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Reverberation Time Analysis in the Makassar Grand Mosque

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Abstract

Mosque as a place of worship for Muslims demands to provide the maximum comfort for its users to make worship more solemn. In fact, many mosques do not pay attention to the comfort of the room, including the acoustic design. This research was conducted using I-SIMPA software, a software used to perform acoustic simulations involving geometric and acoustic parameters on architectural elements in the room with the aim of analyzing the reverberation level in the Makassar Grand Mosque space. The result obtained from analysis on the first floor shows the lowest reverberation time (RT) for 1.13 seconds at points 5, 6, and 8 at 8000 Hz. Moreover, the highest RT is 4.1 seconds at point 5 at 250 Hz and points 2 and 6 at 500 Hz which is exceeds the standard of recommended RT. On the second floor, The lowest RT is 1.38 seconds at point 1 at 8000 Hz and the highest is 4.86 seconds at point 3 at 1000 Hz. The reverberation time in second floor is longer compared to the first floor due to the volume and shape of the room.

Keywords: *acoustics performance, accoustic simulation, I-SImpa, Mosque room, reverberation time*

Introduction

Mosque is one of the buildings that must be considered for the quality of its function because the acoustic quality of the mosque will affect the understanding of the content of lectures in an activity (Yani, 2021). The mosque building is a valuable asset for Muslims. All functions and benefits are in the mosque building, from the profane aspect to the transcendent (Mulyadi et al., 2021). There are three main activities carried out in the mosque room, namely congregational prayers, delivering sermons, and listening and reading verses from the Qur'an (Gumelar, Pauzi, & Surtono, 2018). Eventough, many mosques applied modern designs, unfortunately there are mosques that only pay attention to the exterior and interior beauty but not to the acoustic design. Thus, most of mosques in Indonesia do not have a good acoustic performance (Syamsiyah, Utami, & Dharoko, 2014).

Noise is closely related to the health of one's sense of hearing and one's body and soul (Siska, 2015). As a place of worship, Muslims demand to provide the maximum possible comfort for its users so that the comfort of the worship space can make worship more solemn. One of the factors that can affect the level of comfort is the sound field. (Dewi & Syamsiyah, 2020). erdThe acoustic quality in a mosque is determined by the sound field that is formed in it and is influenced by the characteristics and placement of the sound source installed in it. Almost all mosques use a sound amplifier system to increase the energy of the sound scattered in the room (Mubarok, Suprayogi, & Prawirasasra, 2017). To produce a good mosque sound system requires a good planning as well. Every mosque is unique in terms of acoustics, so various alternative speaker installations should be tried to produce optimal sound (Taufik et al., 2021).

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This study focused on the acoustic system in the form of a reverberation level in the Makassar Grand Mosque room. This research is expected to be able to answer problems and find solutions for better improvements in the future to make the Makassar Grand Mosque maintain and pay attention to the level of user comfort and the role of the mosque itself.

Literature Review

Sound can literally be interpreted as something we hear. Sound is the result of vibrations of particles in the air, and the energy contained in sound can increase rapidly and can travel great distances (Nasution, Wahab, & Nuari, 2018). Noise is an unwanted sound because it is not in accordance with the context of space and time, so it can cause disturbances to human comfort and health (Ellizar, 2018). Acoustics is defined as something related to sound, as Shadily (1987) said that acoustics comes from an English word: acoustics, which means sound science. Acoustics is the science of sound systems and the overall effects that sound has on the audience (Sutanto, 2015).

Reverberation Time (RT) is the time required for sound to decay from 60 dB to 0 dB, which is calculated in units of seconds. Factors that affect the RT are the volume of space, the capacity of the congregation, and the absorptive or reflective scope (Sabtalistia, 2020). Following is the value of the RT range in several spaces shown in Table 1.

