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Towards Safe Cities & Resilient Communities

13 & 14 SEPTEMBER 2018
IMPIANA HOTEL, IPOH, PERAK

ORGANIZED BY :

UNIVERSITI TEKNOLOGI MARA

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AN ASSESTMENT OF OUTDOOR THERMAL COMFORT OF BAITURRAHMAN MOSQUE IN BANDA ACEH

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Abstract - The thermal comfort of the outer space is an important thing to study. This would be the same as well as with the inner space of the mosque, especially if the outer space has a function that is tied to the inner space. Baiturrahman Great Mosque is a building of worship that has an outer space with enough important functions in the form of haraam to perform prayers. The thermal comfort evaluation of the outer space of the Baiturrahman Grand Mosque of Banda Aceh is conducted to determine the thermal condition in order to optimize the function of the outer space in relation to thermal comfort. This research uses done by doing literature review, field observation, interview and filing questionnaire as well as make direct measurements about environmental influences such as air temperature, wind speed, solar radiation, humidity and review the influence of the outer space parts such as floor surface and use of imagery associated with external thermal conditions. Based on the design characteristics of the Grand Mosque of Baiturrahman Great Mosque some things that affect thermal comfort such as the use of floor materials, imagery and vegetation elements. Of the various indicators, which most affect the sensation of heat in the outer space of the Baiturrahman Great Mosque is the availability of imagination elements. In areas where perception is perceived to have the highest value +1,4 is a rather warm sensation and in areas without imagery has the highest value of +1.5 is a warm sensation. While the material element affects the sensation of heat in the skin stimulus due to its conductivity. In this case the natural ceramic floor material provides the highest heat stimulus on the skin with an average temperature of 47.3 ^{o}C and the lowest temperature is found on the shaded grass material of 28.2 ^{o}C.
Keywords - Thermal Comfort, Outer Space, Thermal Condition

1 INTRODUCTION

Banda Aceh,that is in the humid specify climate, has a thermal condition with high radiation and climate temperatures, with high humidity levels as well as fluctuating wind velocity. Therefore, it needs an architectural design that create confortable micro climate. In architectural design, comfort is essential for both inner and outer space.

Baiturrahman Great Mosque Banda Aceh is one of 132 mosques that is located in Banda Aceh.Ithas a land area of 31000 m^2 with a building area of 4000 m^2 (Simas Kemenag, 2017). The mosque that was built since 1875 has been renovated with a large scale, especially on the outside space.Before being renovated, the Baiturrahman Grand Mosque wassurrounded by a lawn with green grass and several types of trees. The grass is known to reduce the heat coming to it because of its good ability to absorb heat. This allows the creation of a cooler thermal environment compared to the condition of the soil without grass. Prior to renovation, treescan provide imagery andalso reduce the heat intensity directly from the sun. Vegetation elements such as grass and trees make the thermal conditions of the outer space becomes cool.

However, the condition of the outer space of the Baiturrahman Grand Mosque has now changed. After the renovation in the outer space, the pasture has been replaced with marble ceramic material. 12 units of large electric umbrella are also installed to provide coolness (Reza Munawir, 2017). This will certainly change the thermal conditions of the area that are affected by the impact of sunlight reflections from the marble floor material. Around the building 35 palm treeshas been planted. But palm trees are less effectivein reducing heat from the sun. The existence of 12 umbrellas is expected to reduce heat, however, the umbrella does not cover the entire floor area.

The design of outer space of Baiturrahman Grand Mosque Banda Aceh which wasrenovated must havedifferent heat conditions. From the above descriptions, this study wascarried out to

evaluate the influence of outer space design on Baiturrahman Great Mosque for thermal comfort around its area.

2 THEORITICAL REVIEW

2.1 Thermal Comfort in Outer Space

According to ISO 7730, thermal comfort is a state of mind that expresses human satisfaction with the thermal environment. Another opinion expressed by Karyono (2001: 24) which means thermal comfort as a hot or cold sensation as a response form of skin sensors to the temperature around him. Thus,based on the above understanding, thermal comfort is a sense of satisfaction that is derived from stimuli or skin receptors which link to the thermal environment.

