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Adaptation of local wisdom in contemporary mosque design for achieving good building physics and earthquake resistance

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Abstract.
The paper aims at proposing the implication of the local wisdom value in designing a contemporary mosque. Local wisdom works successfully in determining a suitable design of vernacular buildings such as traditional mosque. It comprises the considerations on building physics such as sufficient thermal comfort, good daylighting and room acoustics which meets the standard. These parameters are also running fitly with traditional wooden structure of the mosque which is resistant against the earthquake. This article analyses two old mosques in Aceh, Indonesia which are still well standing across their ages. The wooden mosques are Indrapuri mosque in Aceh Besar and Tengku Dipucok Krueng Mosque in Pidie Jaya. The evaluation of the mosques was carried out through observations and some field measurements. This article further examines the adaptations of the local wisdom of the mosque pertaining the building physics and the earthquake resistance that can be applied in the contemporary mosque.

Key words: Local wisdom, mosque design, wooden structure

1. Introduction

Local wisdom as defined in Cambridge Advanced Learner's Dictionary is indigenous, which is naturally existing in a place or country rather than arriving from another place. This indigenous knowledge has been modified through accumulated practical experiences and passed on from one generation to the next. Local wisdom also expresses community knowledge, which is transmitted through tradition[1]. Manugeren emphasizes that Local wisdom is a set of ideas or policies based on the values of virtues found in a community and often applied, believed to be the guidance of life, and handed down from time to time. Based on the definitions, that local wisdom can be understood as a human effort by using their mind to act towards something, object, or events that occur in a particular space [2].

In architecture, local wisdom works on many parts such as facade, structure, and ornaments where those are born from the specific value of indigenousity. Many articles, report as well as personal observations show that the local wisdom secures the building successfully against disasters such as an earthquake [3,4,5]. In Aceh, the local knowledge is entirely closed to Islam due to the religion of the majority of local people. However, Islam itself appreciates the indigenousity which existed earlier than its presence; therefore, Islamic functions were adopted harmoniously in original character [6]. The flashback of the earthquake in 2014 crashing Pidie Jaya ruining many mosques gave a good lesson. The massive concrete mosques with dome roof style collapsed while the wooden traditional still well stood

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with just less damage that can be repaired. The traditional mosque also works manually in giving good and comfort building physics to the worshippers such as thermal comfort, sufficient daylight, and excellent room acoustics. This is what the new mosque mostly absence. All amenities present through electrical tools which mean running the high cost of the energy.

This article, therefore, explores the local pearls of wisdom of traditional mosques in Aceh that can be substituted in contemporary mosque design for achieving durability against the disaster and comfort building physics. This study analyses two traditional mosques in Aceh, namely Indrapuri mosque in Aceh Besar and Tengku Dipucok Krueng Mosque in Pidie Jaya.

The traditional design of the mosque in Aceh has a standard configuration of roof, which is tiered. Based on the history the two mosques studied in this research has the roof made from rumbia leaf arranged in three significant overlappings with the apertures along the perimeter of the tiered roof. The mosque has typical wall remained open above the base wall. However, in Tengku Dipucok Krueng, partitions with traditional ornaments creating leaks for air circulation are installed along the wall perimeter. The base wall, which is around 1 meter high, is made from the river stone. The pond or water container which was functioned for ablution is built at the front integrated into mosque design. The performance shows the roof height, which is about two times of the wall height, which is believed by the previous religion i.e., Hinduism as part of being close to God.

1.1 Indrapuri Mosque, Indrapuri

Indrapuri mosque was built on the 12th century which was functioned initially as the Hindus temple. Later, when Islam came to Indrapuri, Sultan Iskandar Muda converted the Hindu kingdom to be Islamic [7]. This mosque is located in Indrapuri, Aceh Besar, Indonesia, where the place looks peaceful with abundant green space and a large river running some distance beneath the hill where the mosque stands. The mosque, which is an 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 [8]. The open terrace with steps surrounding the mosque creates a magnificent view of the mosque


Figure 1. Indrapuri Mosque from old to present [9]

1.2 Tengku Dipucok Krueng Mosque in Pidie Jaya

Teungku Dipucok Krueng mosque was established during the Sultan's reign Iskandar Muda in 1607 M-1636 AD. This mosque has an octagonal pole which is varied in size depending on the function and location. The 12 pillars of the first roof were 23 cm in size, while the four pillars were 27 cm in length and the central column was 35 cm in size. The mosque building has been repaired several times. The first one was in 1947, where the Beuracan community independently managed the mosque reparation due to several damaged parts. The size of the mosque at that time was expanded from 10 x 10m to 13 x 13m. The roof was changed to zinc from previously thatched roofs. Then the community also made cement walls as a barrier around the mosque with a height of about 95 cm [10].

