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Towards Safe Cities & Resilient Communities

13 & 14 SEPTEMBER 2018
IMPIANA HOTEL, IPOH, PERAK

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AN ASSESSMENT OF SPATIAL COMFORT OF ANCIENT INDRAPURI MOSQUE IN ACEH BESAR, INDONESIA

Laina Hilma Sari[1,2]*, Izziah[1], Erna Meutia[1,2], Zulfian[2]
[1]Architecture and Planning Department, Syiah Kuala University, Indonesia
[2]Center for Thermal, Vibration and Applied Acoustic Studies, Syiah Kuala University, Indonesia

Abstract – This paper aims at assessing the spatial comfort of the ancient Indrapuri mosque including thermal, daylight and acoustic performance. This ancient mosque is located in Aceh Besar and built in the 12th century. The facade has been maintained and conserved. However, some conservation steps were shifted from the principle ones such as using traditional techniques and materials. The data werecollected through survey and mechanical measurement. The results showed that some replacements are needed due tosome spatial discomforts such as higher indoor thermal performance. It is indicated in Olgyay's bioclimatic chart which also shows that the air movement should be increased to reach the comfort zone. The mosque acoustic performance has slightly high background noise,while,the sound pressure level and reverberation time still meet the standard. The daylight remains good shown by none of electrical light switched on during the day including daytime prayer i.e. Zuhr (1 pm) and 'Ashr (4 pm).
Keywords – Old mosque, Thermal Comfort, Acoustic, Daylight

1 INTRODUCTION

Indrapuri mosque is an ancient mosque located in Great Aceh district. The mosque area was initially built in 12th century as the temple of Indrapuri Kingdom. Previously the temple was also well-known as the fortress of the Hindus people. When Islam came to Indrapuri, Sultan Iskandar Muda converted the Hindu kingdom to be Islamic (Disbudpar, 2015). The temple area with stepping terrace was also transformed to be a mosque which is called Indrapuri Mosque.

The mosque which is open layout has three tiered roofs which are supported by 36 wooden columns. The roof was initially made from rumbia leaf which provides upper apertures for circulating out the hot air. The western pulpit was built continuously connected to 1.5 m height of stone fence surrounding the layout plan (Meuko, 2015). The open terrace with steps surrounding the mosque creates a magnificent view of the mosque.


Figure 1 Indrapuri Mosque from the old to the present

This mosque is one of the ancient mosques in Aceh which is preserved yet still functioned as the daily worshipping place for Muslims. However, some replacements were applied such as the roof which was converted to be corrugated zinc sheet. The upper aperture between the tiered roofs was sealed with plastic fiber to protect the room from the rain splash. The floor has been plastered with marble which covers the *umpak* foundation causing the poles planted into the ground. At last, the stone wall was partially coated with cement. This study, therefore, assesses the spatial comfort of the mosque including thermal, daylight and acoustic conditions. This performance will benefit some recommendations to approach sustainable historic building conservation.

2 SPATIAL COMFORT AND MOSQUE

The mosque is a sacred place for worshipping (Al-Hamoud, 2009; Saeed, 1996)which serves to express aMuslim presence as a symbol of Islam as well as space forsocial gatherings, education, and community service (Kahera, et.al, 2009). There are many factors contributing to theshaping of the typology, design, and role of the mosque in amulticultural atmosphere (farrag, 2017). One of the factors is spatial comfort which is required in a mosque for the presence of the solemnness to the worshippers (Al-Hamoud, 2009; Saeed, 1996). The spatial comfort in this study comprises good acoustic performance such as well sound level pressure distribution and sufficient reverberation time; thermal comfort criteria; and adequate daylight provision. Meeting the spatial comfort is also a way to conserve the energy in running the building.Therefore, it isquite essential to be carriedout.

Acoustic performance inside the mosque is critical since well sound distribution would increase the solemnness of the worshippers in performing the prayer. In the mosque, the intelligibility of both speech and other sounds areextremely important, especially for holy tones that must be both spacious and effective. Several acoustical parameters govern speech audibility, intelligibility, and spaciousness of sound; the parameters usually employed in the acoustical analysis of mosques are reverberation time, sound pressure level distribution and sound transmission index (Eldien et al., 2012).