In general, based on ASHRAE 55-2004: 3 there are several factors that affect human reactions to thermal comfort i.e air temperature, radiation temperature, wind speed, humidity, clothing and activity. But the thermal comfort of the inner chamber will be different from the thermal comfort of the outer space. The thermal comfort of the inner chamber is affected by the choice of building material type, shape and / or orientation of the building itself, openings, building area and others (Sastra et al, 2006),whilethe thermal comfort of the outer space is affected by the configuration of the building mass against the temperature in an area, which will affectthe environmental thermal comfort (Wonorahadjo et.al 2008).

Spagnolo et.al (2003) has another opinion about thermal comfort in the outer space environment. According to the comfort of space,itsometimes hasthe same effect as the environment outside space. After he reviewed several studies of thermal comfort in the space of various references, the result is a growing theory that the theory of thermal comfort inner space can be applied to the thermal comfort of outer space without modification. Nastaran, Zaky, Elias and Andreas (2002) states that the thermal comfort of outdoor space is influenced by the energy balance of the human body that is affected by meteorological variables such as air temperature, humidity, radiation and velocity wind and human personal influences such as body metabolism and clothing.

Maidinita, Hardiman and Prianto (2009) stated in his article, 'Spatial Pattern of Housing and Thermal Leisure in Semarang' that elements such as floor surfaces and imagery do affect thermal comfort in an outer space. There is a temperature difference that is affected by the surface of paving, grass, water elements and the use of vegetation in an outer space.

2.2 Standards and Scale

According to Fanger (1970), there is a thermal comfort scale which is divided into three sensation scale as in Table 1 as follows:

Table 1 Thermal Comfort Scale

Large Scale	**Perception**
+3	Hot
+2	Warm
+1	Slightly Warm
0	Neutral
-1	Slightly Cool
-2	Cool
-3	Cold

(Source: Fanger, 1970)

This scale wasused to compare the sensation of heat felt byrespondents due toheat sensation based on measurement. thermal sensation that can be soughtin two ways by asking a questionnaire and making accumulations with the formula. Duringthe submission of questionnaires, the respondents were asked about the sensation of heat they feltby declaring it in the range of numbers as on the Fanger scale.Theresults obtained werelarge percentages at each level of the scale, while the final result with the accumulation of the formula showed the numbers with Fanger scale ranges such as in Table 1.

2.4 Thermal Comfort Relation

There are many similarities to finding thermal comfort in various studies. Indonesia experiences a humid tropical climate. Therefore, the equations used should be based on the humid tropical conditions. Here are some equations formulated by some Sangkartadi et al:

Sangkertadi et. al (2012) conducted field studies in humid tropical climates (locations in Manado City) and managed to havetwo equations of thermal comfort for humans outdoor activities in normal walking (walking) and sitting moderate activities, as follows:

$$YJS = -3.4 - 0.36\ v + 0.04\ Ta + 0.08\ Tg - 0.01\ RH + 0.96A_{DU} \quad (1)$$

$$YDS = -7.9122 - 0.5215\ v + 0.0468\ Ta + 0.1673\ Tg - 0.0007\ RH + 1.4329A_{DU} \quad (2)$$

Note:YJS) when walking normally;YDS) while sitting moderate;Ta) air temperature;Tg) global radiation temperature (black ball temperature);RH) relative humidity and; ADU) The area of human body skin (m^2)

3 RESEARCH METHODOLOGY

3.1 Research sites

This research was conducted in the outer space of Masjid Raya Baiturrahman Banda Aceh. Map of research location can be seen in Figure 1, as follows:

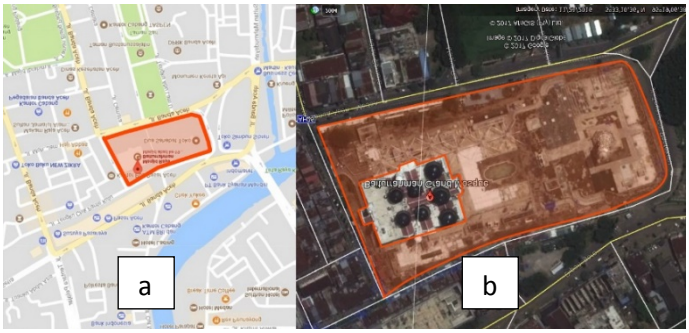

Figure 1 Map of research location. (a) Baiturrahman Great Mosque Banda Aceh and surrounding areas; (b) Outdoor Zone of Masjid Raya Maiturrahman Banda Aceh

