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ADAPTIVE HOUSE DESIGN AND PEOPLE'S HABITS IN ACHIEVING THERMAL COMFORT IN GAYO HIGHLAND ACEH, INDONESIA

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ABSTRACT

Abstract: The Gayo Highland is one of the districts in Aceh Province, Sumatra. Due to the topography, this area has a lower temperature compared than the flat and coastal areas in Aceh. The thermal comfort that is felt is based on a person's mental condition and how he expresses his satisfaction with his thermal environment. In other words, it shows how humans adapt to their thermal environment. Thermal comfort based on human adaptation is known as adaptive thermal comfort. The form of dwelling for the Gayo Highland community has shifted and changed from traditional dwelling to Transitional and Modern forms that influence the Gayo Highland community's adaptation to achieve thermal comfort. Therefore, this paper aims to investigate the house design in Gayo highland in providing warmth to the occupants naturally in the cold environment. Another aim of this study is to investigate the people's habits in warming up the body to deal with the low air temperature in the area. This study shows how the local people adapt themselves through the house element and daily habit to gain the internal thermal comfort.

Keywords: *Local Behaviour, Thermal comfort, Gayo highland, Adaptive thermal*

INTRODUCTION

Thermal comfort is an essential factor of house design in contributing to the well-being of the occupants (Crahmaliuc, 2020). Vernacular housing works best to provide the comfort by adopting the local climate. Around the world, we see the traditional house as the representative of the vernacular dwelling as each part of the world has unique designs to suit the local climate. In this study we go to Gayo highland in the central of Aceh, Indonesia where the warm-humid climate is present. Gayo highland is located at an altitude of 100-2600 m above sea level. The average air temperature during the day in Takengon is 20.2°C, while during the night, it drops down to 17°C. The relative humidity is 96% during the low temperature and 64% during the high temperature. It is lower than the temperature in low-land area in Aceh such as Banda Aceh and places nearby the sea which has an average temperature of 270C.

The house design in this area looks slightly similar to the house in low-land area in Aceh. However, there are some significant differences in the interior. The vernacular house design indicates the charateristics toward the climate. Therefore, this study investigates the house design in Gayo high-land in giving warmth to the occupants naturally in the present cold environment. Another aim of this study is to investigate the people's habit in warming up the body to deal with the low air temperature in the area.

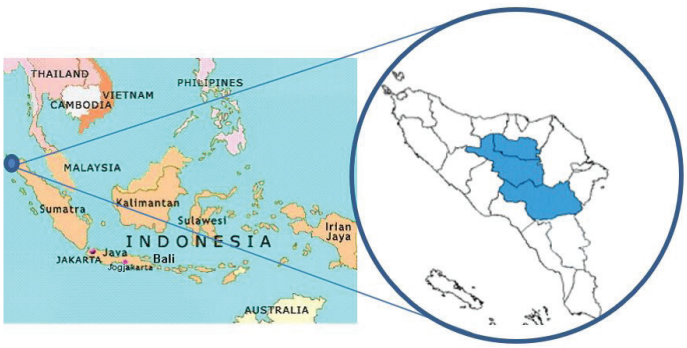

Figure 1. Map of Aceh Province and Gayo Highland

Source : Author

LITERATURE REVIEW

Climate, Architecture and Thermal Comfort

Climate is one of the factors that form architecture. Rapoport (1969) and Waterson (2009) stated that climate is an important aspect that affects the shape determination of vernacular dwellings. Furthermore, Rapoport mentions housing as a means of controlling thermal comfort through environmental control. Limitations of technology on environmental control systems cause humans to adapt to the climate. Climate change that occurs also affects the formation of architecture and will provide changes in comfort in the room, as well as the thermal sensation that will be received by residents, will also change. Humans have different abilities to achieve thermal comfort.