Table 1. RT range value in some rooms

Space function	Recommended RT number range (second)
Recording studio	0.4 – 0.6
Elementary School Classroom	0.5 – 0.9
Meeting room, courtroom	0.7 – 1.2
Cinema	0.8 – 1.2
Multipurpose Auditorium	1.0 – 1.4
Church, Mosque	1.2 – 1.8
Catedral	2.0 – 3.0
Opera House/Theatre	1.2 – 1.6

Source: Sangkertadi (2006)

Soegijanto (2001) classifies the acoustic performance of mosques in Indonesia into five acoustic requirements, namely: clarity of sound loudness level, even distribution of sound, and optimization of reverberation time.

Sound clarity is a major acoustic concern and requires the designation of appropriate volumes, main chamber geometries, and proper use of acoustic-absorbing and diffusing materials as surface finishes. Gül, & Çalıskan (2013) stated that the acoustic design should be integrated into the architecture in the early stages of the mosque concept design. During schematic design, major geometric shapes are generated, and materials are selected to solve aesthetic and acoustical problems (Othman et al., 2016).

Table 2. Room acoustic parameters and allowable limits (occupied space)

Parameter	Recommended range for given volume	Just noticeable difference
T30 (for 500-1000 Hz)	115 s (for speech only to 1.96 s (for religious music)	About 0.1 s
C80 (for 500-1000 Hz)	0-9 dB (for speech + music) – 2 dB to 2 dB (for music)	1 dB
STI	Greater than 0.60	0.05
STL-A	Minimum variations in SPL < 10 dB	2 dB

Source: Gül, & Çalıskan (2013)

From an acoustic point of view, the two determinants of this spatial fragmentation are the location of the sound source, which is associated with the position of the sound source. Acoustically responds to Islamic liturgical requirements and provides living spaces that promote a sense of the majesty of these spaces without the exaggerated echoes that their larger volumes imply (Suárez, Alonso, & Sendra, 2018)

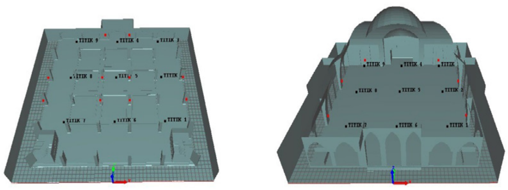
Ismail (2013) found that most contemporary mosques have sound-reflective materials on most of their internal surfaces, except on the floor and on horizontal surfaces, which are usually covered with carpet. Doors are made of wood, and large openings may be made of a single glass. The placement of a central cooling unit or a separate stand-alone unit within the designated space or on the roof amplifies the background noise level within the prayer area and affects the acoustic serenity of the room (Othman et al. 2016). (Table 3)

Methodology

This research method uses a simulation method which is defined as a dynamic system that uses a computer model with the aim of evaluating and improving system performance. Simulation activities are carried out using I-Simpa software to determine the level of reverberation that occurs in the Great Mosque space generated by speakers. In this application, the steps taken are:

1. Scene data. In this scene data, surface material setting, surface receivers setting, sound sources, and punctual receivers were done.
2. The simulation process was carried out on surface receivers (Hz) 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz receiving point.
3. Doing output Reverberation Time (T30).

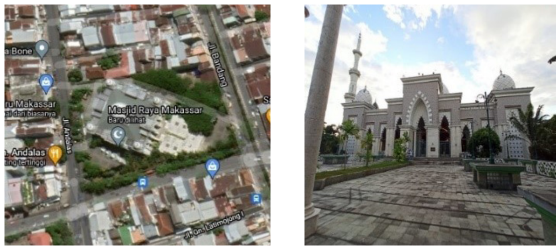
Figure 1. Simulation I-SImpa (a) Floor 1 (b) Floor 2
Source: Author, 2021



(a) (b)

Then proceed with analyzing the data. The research location is the Makassar Grand Mosque which is located on Jl. Makassar City Grand Mosque. The Makassar Grand Mosque has a building coverage area of 10,500 m2, and the total area is 17,000 m2. It has a congregational capacity of 10,000 people.