Thermal comfort criteria in tropics, i.e., Indonesia refers to the formula of neutral temperature in Indonesia developed by Karyono (2015) which indicates that the comfortable indoor temperature in Banda Aceh and its surrounding is specified in 23.4^0C- 29.7^0C (Sari, 2017). This condition is quite challenging to achieve due to high relative humidity (RH) and high air temperature (Ta). To get such comfortable thermal sensation, high air velocity is needed to reduce the relative humidity which is comfortable at 35% to 70% (Evan, 1980; Humphrey, 1992; ASHRAE, 1992; Karyono, 1996; Szokolay, 1990). The effect of air movement is essential to increase the efficiency of sweat evaporation and thus avoid discomfort due to moisture on the skin. In hot humid climate, the most proper air velocity for day comfort is in the range of 0.10 to 0.40 m/s and, indoor air velocities of 1.0 m/s that are delightful and are acceptable up to 1.5 m/s, above that they are unacceptable (Szokolay, 1990). This condition is accommodated in Olgyay's bioclimatic chart which provides the comfort zone considering the air temperature, relative humidity, and air velocity. The higher air temperature, the higher airspeed should be reaching the comfort (figure 8). As commonly known that the air can be circulated naturally through optimal apertures with the cross ventilation system. Good thermal sensation in tropics can also be obtained by the use of low conductivity materials and light color which has little value of heat absorption (Emmanuel et al., 2007; Sari et al., 2018).

Table 1 Measurable scales of lighting (Arab et.al, 2012)

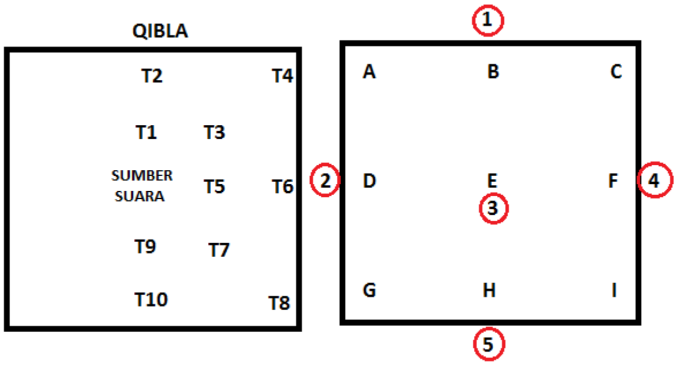
Scale	Illuminance (lux)	Level
1	0 - 19	Total darkness to dark
2	20 - 49	Do not demand a high visibility of the task (public areas)
3	50 - 99	Do not demand a high visibility of the task (orientation during short stop)
4	100 - 199	Do not demand a high visibility of the task (rooms not in permanent use and hallway brightness)
5	200 - 499	Details easy to see at normal brightness for reading or office area
6	500 - 999	Details difficult to see like intricate work for brightness
7	1000 - 1999	Task lighting for highly demanding work - extremely fine details like
8	2000 - 10000	Task lighting for highly demanding work - extremely fine details like special tasks in surgery (10000 lux is maximum brightness from sunlight to indoor area)

9	10001 - 100000	Outdoor area brightness(100000 lux is the maximum measurement)

Building design using daylight system is considered as an excellent passive lighting design. Daylight is lighting obtained from secondary sunlight source. It provides the best source which comfortably matches with human visual response (Arab et al., 2012). To measure the indoor lighting performance illuminance level is utilized. Based on the measurable scales shown in Table1 the illuminance of the mosque should be minimally in scale five which is ranged from 200-499 lux which means that the illuminance quantity is sufficient to easily see or readat normal brightness. In the mosque, the worshippers do not only do salat or prayer, but they also recite AlQuran which needs sufficient light.

3 RESEARCH METHOD

In order to evaluate the quantity and the quality of sound distribution inside the mosque, this study recorded sound pressure level, reverberation time and background noise. The acoustic condition was only measured for one day within the empty room. Omnidirectional speaker (NOR-223) was located in the center of the room which is 1.50m above the ground to represent the condition of standing speech. This speaker provided sound source for calculating the reverberation time (ISO3382) and sound pressure level. The measurement that was carried out on some spots (figure 2) utilized ½ inch microphone as the receiver set on 0.85m above the ground which represented the sitting condition. Before the measurement, the tools were initially calibrated in order to get the correct results. After the measurement of reverberation time and sound pressure level, the background noise was also recorded using RTA 840 and calibrated microphone condenser to identify the room criteria. The tools measured the ambient noise of sound pressure level (SPL) which was also positioned 0.85 m above the ground.



