Evaluation of spatial comfort on vernacular architecture in Aceh Besar District as a form of local wisdom in adapting surrounding environment

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Abstract. Aceh is located in a warm humid climate area. It has high relative humidity, which averages almost 80% and an air temperature of 27.5°C. This study aims to evaluate the structure and material of a vernacular architectural style of the Indrapuri Mosque, located in Aceh Besar district, in relation to spatial comfort. The representation of vernacular architecture in relation to spatial comfort is the implication of the local wisdom value in designing architecture that is adaptive to the surrounding environment. In terms of spatial comfort, the study focuses on examining thermal and daylight performances. In doing this, primary data were collected by conducting a field survey and mechanical measurement. In supporting primary data, written sources as secondary data that related to the study were reviewed. The study found that a few new building materials installed have affected spatial discomfort. These new materials create a high indoor thermal performance. Concerning daylight performance, the whole interior space of the mosque receives adequate sunlight. However, a few building materials that have been replaced with new materials have affected spatial discomfort. The study thus shows that traditional buildings are still suitable to be used in the current time. To anticipate having high indoor temperature, the installment of new material through building conservation activities should pay attention to the character of new materials close to the original building material.

1. Introduction

The architectural representation of vernacular architecture is inseparable from the local wisdom of the community [1]. In this regard, the ancestors had tried to include the condition of the surrounding environment in creating architecture. Some studies show that such a friendly architectural concept addresses climatic needs as well as earthquake resistance. It this therefore vernacular building structure enables to withstand natural disturbances.

Despite its ability to create friendly environmental architecture, the representation of vernacular architecture has been extinct in the modern era. Such a phenomenon gives impacts the on the construction of vernacular building, including old mosque, where its existence has been fading away. There is evidence that many old mosques are still sturdy and able to withstand the earthquake shocks that often occur in Aceh, many new mosques were built with different architectural styles. Some of the new modern style of mosques were built next to the abandoned structure of the old mosque. The
constructions of mosques in Aceh, especially in Banda Aceh, follow architectural trends. Aftermath the Indonesian independence, the trend of the architectural style of the mosque in Aceh copied the architectural style of the great mosque of Baiturrahman. Then in the early 1980s, the architectural style of the Pancasila Mosque emerged. The presence of Pancasila Mosque was initiated by President Suharto, whose idea was to express national identity through the representation of religious buildings [2].

This study, part of previous research that examines the possibility of adapting the concept of vernacular architecture in the current days, aims to explore how local wisdom is applied in the vernacular architectural style of Indrapuri mosque in relation to the surrounding environment. It focuses on examining the spatial comfort of the old Indrapuri mosque, especially the thermal and daylight performances. In designing mosques, spatial comfort aspects play an important role in obtaining the solemnness level of the mosque users, primarily the worshippers [3]-[4]. The Indrapuri mosque is chosen as a sample of this research since it is one of heritage buildings in Aceh and the history record that the mosque played important role as a centre of administration of the Aceh kingdom in the seventeenth century. In this regard, the mosque has been preserved by the local government.

In doing this study, the paper shows that the design aspect of Indrapuri mosque is worth to be applied in modern times. This vernacular mosque provides thermal comfort to the users and minimalizes energy consumption. In terms of building preservation effort, alternatives materials need to be considered in further research, especially to create sustainable historic building conservation where the users could use the mosque comfortably as a space to 'live in' or to 'be in' during these days. Thus, the people will emotionally engage in such a heritage building of Indrapuri that expresses a meaningful past for people [5].

2. Materials and methods
In examining the spatial comfort of the interior space of Indrapuri mosque, the study measures the thermal performance and daylight performance. This work was done within one day. In collecting data, the study used primary data, which was collected through field observation, including taking photos, documenting the data of the building design and structure through measuring and drawing. In terms of thermal performance, the data was collected by using Heat Stress WGBT Meter –TM 188D. The collected data include Globe temperature (Tg), Air temperature (Ta), and Relative Humidity (RH). Concerning air velocity data, an Anemomaaster Model 6113 was used. In addition, an infrared thermometer KW06-280 was used to measure surface temperature. Meanwhile, lux meter was used to measure daylight illuminant created inside the mosque. In addition to primary data, secondary data related to traditional architecture and architecture conservation were collected and reviewed.