3.3 Research methods

The research method used wasquantitative and descriptive method. The evaluation made referredto the aspect of thermal comfort in the outer space of Baiturrahman Grand Mosque Banda Aceh. Here are some data collection methods that were done:

1. Literature review
   This method wasdone by collecting data and information relating to thermal comfort of outer space Baitrrahman Grand Mosque Banda Aceh.
2. Observation
   This method was conducted by having direct observation of the field that is located outside of Masjid Raya Baiturrahman Banda Aceh.
3. Questionnaire
   This method wasdone by distributing questionnaires to the community and asked themabout their thoughts of the thermal sensation particularly the Thermal Sensation Vote (TSV) specified in Table 1. (Questionnaire attached)
4. Measurement

This method was done bymeasuring the outer thermal condition of the Baiturrahman Grand Mosque using thermal measurement tools such as:

a. Measure wind speed by using anemometer. By paying attention to the direction of the coming wind, the anemometer is placed facing the direction of the wind.

b. The air temperature, the temperature of the black ball radiation and air humidityare measured using theHeat Stress Thermometer.
c. The temperature material is measured using Infrared Thermometer.

In this study, there are twenty points of measurement. The measurement points of this study can be seen in Figure 2. The measurement points weredivided into seven parts of the study based on the condition of imagery that is under the umbrella of an electric umbrella; above the open courtyard; under the auspices of the building; on grass areas without shade; on grass areas with shade trees; on areas near the pool without shade; on the pedestrian way without shade. The division of the measurement points can be seen in Figure 2 and Table 2.

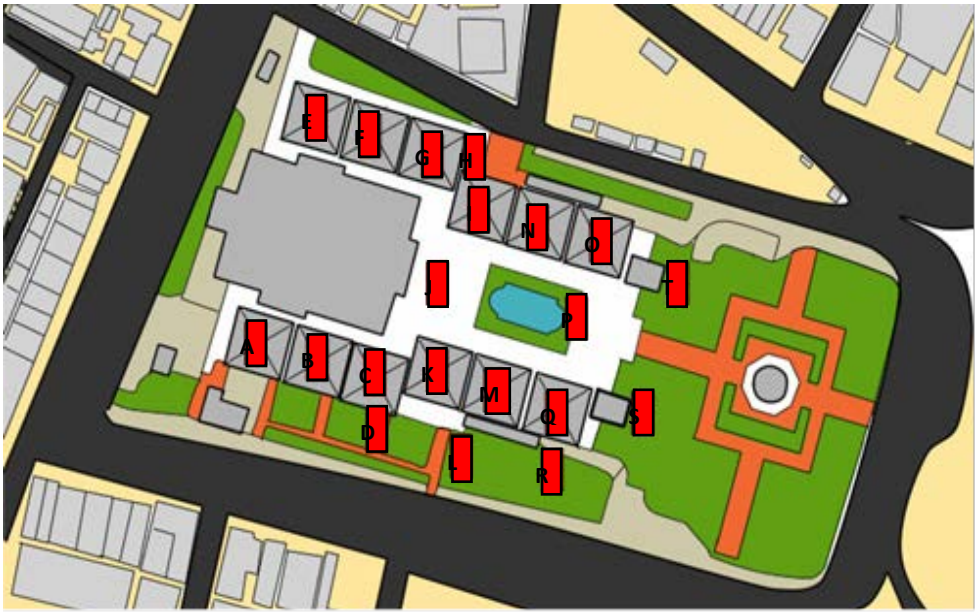

Figure 2 Thermal Measurement Point

Table 2 Location of measurement area based on Puppet

Measurement Points	Description
A,B,C,E,F,G,I,K,M, N,O,Q	Under the shade of the electric Umbrella
J	Above the open courtyard
T,S,H	Under the shade of the building
R	In the grass area without shade
L	In the grass area with shade trees
P	In the area near the pond without shade
D	In the pedestrian area without shade

In this study, every 20 points weremeasured in a certain time span in one round, carried out sequentially from point A to point T. The range of time is between 10: 00-10: 30, 11: 00-11: 30, 12 : 12: 00-30: 14: 00-14: 30, 15: 00-15: 30 and 16: 00-16: 30. After the measurement, it will take the results of a calculated average with the same condition.