Legend:

T1-T8: Acoustic measurement

A - I : Floor temperature (^{0}C), Illuminance (lux) and Air speed (m/s) measurement

1 - 5 : Surface temperature (^{0}C) measurement

Figure 2 The position of the measurement

Thermal performance was evaluated by utilizing heat stress meter to record Globe temperature (Tg), Air temperature (Ta), and Relative Humidity (RH),while,the surface temperature (0C) of the building envelope was recorded using an infrared thermometer; and Air velocity (m/s) was measured using an anemometer. At last, the illuminance of daylight received inside the mosque (E) was measured using lux meter. The measurement was carried out for one day on May, 3rd 2018.

4 RESULTS AND DISCUSSIONS

4.1 Acoustic Performance

a. Sound Pressure Level

Figure 3 is the contour map of sound pressure level (SPL) which shows the even distribution of SPL in every position in the room. It means that SPL distributions are loud enough to be received by the listener against the background noise. The difference of sound pressure level in every position of the rooms meet the criteria which are less than 10dB of the sound source.

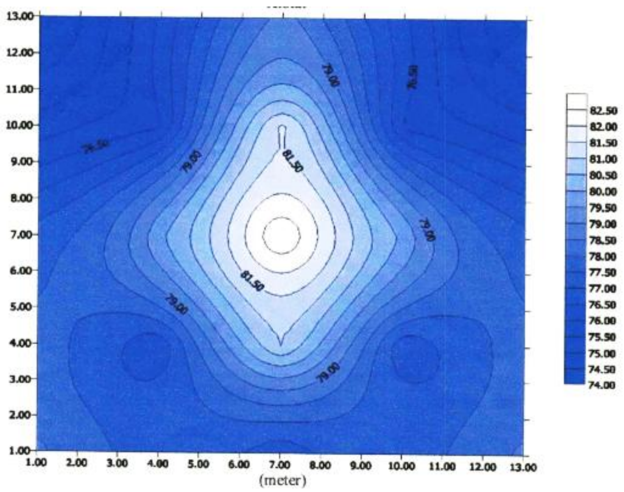
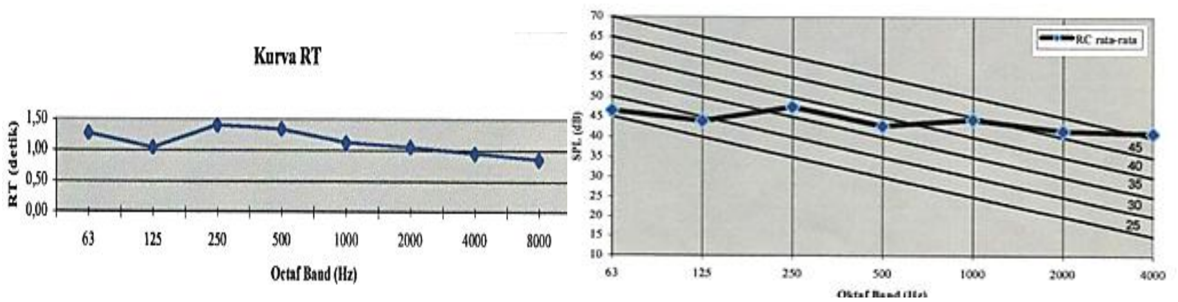


Figure 3 Sound Pressure Level Distribution in Indrapuri Mosque

b. Reverberation Time

The Reverberation Time (RT) curve (Figure 4.a) shows the uneven RT on every frequency for on octave band. It shows that the curve increases in low frequency (125 Hz- 250Hz) which is around 1.0-1.4 second, while in medium frequency the curve decreases to 1.2 second and running down below to 1 second on high frequency (4000-8000Hz). This condition shows an optimal performance of speech room criteria which also justifies an excellent performance of mosque design of Indrapuri Mosque.



(a) (b)