'Thermal comfort' is the term used to describe a satisfactory, stress-free thermal environment in buildings and, therefore, is a socially determined notion defined by norms and expectations. The idea of what is comfortable has undoubtedly changed from one time, place, and season to another (Chappells & Shove, 2005 in Nicol & Roaf, 2017)). Thermal comfort is defined as a person's state of mind that expresses his satisfaction with his thermal environment (Liu et al., 2012). The most affective factors on human thermal comfort are the environmental factors which cover many aspects which have to be taken into account i.e. air temperature, humidity, radiant and air movement (ASHRAE-55, 2004) and (Parsons, 2002). In addition to that are metabolic rate which is generated by human activity and body insulation which is clothing. Besides, thermal comfort can be affected not only by environmental factors, but also social, culture and other aspects have relative attributions (Djongyang et al., 2010).

From several studies of thermal comfort conducted on perceptions of thermal satisfaction, it is often found that there is variation in each person's comfort temperature (Prawoto and Effendi, 2019). The International Standards ISO-7730 (2005) considered that since there is an individual difference, it is not an easy task to specify the thermal comfort, but it is possible to modify the environment to be accepted by certain percentage of the occupants. This percentage has been estimated by 80-90% of the occupants (ISO-7730, 2005).

The perception of thermal comfort has changed from time, place, and season to time (Chappells & Shove, 2005 in Nicol & Roaf 2017). The thermal comfort that is felt is based on a person's mental condition and how he expresses his satisfaction with his thermal environment, which shows how humans adapt to their thermal environment. Several discussions about thermal comfort based on human adaptation are known as adaptive thermal comfort (Rijjal et., 2010). Resident adaptation behavior is closely related to daily activities. In mountain society, daily activities have specific things that create different things. Therefore, social and cultural factors can also influence occupant's behavior in achieving the perception of thermal comfort.

The adjustment of human behavior to thermal comfort is based on the adaptive thermal comfort model, which is defined as a thermal preference which is the result of a physiological response to indoor parameters and desires based on climate-cultural determinants such as past experiences (Auliciems in Darmawan, 1999 and Alfata, 2011). Three approaches to the form of adaptation in this adaptive process are behavioral adjustment (including the adjustment of clothes worn), physiological adaptation (or acclimatization), and psychological reactions (or desires/expectations) (de Dear, Brager, and Cooper, 1997 in Alfata, 2011). The issue of thermal comfort with an adaptive approach has become a basis for determining thermal comfort in buildings (Prawoto and Effendi, 2019). The adjustment of human behavior to thermal comfort is based on the adaptive thermal comfort model, which is defined as a thermal preference which is the result of a physiological response to indoor parameters and desires based on climate-cultural determinants such as past experiences (Auliciems in Darmawan, 1999 and Alfata, 2011).

Overview of Gayo Highland Traditional House

The old vernacular of Gayo highland is known as Umah Time Ruang, a house with a balanced layout. This house is a longhouse and related to the patrilineal system, which is inhabited by many families. Snouck Hurgronje (1903) and Kreemer (1922) described the Gayo house (Umah Time Ruang) as resembling the Acehnese house, which is being elevated, built on a post, and divided into three parts. The traditional house in Gayo Highland looks similar to any other Acehnese traditional house from the

general appearance. The place was east-west oriented, while most of the openings face north-south.

Figure 2. Gayonese Traditional House

The Gayo house looks different from the Acehnese traditional house from the staircase and veranda called lepo at the entrance, located on one of the short sides, mostly the eastern one. Two main entrance doors located on the veranda, one door on the left side to access the male living rooms and the other on the right side to access the female living rooms. In the middle row, there are bedrooms (umahrinung) located surrounded by the living room (serambi) which are occupied by the married children (figure 2). The height of the Gayo Highland house reaches about 2 to 2.5 meters from the ground. The high floor was made to protect the occupant from the wild animals.