Figure 2. Front and rear sides of Tengku Dipucok Krueng Mosque (Photo by Laina)

2. Research methods
This study collected the data through observations and some field measurements. The observations worked on the mosque design and structure which were recorded through measurable and architectural drawing; and photos. Some interview and related literature review supporting the data were carried out simultaneously.

3. Findings
The study analyses the character of local wisdom of the mosque, which represents the contributor of good building physics and toughness again disasters. In the figures, Indrapuri mosque and Tengku Dipuok krueng mosque are abbreviated to M.I and M.T respectively. The analysis works based on table 1 which figures out the observation data.

Table 1. The Character of the two mosques.

Parameter	Indrapuri Mosque (M.I)	Tengku Dipucok Krueng Mosque (M.T)
Location	Built on high large open space next to the river.	Built just next to the main road.
Floor plan size	15,6 x 15,16 m	12,7x13,17 m
Number of columns (pillars)	36 with four main pillars at the center	33 with one main pillars at the center
Column design	Octagonal prism	Octagonal prism
Foundations	The foundation is above the ground, called umpak	The foundation is above the ground, called umpak
Roof design	Three-story roof made from zinc- metal roof (the history noted that previously the roof is made from sagoo leaf)	Three-story roof with tiny ornamented dome at the top (the history noted that previously the roof is made from sagoo leaf)
Aperture types	Apertures with the height of about 40cm are along the wall and the roof edges. No ornaments.	Apertures with the height of about 115cm are along the wall. The apertures at the northern and southern side are slightly decorated with local wooden ornaments, while the western and eastern side are filled with massive wooden decorations.
Ornaments	The ornaments are just simple at the wooden roof structure.	The mosque is rich of ornaments on the overal facades such as walls, roof structure, gables and fascia.
Wall design	Stone wall designed like fortress with the height of 124 cm	Stone wall designed like fortress with the height of 136 cm
Floor	Ceramic tile floor (Long time ago, it was compacted land)	Ceramic tile floor (Long time ago, it was compacted land)

3.1 Building physics
Relating to science architecture and building physics, the performance of the two mosques shows the character of a passive cooling strategy. Aceh, which is located in warm-humid climate, has high relative humidity, which the average is nearly up 80% and air temperature, which is 27,5^{0}C. The high relative humidity should be best reduced through the sufficient air ventilation [11]. As the high-temperature rise, the high roof integrated with the openings circulates the hot air out of the mosque. The light material

such as leaf installed on the roof also works perfectly in reducing the high air temperature due to the low conductivity value of the blade.

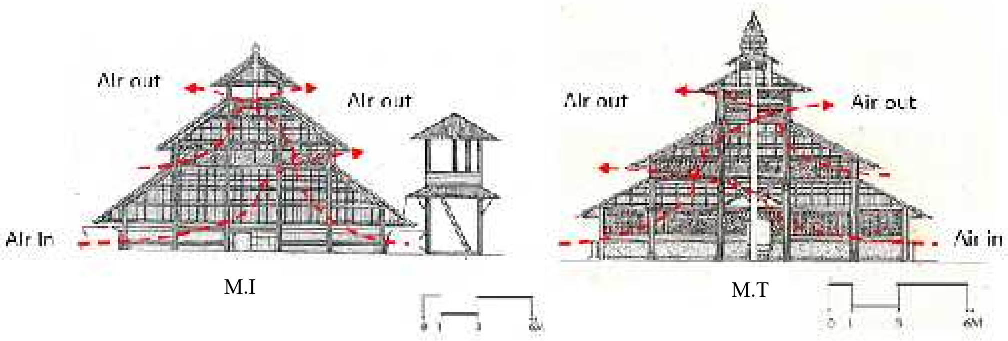


Figure 3. The cross ventilation circulating out the hot air through the roof [12]