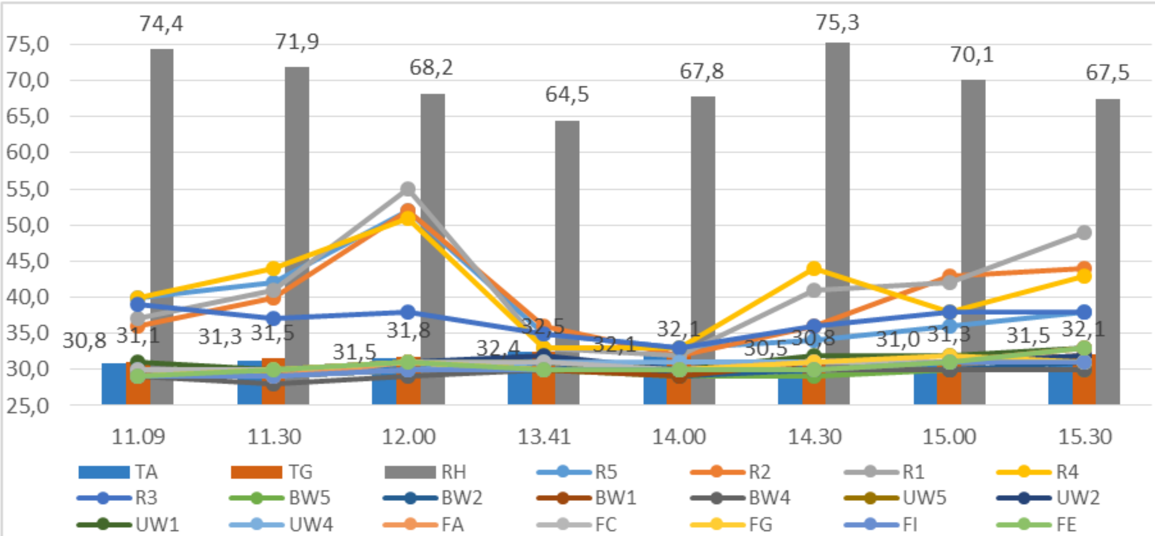
Figure 4 (a) Reverberation Time Curve of Indrapuri Mosque. (b) RC curve showing the back ground noise inside Indrapuri Mosque

c. Back Ground Noise

The mosque which is located slightly remote from the main street,surrounded by stepping walls, should have the background noise that will make it acceptable as the praying area. However, during the measurement, the zinc roof that was previously installed with *rumbia* leaf made some intermittence noise that is shown in Figure4b. RC curve shows that the average value stands on RC-40 and 45 which is noted as higher than recommended background noise in worshipping place.

4.2 Thermal performance

The thermal performance of Indrapuri Mosque was indicated through the air temperature, globe temperature, relative humidity and the surface temperature of roof, wall, and floor. Figure 5 shows that the wall and floor temperatures are dominantly located at 27^{0}C to 32^{0}C which are slightly closed to air and globe temperatures. While the zinc roofs facing east, west, south and north suffer high temperature rising to 50^{0}C -55^{0}C at noon, then running down to 35^{0}C at 1 pm-2 pm. In the afternoon they slightly rise toward 50^{0}C. Meanwhile, the Relative Humidity stays at around 65% to 75% which is somewhat higher than the comfortable range of RH which is between 35% and 70%.



TA: Air temperature (^{0}C) TG: Globe temperature (^{0}C)
RH: Relative Humidity (%) R : Roof temperature (^{0}C)
BW: Bottom Wall temperature (^{0}C) F : Floor temperature (^{0}C)
UW: Upper Wall temperature (^{0}C)

Figure 5 Temperatures and Relative Humidity inside Indrapuri Mosque

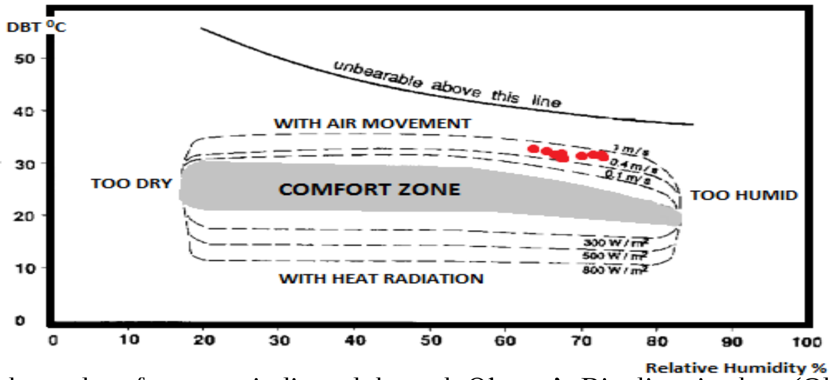


Figure 6 The thermal performance indicated through Olgyay's Bioclimatic chart (Olgyay, 1992)

Figure 7 The roof aperture sealed with plastic and the fans installed and attached to the wooden beams

The air velocity was recorded in two conditions namely 80cm and 120cm above the ground illustratedwith number 1 and 2 respectively next to the alphabets (A-I) thatrepresentsthe measured area (Figure 8). It shows that the airspeeds are dominantly in the comfortable zone which is around 0,1-0,4m/s. However, based on Olgyay's Bioclimatic chart, the airspeed will not give comfortable thermal sensation due to high airspeed and relative humidity. Figure 6 shows that once the air temperature (DBT^{0}C) and the Relative Humidity (RH%) are traced on the Olgyay's Bioclimatic chart, it shows that the thermal performance is out of the comfort zone. The mosque with the sealed aperture of the second roof (Figure7) and some wall apertures covered with cupboard and whiteboards (figure 10) are probably the reason for this condition. To upgrade the thermal performance to be included in the comfort zone, the air movement must be increased up to 1 m/s. The worshippers approve this condition by installing fans to overall beams in the mosque in order to get more air movement (Figure 7).