3. Results and discussion
3.1. The representation of the vernacular Mosque: Local wisdom and spatial Comfort
In creating architecture, local wisdom values become sustainable characteristics since it includes the thought on how architecture integrates to local culture and local climate [6]-[7]. In architectural representation, local wisdom, which contains some values regarding the surrounding environment, is expressed in the building's facade, structure, and ornamentations. In this regard, many sources claim that such a local wisdom value has been able to save the building from natural disasters [6]-[7]. In Aceh, local wisdom likely relates to Islamic cultural background due to the Muslim majority of Acehnese people. Since the local wisdom value had been existed before Islam came to Aceh, Islamic though, however, appreciated the local value as long as such values do not create conflict with the Islamic principles principles [6]. The most striking character is the use of meru type of roof, which is the hindu’s architectural element found on the mosque roof.
The sacred mosque has been used not only for worshipping but also as a place for social gathering, Islamic studies, and community service [8]. In terms of building performance, the spatial comfort factor becomes one of several factors which is a need in the architectural design of mosque in order to reach the solemnness level of the worshippers [3]-[4]. Since the study looks at the building in relation to the surrounding environment, the spatial comfort factor includes thermal comfort and sufficient daylight distribution. Concerning Tropical climate, Karyono (2015) develops the formula of neutral temperature in Indonesia and claims that the comfortable indoor temperature of the regions in Indonesia, including Banda Aceh and its surrounding area, is between 23.40°C – 29.70°C [9]. However, to obtain a comfortable thermal sensation in the Banda Aceh region with its tropical climate and relatively high humidity, high air velocity is needed to lower humidity [6]. In other words, by having high air velocity, the relative humidity is decreased. The comfortable relative humidity is from 35% to 70% [9]-[10]-[11]. In referring to Szokolay [11], Sari et al [6] explains that the proper air velocity for day comfort in a region with a hot and humid climate is between 0.10 to 0.40 m/s and indoor air velocities consider as delightful to acceptable is between 1.0 m/s - 1.5m/s.

The provision of proper thermal sensation in the tropics region can also be obtained by the use of low conductivity materials and light color, which has little value of heat absorbance [12]-[13]. In terms of Daylight performance, the standard illuminant for the mosque ranged between 200 – 499 lux. As the mosque's function is also a place to read Quran, the illuminant quantity is supposed to be adequate to see objects at normal brightness for reading activity [6].

3.2. Historical background: The history and the building design.

The Indrapuri mosque is commonly called as Indrapuri mosque. This mosque is located in Indrapuri village,Aceh Besar district, about 35 km east of Banda Aceh city. During the golden age in the seventh century, Sultan Iskandar Muda built the Indrapuri mosque, which was named after the area where it was built [2][13]. When the sultan and his people left the royal city due to a cholera epidemic that attacked the Aceh kingdom area, the sultan chose the Indrapuri mosque to become the center of the Aceh kingdom administrations [13]. Meanwhile, the Dutch troop came to Aceh and took control of the palace during this epidemic time. Concerning the mosque structure and its function, the sultan built an enclosed wooden mosque on high large open space, about 33,875 square meters, alongside the Krueng Aceh that passed through the Indrapuri market area (figure 1). The structure was constructed on the ruins of a Hindu temple built during the Lamuri Hindu kingdom in the 10th century [11].

![Figure 1. Map : The location of Indrapuri mosque.](image_url)
incoming enemies. The walls of the mosque are relics of the temple. Its 1.46 meters high wall that surround the mosque is previously decorated with reliefs of dragons. However, such animal reliefs were removed when the walls became the mosque walls. Few parts of the walls have been damaged. It can be seen from a few peeled wall plaster that the walls are made of 40cm x 20 cm black stone slabs with a thickness of 5 cm.

Since it was built, this mosque has undergone several renovations (Figure 2). The works include changing the roof covering material from thatch leaves to zinc roofing, installing ceramic floors, and installing plastic material at the opening between layers of the pitched roof. This was conducted due to the occurrence of rainwater seepage between the roof layers.

![Figure 2. The Indrapuri mosque.](image)

Like any other vernacular mosques found in the Aceh region, the mosque has wooden structures supporting tiered roofs. Indrapuri Mosque has 36 wooden columns standing in a grid dimension of 3 x 3 m. The Indrapuri mosque was mainly built with 15m x 15m wood dan 11,65 m high in terms of building structure. There are two doors found on the north and east, a pool of water for ablution at the front of the mosque. The building has 36 wooden columns, which stand in a grid dimension of 3m x 3m, to support the tiered roof. All columns stand upright on pedestal foundations made of river stones that are not rigidly tied to the ground. However, these days, the building foundations are covered by the floor construction so that all columns are attached to pedestal foundations planted underneath floor construction. The floor material has been changed from wood to marble.