4 RESULTS AND DISCUSSION

4.1 Imaging Condition

Shadows in the outer space of the Baiturrahman Grand Mosque of Banda Aceh are obtained from several shades, including the shade of electric umbrellas, shade path and a few trees. The study was conducted on February 28, 2018 - March 2, 2018, when the sun is closer to the equator.

The different shade of Masjid Raya Baiturrahman Banda Aceh running from morningto afternoon show the less possibilities of the people to get shaded (Figure 3).

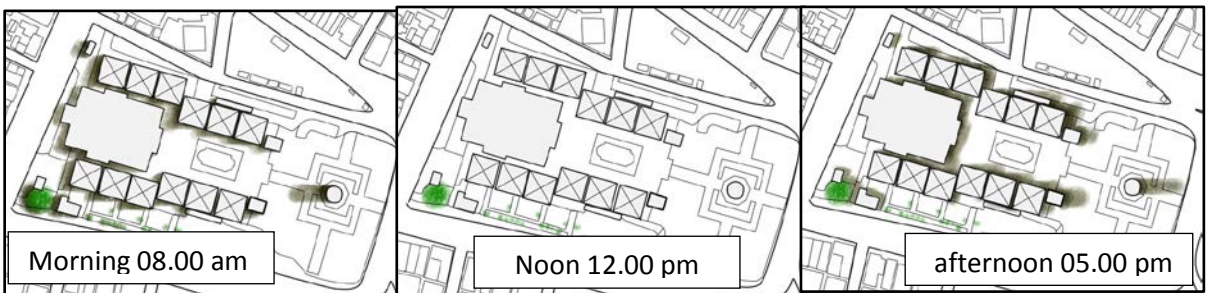

Figure 3 The changed of imagery condition in the morning - noon – afternoon

4.2 Measurement Data Results

After the process of measurement, the numbers are converted into formula using Sangkartadi calculation formula 1 and 2 which can be seen in Table 3. Based on Table 3 it can be seen that the thermal state based on the influence of the imagery shows the highest number in condition 2, 4, 5 and 7, that is respectively the marble floor area in the open courtyard, the open grass area, the grass area near the date palm and the pedestian way area. This is influenced by the absence of imagery in the area that hadresulted in the heat recovery from the rising solar radiation.

Table 3 Simulation results on circumstances based on viewing conditions

POINT	TA(^{o}C)	TG(^{o}C)	RH(%)	V (m/s)	YJS	YDS	Perseption
1	31,2	36,1	64,0	1,52	1,3	1,4	Slightly Warm
2	31,5	37,1	63,7	1,56	1,4	1,5	Warm
3	31,5	37,7	65,1	1,92	1,3	1,4	Slightly Warm
4	31,4	37,3	64,4	1,68	1,4	1,5	Warn
5	31,5	37,2	64,4	1,55	1,4	1,5	Warn
6	31,4	37,0	64,4	1,54	1,3	1,4	Slightly Warm
7	31,6	36,5	63,6	1,25	1,4	1,5	Warm

Note: (1) Under Umbrella: (2) Above the Open Court; (3) Open courts near the pond; (4) Open Grass Area; (5) Grass Area Near Dates Tree; (6) Grass Area under Building Shade and; (7) On the pedestrian path (natural ceramic stone area).

Another thing to consider is the temperature of the material. Based on Table 4 it can be seen that the highest material temperature wasfound in natural stone ceramic with no shade condition that is 47.3^{o}C. But the natural stone ceramic area is an area that is not directly affected by the skin, where the visitors are still allowed to use footwear. Thus,high temperatures are not a problem. In the marble floor area without shade temperature acquisition is also quite high that is 37.6 ^{o}C. This area is an area that is prohibited from using footwear.Therefore,the skin can feel its heat temperature directly. The lowest temperature obtained was on the Grass with 28.2 ^{o}C.

Table 4 Results of Material Temperature Measurements on the Outer Space of Masjid Raya Baiturrahman Banda Aceh.

Condition	Average Material Temperature (^{o}C)
Marble floors shaded by umbrella	32,3
Marble floors without shade	37,6
Theexposed grass	33,5
The shaded grass	28,2
Natural Stone Ceramics without shade	47,3

In addition to measuredata, there are also questionnaire data to see firsthand the responses felt by visitors. Unlike the results of the measurement, most visitors feel that the thermal state is quite comfortable, this can be seen in Diagram 1 which shows that the majority of the respondents (75%) felt a relatively neutral thermal condition, then there were 28 respondents who felt that the thermal conditions of the outer space feel warm, 22 respondents feltslightly cool, 15 respondents feltslightly

warm, 6 respondents felt cool and 3 respondents felt hot. The above situation occurs because of the adaptive nature of humans atthe surrounding temperature by looking at the highest percentage of respondents coming from Banda Aceh.