Figure 4. Aperture types of the two mosques (Photo by Laina)

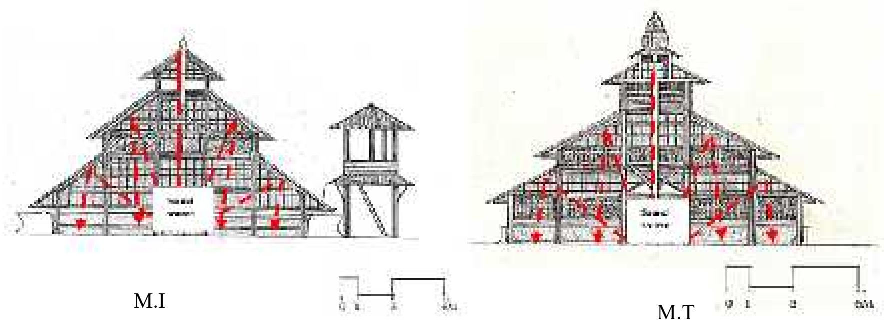


Figure 5. The pitch roof distributing the sound to the worshippers [12]

Based on the interview to the worshipper of the two mosques as well as the field observation, the mosque has good sound distributions. Without any loudspeakers, the worshipper in any directions could listen to the imam sound well. In, some theory, the floor plan of the mosque, which is less than 15x15m works perfect in distributing the sound. The two traditional mosques have the dimension roughly 14x 14 m which meet the standard of proper sound distribution. It is supported by the pitched roof which can distribute the sound better than the concave or dome roof which is distributing the sound to the center. The repeated sound distribution to the same area due to the arched ceiling will create an echo that can distract the quality of the sound itself.

Daylight is also well distributed in the overall room. The clerestories on the tiered roof and the apertures surrounding the wall create the large inlet for the daylight (figure 3). The sunlight comes into the room is the reflected light either internally or externally. Therefore there is no glare, and at the same time, the heat from outside is also minimized.

3.2 Building structure

The two mosques have wooden structure supporting the tiered roof. The two mosque Indrapuri mosque has 36 wooden poles standing in a grid dimension of 3 x 3 m. While Tengku Dipucok Krueng has 13 main pillars of 27cm and 22 supporting pillars of 23 cm in size. Four main poles in the center are substituted by only one supreme pillar standing reaching up to the pitch roof edge.

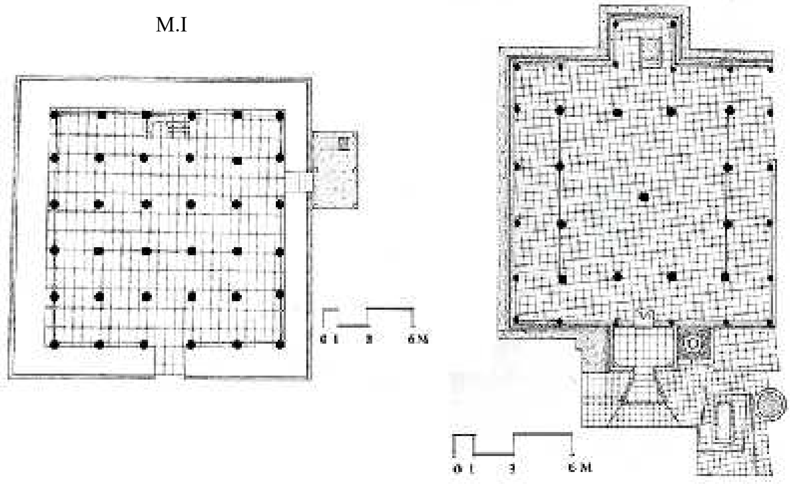


Figure 6. The floor plan of the mosques [12]

All the poles erect on the swear foundation, which is not connected to the ground. The local wisdom brought from this pole type is the mosque stay flexible if there are some shakes. This condition is agreed by a lady living in a traditional wooden house with a swear foundation. She said that during the tsunami and the earthquake in 2004, her home was removed to roughly 20 meters distances without any significant breaks. Meanwhile, the concrete houses collapsed and left in ruins.