Figure 2. (a) Location and (b) Makassar Grand Mosque Building
Source: Author, 2021



(a) (b)

The location of the measurement points for the mosque room consists of nine measuring points for the first floor and nine measuring points for the second floor using the grid method. Three measuring points are located in the back row, three measuring points in the middle row, and three measuring points in the front row. The height of the measuring points is set to 1.20 m according to the recommended height standard, and the distance between the points is set to 8 m.

Figure 3. Place the measuring point on the first floor
Source: Author, 2021

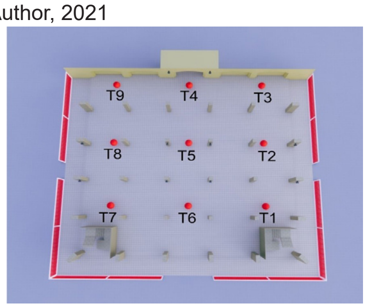
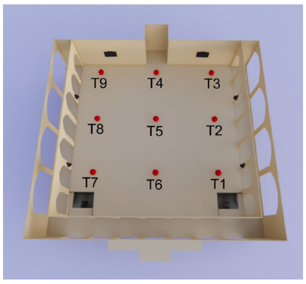


Table 3. Sound Absorption and Scattering coefficient of materials

Material	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz	8 kHz	Scattering factor
Sandblasted travertine	00.1	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.15
Solid timber door	0.14	0.14	0.10	0.06	0.08	0.10	0.10	0.10	0.25
Double glazing	0.10	0.10	0.07	0.05	0.03	0.02	0.02	0.02	0.10
Single pane of glass	0.08	0.08	0.04	0.03	0.03	0.02	0.02	0.02	0.10
ceramic tiles	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.15
2 x 13 mm gypsum. Board on frame, mineral wool backing in 50 mm cavity	0.15	0.15	0.10	0.06	0.04	0.04	0.05	0.05	0.10
12 mm wood on studs	0.28	0.28	0.22	0.17	0.09	0.10	0.11	0.11	0.10
Perforated MDF Panel-top acoustic 5/3T, thickness (1.6 cm) with mineral wool backing in 200 mm cavity (130m2 in total) or equivalent	0.20	0.30	0.80	0.95	1.00	0.80	0.60	0.60	0.10

Source: Gül, & Çalıskan (2013)

Figure 4. Place the measuring point on the second floor
Source: Author, 2021



Results and Discussion

1. Plans and sections of the Makassar Grand Mosque

The Makassar Grand Mosque consists of two floors. The detail of floor plans for the 1st and 2nd floors can be seen in Figure 5 and figure 6, as well as sections of the Makassar Grand Mosque in Figure 7 and Figure 8.

