

# Evaluation of acoustical comfort in mosque

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**Abstract.** There are various worship activities held at mosque, such as reciting, prayers and Friday sermon and acoustically, it is categorized as speech. Syamsul Ulum Mosque (MSU) located at Telkom University, Indonesia was taken as an object for research since there were no information nor historical data about actual acoustic condition and acoustical design. Main hall, considered as primary venue, is taken as analysis area. Measurement covers only speech-related objective parameters; reverberation time (RT), Definition (D50), Sound Strength (G) and Noise Criteria (NC). Furthermore, identification of proper area-for-speech activity and uniformity of distribution energy of impulse response parameters is illustrated by map contour. Since there is some value at certain areas does not have value within recommendation range, the main hall of MSU is inappropriate venue to accommodate worship activities.

## 1. Introduction

Mosque is foremost place of worship for Muslims and various activities are using it as a venue. Basically, there are three routine worship acoustic-related activities held at mosque: audibility of prayer order, listening & understanding speech during sermon and listening and/or reciting verses from Holy Quran [1]. All these activities require a high level of speech audibility and intelligibility because it is directly related to devoutness of followers.

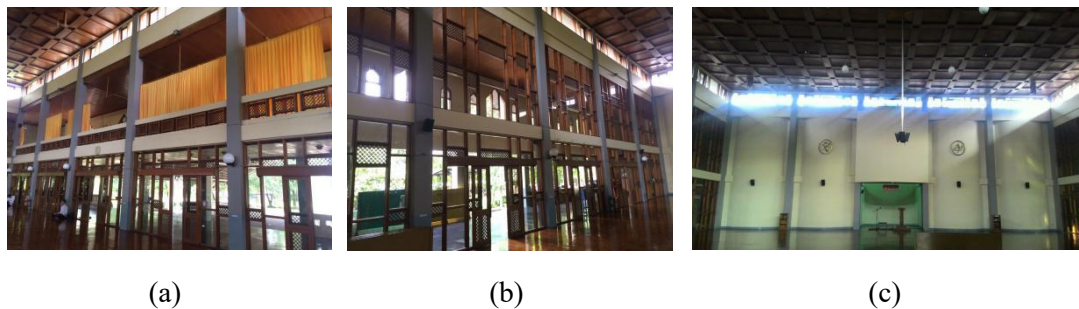
According to previous research, acoustic requirements to be fulfilled are sufficient loudness, prevalent sound distribution, optimum reverberation time, low background noise, and high speech intelligibility [2]. Those conditions are quantified into objective parameters such as sound pressure level ( $L_p$ ), Reverberation Time (RT), Sound Strength (G), Noise Criteria (NC) and Definition (D50). The objective of this research is to measure objective parameters at mosque and compared it with recommendation value for speech activities hence actual acoustic condition of object study is identified.

## 2. The object study

Object of this research is Syamsul Ulum Mosque (MSU) which is located at Telkom University, Indonesia. MSU consist of two floor but area of 2<sup>nd</sup> floor is lesser than 1<sup>st</sup> floor so there are void inside mosque. Focus of this research only at 1<sup>st</sup> floor because main activities are located at it. 1<sup>st</sup> floor has square shape with dimension 24x24 m and height around 9 m. There is juttred area in front of hall for prayer leader.

Boundary of mosque dominantly covered by wood material. All floor is made from solid hardwood and so ceiling is. Sun light penetrates into main hall through glasses with wooden frame from right, left and back side of object. The perimeter of front wall is semi ellipsoidal form made of smooth concrete. Interior of main hall is illustrated at **Figure 1**.





**Figure 1.** Main hall of MSU. (a). rear view, (b). right side view and (c). front view.

### 3. Measurement

Data is taken by using microphone, DAQ, omnidirectional speaker and personal computer. Speaker was located at front of main hall while position of microphone represents audience position. During Friday sermon, main hall is fully occupied by around 200 persons so measurement must to cover all observer area. It was accommodated by took sample from 56 different position with certain configuration. Measurement point has distance around 3 m between point and 2 m from point to the nearest wall. The height of receiving sensor was set to 75 cm or height of human ear in seating position.

Sound source is fed by signal impulse and located at front of main hall. The decaying sound that emitted from source is captured as impulse response. Each parameter is calculated from impulse response with one-octave filter from 125-4000 Hz [3]. Reducing noise exposure to sensor is very critical, as consequence, measurement was taken at night while there were nearly no activities in nearby environment.

### 4. Result

As basis of reference for speech activity, the object is expected to have result within recommendation value as presented at **Table 1** Measurement results are presented in two type a) statistical value (mean, maximum, minimum and standard deviation) and b) contour map. By presenting both, the variation value and its position is visualized. For contour map, area for leader prayer is excluded.