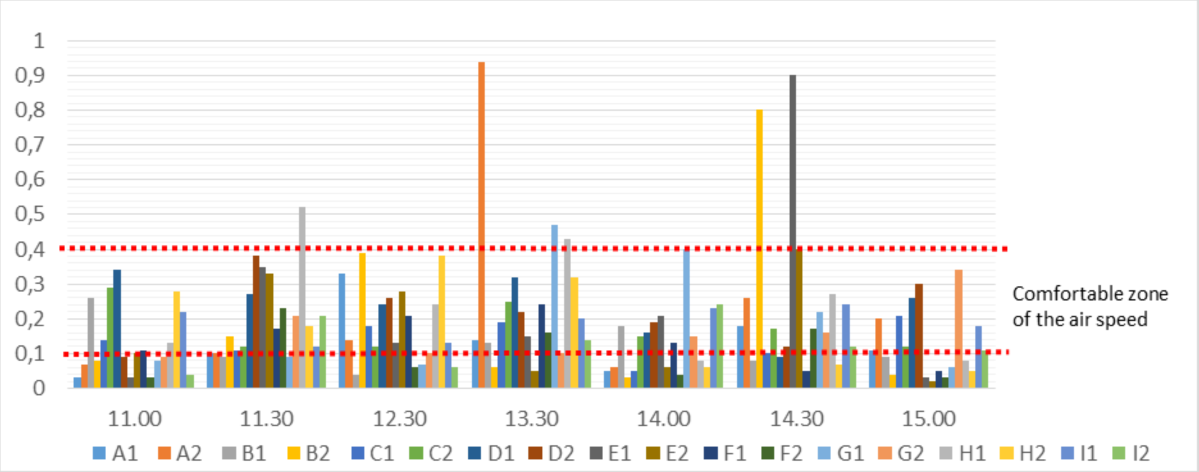


Figure 8 Air velocity (m/s) inside Indrapuri Mosque

4.3 Day Light Performance

Figure 9 shows that overall room has sufficient daylight illuminance which some areas such as A, D, G, H reach up to 2000 lux. Only area C and B suffer the minimum illuminance. Area B at the qibla position facing northwest and C facing north have been partitioned with some cupboards and whiteboards which reduce the illuminance of the daylight which is around at 100-200 lux.

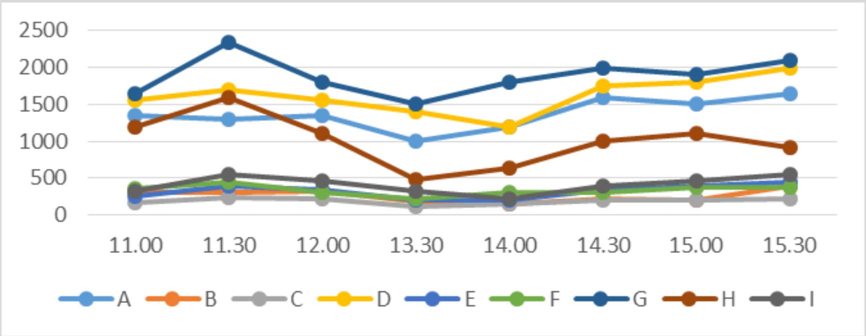


Figure 9 Daylight illuminance (lux) received inside Indrapuri Mosque

Figure 10 Wall apertures partitioned with cupboards and whiteboards

5 CONCLUSION

Indrapuri Mosque shows that some replacements have caused some spatial discomforts such as high indoor thermal performance, high background noise and low illuminance of daylight in some spots. This study indicates that installing new materials should be minimized to achieve the optimal spatial comfort. Alternatively, we could conserve the mosque by installing the materials or properties closed to the original one. In addition, attachinginformation and supporting furniture should also be wisely managed to obtain not only the facade but also the indoor comfort.

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