Figure 5. 1st Floor Plan

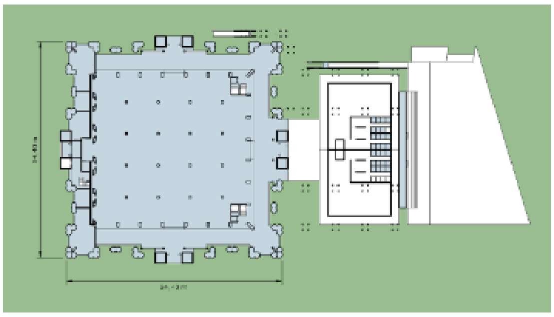


Figure 6. 2nd Floor Plan

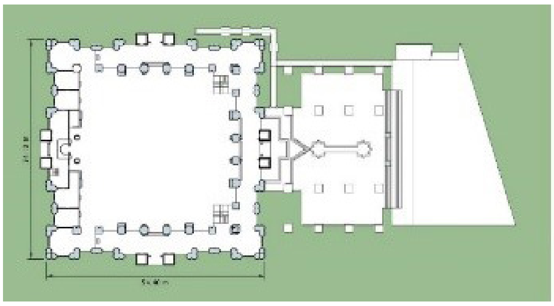


Figure 7. Section A

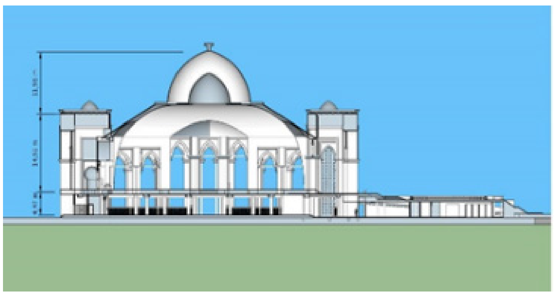
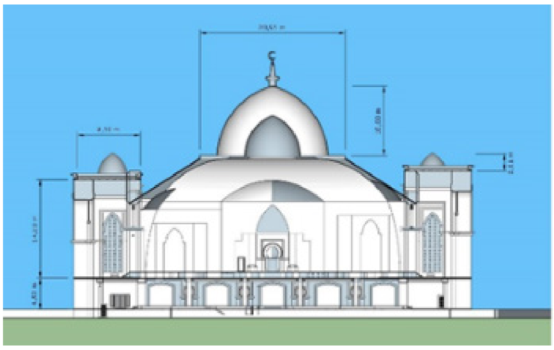


Figure 8. Section B

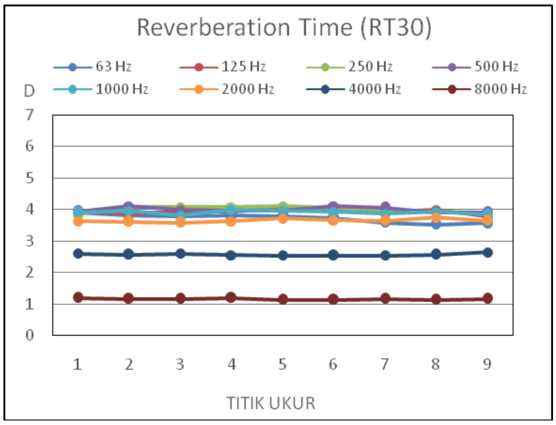


2. Simulation Reverberation Time (RT30)

Reverberation Time (RT) simulation at the Makassar Grand Mosque was measured at 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz. Speakers were placed on a height of 2.20 m and nine measuring points with 15 m spaces using the grid method placed on a height of 1.20 m.

The first-floor measurement uses ten speakers, which are adjusted to the number and placement of speakers in the mosque. From the results of the Reverberation Time (RT30) measurement on the first floor, the reverberation produced at each measurement point has a different time, the lowest is 1.13 seconds at points 5, 6, and 8 at 8000 Hz, and the highest is 4.1 seconds at point 5 at 250 Hz and points 2 and 6 at 500 Hz exceed the recommended standard for reverberation time (RT). This is because the room is large, and the type of material used has a smooth and solid surface, which is not good for sound absorption and produces a lot of sound reflections that cause a longer reverberation.

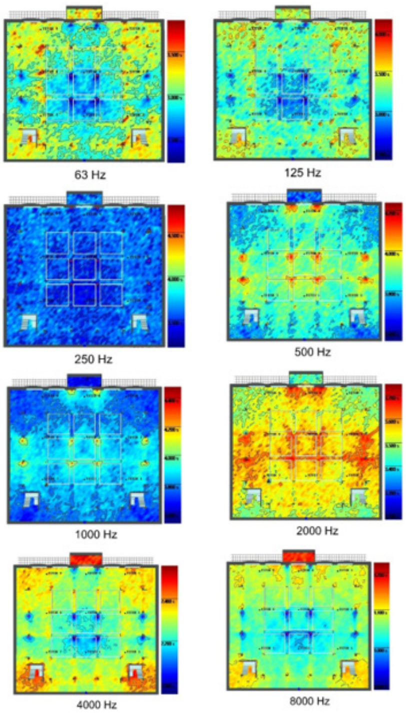
Figure 9. First Floor RT Graphics
Source: Author, 2021



In the graph above, the reverberation time at each measurement point as a whole almost has the same time in each (Hz). The lowest reverberation time is at 8000 Hz for 1 second, and the highest is at 63 – 2000 Hz, which is buzzing for 4 seconds.