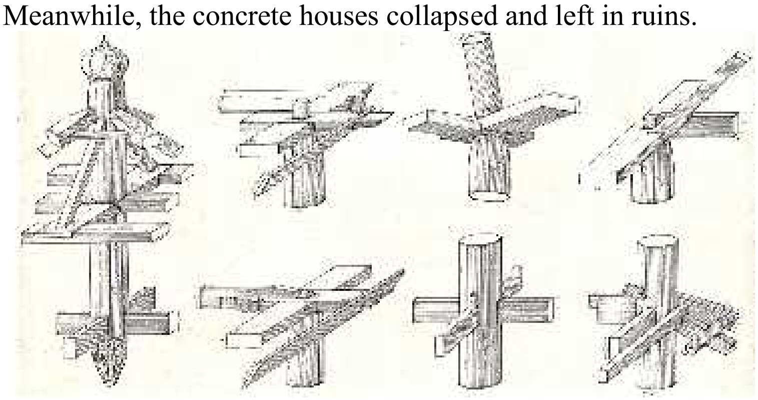


Figure 7. Wooden peg system in Indrapuri mosque (Beam and column supporting roof structure)[12]

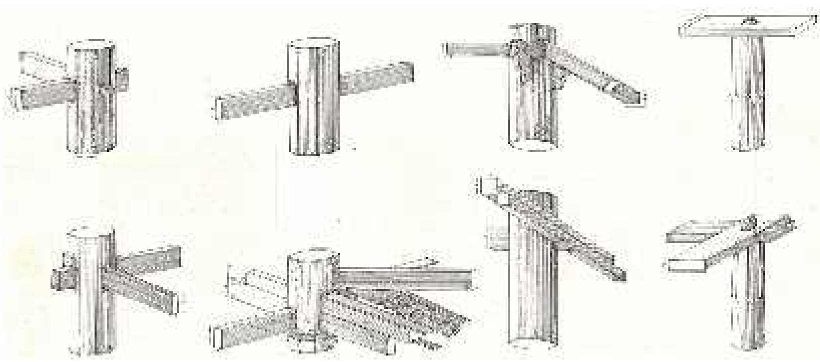


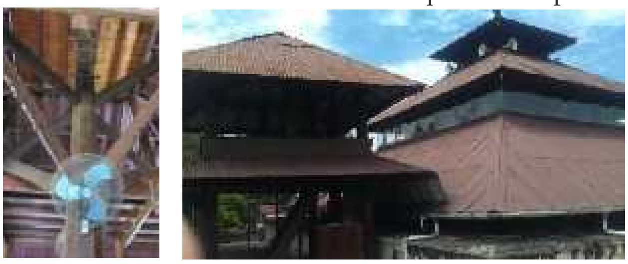
Figure 8. Wooden peg system in Tengku Dipucok Krueng mosque (Beam and column supporting roof structure) [12]

The wooden structure as commonly installed in many traditional buildings is installed without nails, yet using the pen and wedges (figure 7). The peg system creates the building flexibly moving following the shakes in any case of an earthquake. The two mosques have a different way of supporting the roof. Indrapuri mosque equally distributes the roof loads to 36 wooden poles. Meanwhile, Tengku Dipucok Krueng mosque has one first pole located in the center bearing the center highest tiered roof load. The second tiered roof load is carried by 12 wooden poles, and 20 wooden poles support the remaining tiered roof at the lowest level.

M.I M.T

Figure 9. Roof structure of the two mosques (Photo by Laina)

Indrapuri mosque exposes all the roof structure. Meanwhile, Tengku Dipucok Krueng covers the top roof structure with the high wooden floor yet remains the rectangle hole in the middle. The size of the opening allows one person climbing up the central pole, reaching the top level. In this case, we predict that in the old age the Muazzin (someone sounding Azan for calling the worshipper to the prayer) climbed up the central pole which is designed with footsteps to voice Azan from the top (figure 10) while Indrapuri mosque has a wooden tower next to the mosque for the place of performing Azan.