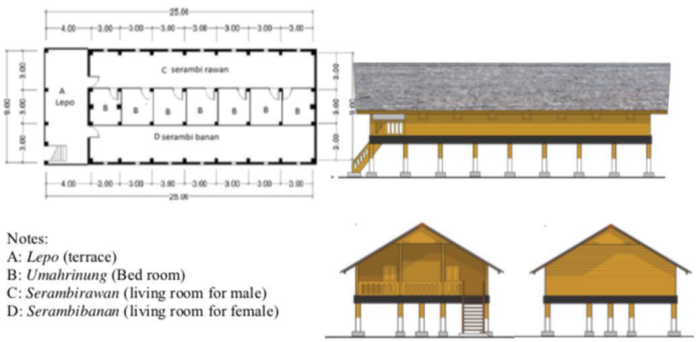

Figure 3. Gayo Highland Traditional House

Source: Sari et.al (2016)

It is currently challenging to find Umah Time Ruang in Gayo Highlands. It is related to the housing's social structure, where the Gayo dwelling is inhabited by more than one family to become a dwelling occupied by one family. It happened in the 1950s, where the spatial design shifted to a single residence called Umah Blah Bubong (Bowen, 1991).

Along with the times, the community that lives in the Gayo highlands has changed. Traditional forms of housing have begun to be abandoned, turning into shelters with transitional and modern arrangements. This change is related to the rapid development of modernity and readily accepted by the Gayo highland community.

The Gayo highland community has left traditional settlements earlier than the other traditional communities in Sumatra (Bowen, 1991), so that the existing forms of housing are currently various in design (Figure 3). Traditional houses are scarce, with only three units left. This house has been converted into a museum and has become state property. Material development also influenced the formation of housing in the Gayo Highlands. The use of concrete and zinc roofing materials is more dominant than the use of wood materials.

Figure 4. The shifted dwelling forms in the Gayo Highlands toward modernity
Source: Author

This research refer to previous research conducted by Sari et al. (2015, 2016). Sari conducted thermal measurement on two houses in Gayo Highland such as the traditional and current house. These two studies show the thermal performance in buildings. The studies found that the average air temperature during the day in Takengon is 29°C, while during the night, it drops down to 17°C. The relative humidity is 96% during the low temperature and 64% during the high temperature. Those values are traced on Olgya's bioclimatic chart to find out the position against the comfort zone. The condition during the day (yellow dot 1) is nearly out of the comfort zone boundary, yet it is still comfortable. Meanwhile, the condition during

the night is out of the comfort zone (yellow dot 2). Such situations require the house in Takengon to be designed to provide comfortable warmth during the night.

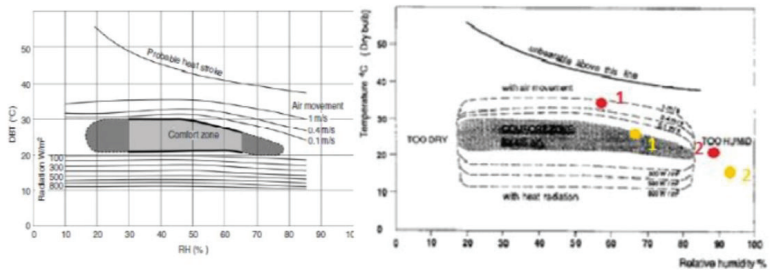

Figure 5 a. Olgya"s Bioclimatic Chart (Szokolay, 2004), b. Extensive Olgya"s Bioclimatic Chart

Source: Sari et.al (2016)

METHODOLOGY

This study was developed quantitatively through questionnaire and field observation. The thermal comfort sensation is initially indicated to receive the Thermal Sensation Vote (TSV) of the local people regarding the local climate. The research goes further by examining the house design element in traditional and current house in coping and adapting with the slightly cold environment through observation and desk literature review for the previous relevant study. The people's habits toward being adaptive to the local climate is evaluated through questionnaire.

The questionnaire was distributed to 53 respondents living across Gayo Highland. The thermal sensation vote was designed on 7 thermal scale to indicate the people's thermal sensation and preference. To find out the local habit which is adaptive to local climate is obtained through multiple-choice question by adding an "other" option.