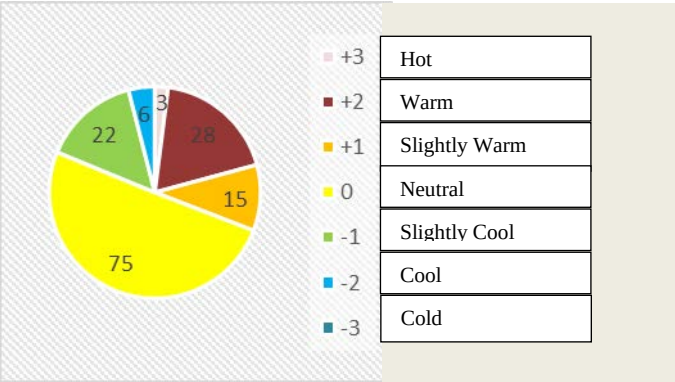

Diagram 1 Thermal Comfort Expectations

In Diagram 2, When respondents answeredquestionnaires about their expectations of thermal conditions most of them hoped that the thermal state could be cooler which constituted 75% of the respondents.

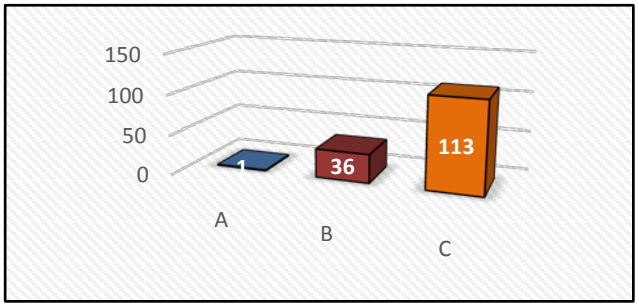

Diagram 2 Thermal Comfort Expectations
Note: (A) Warmer; (B) The temperature is quite comfortable and; (C) Cooler

In Diagram 3, the respondents gave some recommendations for mosque design recommendations to make it better.123 respondents said that in order for the design to be given more trees, 26 respondents said that there should be more umbrellas and 23 said to add other aesthetic elements such as flowers.

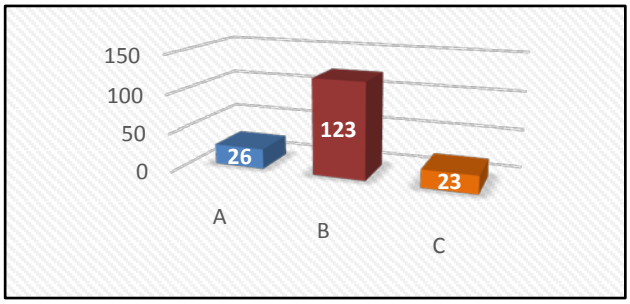

Diagram 3 : Hope for Improved Design
Note : (A) Made more umbrellas; (B) Planted more trees and; (C) Includeother aesthetic elements such as flowers

5 CONCLUSIONS AND RECOMMENDATIONS

Based on some descriptions above a conclusion can be drawn.Outer Space of Design of Baiturrahman Great Mosque used material of white marble floor. It has a major shield element of 6 electric umbrellas. The surface of the grass is planted on a heap of soil above the basemant.The thermal situation in the outer space of the mosque on average is in the range of warm. Floor materials that are not covered by shade hashigher heat levels than those not, especially on skin sensations when touching the surface of the material.The respondents felt quite satisfied with the thermal circumstances of the Baiturrahman Grand Mosque of Banda Aceh. However, they also expect that the thermal conditions will be cooler.

Recommendations to improve the thermal situation is to provide a cooler thermal conditions such as by adding shade elements to the outer parts of the unoccupied mosque. Like planting trees in some sections of an open grass lawn that is useful in reducing heat. In addition, an electric umbrella to cover the entire surface of the floor can also be added. Electric umbrellas are installed continuously so that no hot gaps can enter the floor. The other recommendation is adding some shade vegetation that can lower the ambient temperature and reduce heat.

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