**Table 1.** Recommendation value [4][5].

Parameter	Value
RT	0.6-0.7 s
NC	25-30
G	>0 dB
D50	>0.86

#### 4.1. Background noise

Background noise measurement was taken at several position in order to get the largest value of sound level pressure for each middle frequency plotted at NC curve. Since there were no significant activities around object and no active mechanic & electronic devices inside mosque, practically energy level of noise was low and it shown by value of NC is 25.

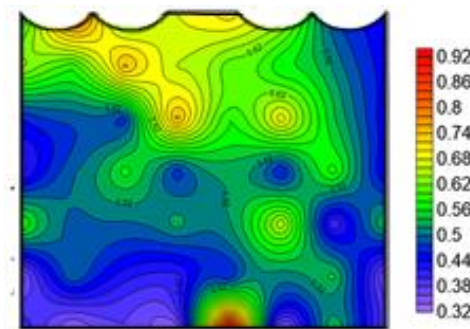
#### 4.2. Reverberation time

The definition of reverberation Time (RT) is time it takes for a room to diminish sound energy by 60 decibels [6]. This parameter is very important and being used as baseline for designing room whether

for speech or music. In subjective perspective, RT is perceived as ‘dead’ or ‘live’ room. Room with long reverberation time is perceived as ‘live’ while short time ‘dead’. The measurement result of RT is plotted at Table 2 and the energy distribution pattern from RT parameters can be seen on contour map at Figure 2.

**Table 2.** Measurement result of reverberation time.

Category	Value (s)
Average	0.51
Max	0.82
Min	0.33
Standard deviation	0.10

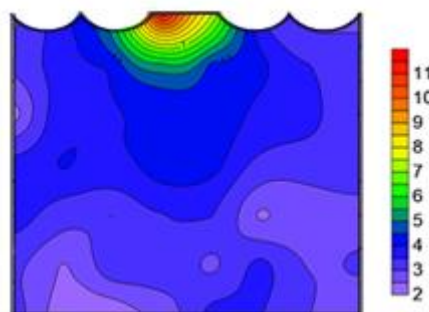


**Figure 2.** Contour map of reverberation time.

Comparing measurement result at **Table 2** with recommendation value, most area is categorized as ‘dead room’ and acoustically does not suitable condition for speech activities. According to Figure 2, the best positions for listening activity are at front near prayer leader, middle and rear area while the rest is inappropriate for listening activities.

#### 4.3. Sound strength ( $G$ )

By definition, sound strength ( $G$ ) is the comparison of received energy to energy of direct sound at 10 m from sound source. Whenever energy of direct sound is larger than total energy,  $G < 0$  dB, it means acoustical characteristics tend to absorb energy. That is unexpected condition and every measurement points have to be larger than 0 dB [7]. Material surfaces of MSU is quite reflective, it is demonstrated by value of  $G$  larger than 0 dB. Illustration of  $G$  contour is at Figure 3.



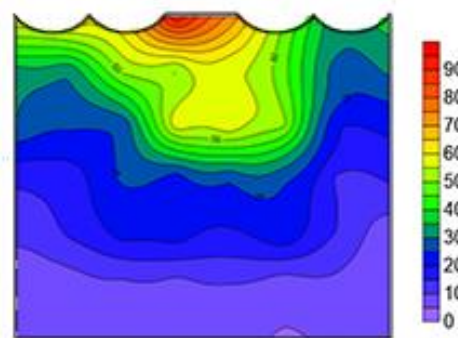
**Figure 3.** Contour map of sound strength.

#### 4.4. Clarity (D50)

Clarity or D50 is defined as ratio of early reverberant energy after direct sound to total energy received [8]. For speech, energy of early reverberant in first 50 ms has significant impact to intelligibility. Table 3 shows the value of D50 parameter, representing statistical data from all measured points. There are positions with value larger than 75% but as most data is scattered around 19.97% from 24.24 %, it indicates that most area of main hall has ‘good’ category of speech intelligibility. The position of each value could be accessed at Figure 4.

**Table 3.** Measurement result of clarity.

Category	Value (%)
Average	24.24
Max	90.76
Min	5.32
Standard deviation	19.97



**Figure 4.** Contour map of clarity.

## 5. Conclusion

The conclusion of this research have found that MSU have improper acoustic condition to perform speech activities. The result of acoustic parameters measurement shows the average value of RT is 0.51 s, 24.24 % of D50 and G is larger than 0 dB in all receiver position. According to recommendation value, impulse response based parameters (RT and D50) do not fulfil the minimum threshold. Only certain position meets the requirements, especially at front row (near podium). However, there is good thing about acoustic performance at MSU is the boundary has sufficient characteristic to reflect acceptable energy across main hall. Also, background noise is very low so the change of sound masking is nearly zero.

## References

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