The wooden structures of the mosque, like those used in many traditional buildings, are installed without nails but using pegs and wedges. (Figure 3). This wood joints system provides flexibility to the building structure. As a result, such a construction technique protects the building from the earthquake shake [6]-[7]. The evidence is that the damage of the mosque structure aftermath the 8.9 richer scale earthquake that hit Aceh region in 2004 is hardly seen

![Figure 3. The wooden join system found in Indrapuri mosque, using the pen and wedges.](image)

3.3. Architectural design of mosque and its environmental responsive
In the representation of vernacular architecture, local wisdom value which concerns with the surrounding environment, local material, and climate, become a guide to the building design [1]-[11].
This study concerns how the architectural design of mosque responds to the local environment to obtain spatial comfort. Concerning this, the study refers to Al-Hamoud and Saeed who argue that the spatial comfort is needed in the design of mosque in order to present the solemnness of the worshipers when they pray [3]-[4]. On the other side, fulfilling spatial comfort in the building design could save the energy that runs the building. In relation to environmental sensibility, spatial comfort includes thermal comfort criteria and daylight provision.

3.3.1. Daylight performance. In terms of daylight, based on observation and interviews with the users, the whole interior space of the mosque receives adequate daylight illuminant. Having the clerestories on the tiered roof and opening on the four sides help bring the indirect sunlight inside the building (figure 4). As a result, the sunlight that comes into the room does not create glare, and the heat can be minimized.

Figure 4. The aperture on the roof part was covered by plastic (left) and the daylight illuminant in the interior.

As mentioned before, the mosque is also used to learn Islamic teaching, including reading the Qur'an. Concerning this, the normal brightness for reading space is ranged between 200-499 lux [14]. The study measured the illuminant of the interior space of the mosque and recorded that the daylight illuminant of most areas near the walls reaches up to 2000 lux. However, since the color of wood material is quite dark, it reduces the brightness of the space. There are few areas where some furniture are placed, receives the lowest value of the daylight illuminant, which is around 100 – 200 lux.

3.3.2. Thermal performance. In terms of thermal performance, the traditional architecture of Acehnese, similar to other vernacular buildings, is adaptive to local climate. Concerning architectural science and building physics, the Indrapuri Mosque shows the character of a passive cooling strategy. Aceh, located in a warm humid climate, has high relative humidity, which averages almost 80%, and an air temperature of 27.50°C. In dealing with the local climate where the humidity is high, the mosque provides abundant ventilations on walls and the opening between the three-stories roof. These openings allow wind to come in and out of the mosque surfaces and cool the room inside (Figure 5).

Figure 5. The openings found in the building surfaces.

The study shows that relative humidity in Indrapuri mosque fluctuates between 64% - 75%. Such percentage is higher than a comfortable RH range, which runs between 35% - 70%. The air and globe
temperature has an average of around 31°C. Initially, the roof covering was made of rumbia leaves. The use of this leave material provides upper cavities for circulating the airflow. When the high temperature rises, the high roof integrated with the openings will circulate the hot air out of the mosque (figure 5). In addition, thatch leaves installed on the roof also work perfectly in reducing the high air temperature due to the low conductivity value of the leaves.

Previous research has been conducted on the thermal performance of traditional Acehnese houses whose roof covers use thatched leaves. This study found that the inside air temperature of the traditional house is closer to the comfort air temperature, ranging from 26.6°C to 29.7°C. In the case of mosque whose originally used thatch leaves as roof covering, its air temperature is similarly to that of the traditional house. In spite of that, the roof covering of the mosque has been changed from thatch leaf to zinc material. The temperature of zinc roof surface reaches up to 55°C, yet the average surface temperature of low stone wall and floor are also close to 31°C. In order to provide a comfortable sensation in the room, the partition plastic fiber found on the roof area is dismantled. Having had back the sufficient aperture could circulate air and, thus, help to reduce the high Relative Humidity (RH) [15].

4. Conclusions
In examining the spatial comfort of the Indrapuri mosque, the study proves that the traditional Indrapuri mosque is environmentally responsive. Thus, it gives a solemn feeling to the mosque users. This study proves that the traditional architecture of the Indrapuri mosque is still suitable to be used these days.

As the building has undergone several renovations, the original material has been replaced by new ones. Zinc, replacing the original material of thatch leaf, was constructed on the roof covering, and the plastic fiber was installed to cover space between the tiered roof. These changes have been caused some spatial discomfort, especially the thermal performance. The study shows that the mosque's thermal performance is out of the comfort zone. Such a condition is caused by high relative humidity and air temperature inside the room with low air speed comes into the room. Therefore the use of new material should be minimized or closed to the character of the original building material in order to maintain the local wisdom value in creating environmentally responsive architecture.

Concerning daylight performance, the arrangement of some furniture has caused low luminance in few spots. However, the mosque design with its low stone wall and aperture between the tiered roofs help create a comfortable standard toward daylight illuminant. The installation of new materials does not have a significant effect on the daylight illuminant. This study proves that a heritage building of Indrapuri mosque still gives solemnness to the users as it fulfills spatial comfort criteria. For building conservation activities, replacement of or adding to new materials should be considered to the original material characteristics so that the spatial comfort can be maintained,

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