Javanese Christian Church (GKJ) in the range of 63 Hz - 2 kHz, with a church capacity of 700 people and 0% *occupancy* exceeds the established standards. This has an impact on the acoustic quality of the space, especially on the reception of *direct sound* if in worship activities there are speeches or singing. The fact that the RT value obtained exceeds the standard can result in a *delay* in the reception of sound generated from the sound source to the *audience* (congregation) which can produce *echo* so that the sound received by the *audience's* ears is not good. The RT value that far exceeds the standard can be caused by the curvy shape of the building and also the use of construction materials in spaces that are more *absorbent*. [14]

The shape and pattern of the ceiling also greatly affect the level of *loudness* in the Church because it can enrich the useful initial reflection pattern. This is because the ceiling is the most extensive *reflector* (sound reflecting field) when compared to other fields such as side walls that cover the surrounding area. [15]. Some ways that can be done to reduce the RT value are by changing the ceiling material or changing its height and shape.

5. CONCLUSION

In the process of designing a place of worship such as a church, it is necessary to analyze its acoustic quality first so that when carrying out religious activities, the quality of the sound produced can be heard optimally by the congregation in attendance. In accordance with the noise standards set by the state in the Decree of the Minister of Environment KEP-48 / MENLH / 11/1996, it is stated that the noise limit in places of worship is at 55 dB. From the results of calculations, measurements, and simulations using *ecotect 5.50 software* on sound quality in the Javanese Christian Church (GKJ) Bandung, it can be concluded that the noise level in the room exceeds the standard with an average of 58.9 dB with the highest noise value of 74.9 dB.

In addition, the *reverberation time (RT)* value at GKJ Bandung also still exceeds the established standards. This indicates that the acoustic quality at GKJ Bandung is not good. Some ways that can be done to improve the acoustic quality is by combining *reflective* and *absorptive* materials that follow the shape of the church and can reflect or muffle sound as needed as well as by installing a combination of *barriers* made of plants such as shrubs or shrubs to reduce noise entering the room.

REFERENCES

1] P. Domenighini, E. Belloni, C. Buratti. (2023). Experimental subjective and objective analysis of speech intelligibility and acoustic comfort conditions in an unchanged XVII century Italian church. *Applied Acoustics,* 205. https://doi.org/10.1016/j.apacoust.2023.109267.

[2] Kostia, Z. Y., & Kusnaedi, I. (2022). Review of Acoustic Comfort in Hotel Rooms at The Papandayan Bandung. *REKAJIVA Journal of Interior Design*, 1(2), 59 - 67.

[3] Sangkertadi & Manganguwi, R. (2021). Noise Level and Sound Propagation Due to Outside Sound at the Church of the Gospel of Minahasa (GMIM) Unsrat Campus and GMIM Bethesda Manado. *Scientific Journal of Science,* 21 (2), 130-136.

[4] Istiadji, A. D., & Binarti, F. (2016). Ecotect Simulation Study as Auditorium Acoustic Redesign Approach. *DIMENSI (Journal of Architecture and Built Environment).*

[5] Lisyana, & Indrani, H. C. (2013). Study of Acoustic System in the Catholic Church of Santa Maria Tak Bercela Surabaya. *INTRA JOURNAL,* 1(2), 1- 7.

DOI: https://doi.org/10.17509/ jodie.v4i1.67500
p- ISSN 2798-2246 e- ISSN 2798-2165

[6] Zuckerwar, A. J. (2003). Acoustical Measurement. *Encyclopedia of Physical Science and Technology,* 3(1), 59 - 60.
[7] Ahnert, W., & Tennhardt, H. P. (2008). Acoustics for Auditoriums and Concert Halls. Routledge.
[8] Ola, F. B. (2022). Acoustic Design in Historic Buildings. *E-DIMAS: Journal of Community Service,* 13 (1), 53 - 61.
[9] Beranek, L. L., & Mellow, T. J. (2012). Room Design for Loudspeaker Listening. *Acoustics: Sound Fields and Transducers.*
[10] Indrani, H. C. (2004). Effect of Interior Elements on Auditorium Acoustic Characteristics. *INTERIOR DIMENSION*, 2 (1), 66 - 79.
[11] Arikunto, S. (2006). *Research Procedures (A Practice Approach).* Jakarta, Rineka Cipta.
[12] Indonesian's Minister of Environment no.48. (1996). *Noise Level Standards.*
[13] Tohyama, M. (2023). *Spectral and temporal effects of signals on speech intelligibility Acoustic Signals and Hearing.* Academic p. (2020), pp. 63-88. https://doi.org/10.1016/b978-0-12-816391-7.00012-7

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