The simulation of the contour pattern on the first-floor room aims to provide an overview of the pattern of sound distribution produced by the speakers and describe the pattern of Reverberation Time (RT30) in the room. In each contour pattern at each (Hz), the distance between the contour colors is 0.500 seconds. (Table 4)

Figure 10. Floor RT30 Contour Pattern
Source: Author, 2021



On the 1st floor, at 63 Hz, 125 Hz, 4000 Hz, and 8000 Hz, the lowest reverberation time is in the center of the room. For 250 Hz, the hum is almost evenly distributed, but at 500 - 2000 Hz, the center of the room has a longer reverberation.

On the second floor, measurement using six speakers, which are adjusted to the number and placement of speakers at the Makassar Grand Mosque. From the results of the Reverberation Time (RT30) measurement on the second floor, the reverberation produced at each measurement point has a different time, the lowest is 1.38 seconds at point 1 at 8000 Hz, and the highest is 4.86 seconds at point 3 at 1000 Hz exceeds the recommended standard for reverberation time (RT30). And the reverberation time is longer than on the first floor. This is because the room is taller than the first floor, then it is also influenced by the ceiling form factor that uses the dome model. Also, it utilizes the same type of material used on the first floor, which has a smooth and solid surface.

Figure 11. Second Floor RT Graphics
Source: Author, 2021

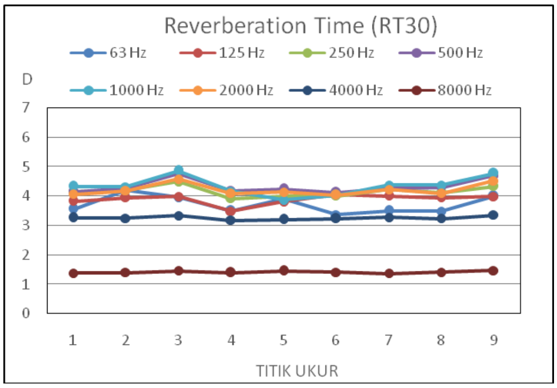


Table 4. First floor RT30 Analysis

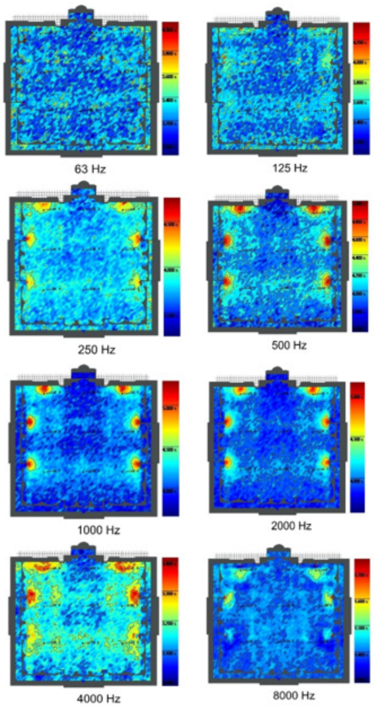
Frequency	T1	T2	T3	T4	T5	T6	T7	T8	T9
63 Hz	3,89	3,82	3,77	3,8	3,79	3,73	3,58	3,52	3,56
125 Hz	3,94	3,87	3,93	3,94	4,05	3,96	3,94	3,98	3,78
250 Hz	3,84	4,07	4,07	4,08	4,1	4,06	3,96	3,93	3,89
500 Hz	3,94	4,1	3,99	3,95	3,96	4,1	4,06	3,91	3,91
1000 Hz	3,91	3,95	3,81	3,98	3,96	3,93	3,86	3,92	3,85
2000 Hz	3,63	3,61	3,58	3,63	3,71	3,66	3,64	3,74	3,64
4000 Hz	2,6	2,56	2,6	2,55	2,54	2,53	2,54	2,56	2,64
8000 Hz	1,18	1,16	1,15	1,19	1,13	1,13	1,15	1,13	1,16
Average	3,37	3,39	3,36	3,39	3,41	3,39	3,34	3,34	3,30