M.I M.T

Figure 10. Steps-up on the pole and wooden tower for performing azan (Photo by Laina)

4. Adaptation of Local Wisdom in Contemporary Building Design

Considering the two traditional mosque design, the local wisdom that may be applied to the contemporary design are analyzed through the following aspects. First, local knowledge must be integrated with the understanding of the surrounding nature and culture. Second, local wisdom is dynamic. It is flexible to the global situation. Third, the use of local wisdom must be sufficient to provide income, reduce cost/expenses, production efficiency, and improve quality of life. Fourth, it is elaborative but straightforward and comprehensive. It is usually oral in nature. It is adapted to local, cultural, and environmental conditions. It is dynamic and flexible. It is tuned to the needs of local people. It corresponds with the quality and quantity of available resources. It copes well with changes.

While the current mosque design needs some essential considerations such as large size for accommodating a high number of worshippers, proficiency of comfort including thermal, daylight, and room acoustics comfort; the mosque also should be a place for rescue or prepared with disaster mitigation. From these considerations, in the case of developing wooden mosque with natural ventilation and daylight for contemporary design, the local knowledge that probably could be adopted are the floorplan size, buiding structure and building materils.

The floorplan size could be design in 15x 15 m grid. Where each grid is supported with one loudspeaker. In that size, the roof ceiling is designed with the tilt of 30^0 to 40^0 to allow the thorough sound distribution. The roof in the grid should have apertures for allowing the daylight and natural air circulation. In order to avoid hard wind, the barrier such as secondary facade or any wooden ornament is essential to locate nearby the apertures. This grid can also be a base in designing structure construction for bearing the load.

Peg system can be still adopted in the grid of 15 x 15 m. For considering larger space for accommodating the worshipper the wooden pole strategy in Tengku Dipucok Krueng can be implied by installing only one primary big pole in the middle for supporting the roof load. To mitigate the mosque in case of flooding and any damage that will harm the floor, the floor can be raised above the ground. This way is traditionally applied in Acehnese traditional house, which is about 2,5 m built above the ground.

The roof materials, wall, and floor are also analyzed considering local wisdom approach. For a good design of the roof, some approach should also consider the followings [13]:

- Weather resistance;
- Water and frost resistance;
- The strength of roofing material is the ability to carry dynamic (wind, atmospheric precipitation) and static (the weight of the snow masses, etc.) loads;
- Biostability and corrosion resistance;
- Good sound insulation properties – the ability to create reliable and highly efficient protection against external noise;
- Durability;
- Environmentally friendly;
- Fire safety - an advantage have a non-combustible or slow-burning materials; and Efficiency

The current condition of the roofing material applied in the mosque is the zinc roof. From the other research evaluating the modifications of the two mosque which is the use of zinc roof instead of rumbia leaf, zinc roof causes higher indoor globe temperature and the possibility of background noise due to the hard wind blowing the roof [9]. Rumbia leaf is quite useful for roof material. However, it is fast-burning material, and the availability has been scarce and rare. In some studies, clay has been analyzed as good material due to its excellent corrosion resistance, high sound insulation, and low thermal conductivity hence small surface temperature. The weight is about 50kg/ m2, which is heavier about 15kg than the leaf roof (thatch roof). However, this is still fine as the load for a wooden structure. Therefore, in this case, the writer proposes the use of a clay roof. A clay roof is better compared with the metal roof [13, 14].

A mosque is also locally functioned as a place for escaping from the disaster. Tsunami in 2004 proved that some mosques were safe and many victims run and saved themselves to the mosques. They dedicated themselves to have their last breath in the mosque which is closed to the God. Being died in the mosque is very valuable rather than being died in another place. The local people extend the height of the mosque above the ground. This indegenous knowledge as well as the existance of tower in a mosque meet the standard of the need escape building in disaster prone area [15, 16, 17].

5. Conclusion

This study analyses two traditional mosques in Aceh, namely Indrapuri and Tengku Dipucok Krueng mosques. The mosques that have traditional building structure and material and have been able to withstand for more than 100 years. The Local wisdom in the mosques includes the wooden peg structure, the building material, and the architectural design. The possible local pieces of knowledge that can be adopted in the contemporary wooden mosque design for gaining the sustainability in building physics and earthquake resistance are the layout dimensions, wooden peg system, especially for supporting the roof load, architectural design, including roof form and aperture design. This study is still a proposal for designing the modern mosque applying the local knowledge. However, it has not analyzed yet further either with simulations or lab works. Therefore this study recommends a further investigation in developing the mosque design.

6. Acknowledgment

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