Source: Author, 2021

In the graph above, the reverberation time at each measurement point as a whole almost has the same time in each (Hz). The lowest reverberation time was at 8000 Hz for 1 second, and the highest was at 1000 Hz, which buzzed for 4 seconds.

The simulation of the contour pattern on the second-floor room aims to provide an overview of the distribution pattern of the sound produced by the speakers and describe the Reverberation Time (RT30) pattern in the room. In each contour pattern at each (Hz), the distance between the contour colors is 0.200 seconds. (Table 5)

Figure 12. Contour RT30 pattern on the second floor
Source: Author, 2021



On the second-floor contour pattern, the reverberation time that occurs at every Hz is almost evenly distributed when viewed from the color pattern from the simulation results, which shows the spread of reverberation that occurs at each (Hz) is the same.

Based on the analysis of the results of research on Reverberation Time (RT30) at the Makassar Grand Mosque for the first and second floors, it is considered not good because exceeding the recommended conversational reverberation time standard, which is <1.30, especially on the second floor which has a very high reverberation time this is due to the large space factor where the room is 1,600 m2 and the shape of the room design. Because the second floor uses a dome-shaped ceiling which is higher than the ceiling on the first floor, which uses a trapped ceiling with a height of 3.5 to 4 m.

On the first floor, the lowest reverberation was 1.13 seconds at points 5, 6, and 8 at 8000 Hz, and the highest was 4.1 seconds at point 5 at 250 Hz and points 2 and 6 at 500 Hz exceeding the recommended standard for reverberation time. (RT). On the second floor, the lowest reverberation was 1.38 seconds at point 1 at 8000 Hz, and the highest was 4.86 seconds at point 3 at 1000 Hz. And the reverberation time is longer compared to the first floor.

The solution given by the researcher to this problem is by adding carpet material to the floor in order to reduce the reverberation time in the Makassar Raya mosque room because this type of carpet material has a very good absorption of sound.

Table 5. Second floor RT30 Analysis

Frequency	T1	T2	T3	T4	T5	T6	T7	T8	T9
63 Hz	3,56	4,2	3,96	3,5	3,91	3,37	3,5	3,49	4,01
125 Hz	3,83	3,95	3,99	3,48	3,82	4,07	4	3,94	3,99
250 Hz	4,16	4,2	4,49	3,92	3,99	4,01	4,24	4,12	4,33
500 Hz	4,15	4,26	4,76	4,19	4,24	4,12	4,26	4,3	4,7
1000 Hz	4,33	4,32	4,86	4,17	3,87	4,03	4,38	4,38	4,78
2000 Hz	4,07	4,19	4,59	4,1	4,14	4,03	4,23	4,1	4,52
4000 Hz	3,26	3,25	3,34	3,18	3,2	3,23	3,28	3,24	3,36
8000 Hz	1,38	1,4	1,46	1,39	1,45	1,41	1,37	1,41	1,47
Average	3,59	3,72	3,93	3,49	3,58	3,53	3,66	3,62	3,90

Source: Author, 2021

Conclusion

From the analysis results, there is a problem with the reverberation time, which causes the acoustic quality of the Makassar Grand Mosque to be less good, where the reverberation time produced by the speakers is too long and exceeds the recommended standard because the type of material used in the Great Mosque of Makassar is not suitable for acoustic absorption so that there are many sound reflections that spread in the room which can interfere with the comfort of hearing the room users.

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