RESULTS AND DISCUSSIONS

Thermal Sensation Vote

The 53 respondents who participated consisted of 30 women (55.8%) and 23 men (44.2%), with an age range between 20-60. Respondents were asked to evaluate the thermal environment through the thermal impression scale and the thermal preference scale. The thermal sensation vote consists of seven thermal scale, namely -3 (Cold), -2 (Cool), -1 (Slightly cool), 0 (Neutral), 1 (Slightly warm), 2 (Warm), and 3 (Hot). At the same time, the thermal preference scale is 1 (Cooler), 2 (Fixed), and 3 (Warmer).

Table 1 shows that at night and early morning, up to 90% of the people voted slightly cool to cold. While the remaining percentage of respondents were in the comfortable zone. It means during those hours the majority of the people were dissatisfied due to the cool sensation. Therefore, Table 2 shows that the majority of the respondents prefer to get warmer during that time. Whereas, during the day, 34.6% of respondents feel neutral which means neither too hot or too cold. 36.5% mentioned feeling slightly cool and cool, and the remaining 28.1% feel slightly warm to hot. This condition does not show a big number of respondents were dissatisfied with the thermal environment. Therefore, during the day up 67.35% of the respondents do not want to have any change with the thermal environment (neutral/ fixed). This thermal sensation and preference show how the people in Gayo highland deal with the local climate which gives an understanding of how they built their houses.

Table 1. The Thermal Impression of the Gayo Highland Community

	Thermal Impression						
Physiological Aspects	Cold (-3)	Cool (-2)	Slightly Cool (-1)	Neutral (0)	Slightly Warm (1)	Warm (2)	Hot (3)
Thermal sensation at night and morning	20.8%	47.2%	20.8%	11.3%	-	-	-
Thermal sensation during the day	-	(7.7%)	(28.8%)	(34.6%)	(17.3%)	(7.8%)	(3.8%)

Source: Author

Table 2. The Impression of the Gayo Highland People's Thermal Preferences

	Thermal Preference		
Psychological Aspects	Cooler (1)	Neutral (Fixed) (2)	Warmer (3)
The craving for thermal sensations at night and early morning	4 (7.7%)	13 (25%)	36 (67.35%)
The craving for thermal sensation during the day	6 (11.5%)	36 (67.35%)	11 (21.2%)

Source: Author

House Design

The investigation of house design element initially worked on Gayonese traditional house which is called Umah Pitu Ruang. As previously described, the traditional house is made from timber wall and sago leaf roof. The bedrooms stand in a row in the middle (Figure 3). There are no direct access of window to the outside. The female and male living room stands like a protector against the outside (Figure 6). This is what makes it very different from the Acehnese traditional house in low-land area, where the bedrooms have direct access to the outside. The Gayonese house has a similar style to the building design in cold climate such as European countries. The buildings are designed to trap the heat during the day to provide warmth to the inner room during the night. Figure 6 shows the sun space concept in cold climate builing which is similar to the design in Gayonese house, where the surrounding living room traps the heat to warm the bedroom during the night. This design supports how the Gayonesse feel dissatisfaction during the night and how the house design solves the problem.

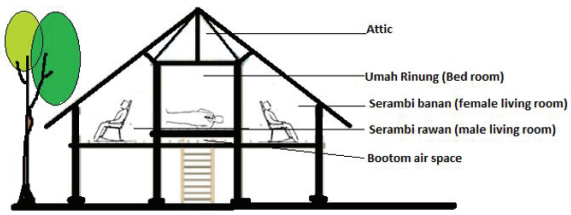

Figure 6. Rooms Surrounding the Bedroom in the Traditional House

Source: Sari et.al (2016)

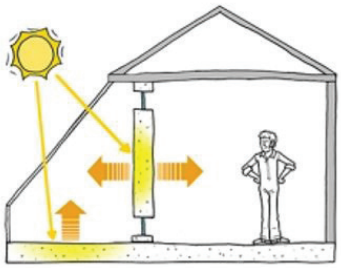

Figure 7. Sun Space Design in Cold Climate Building

Source: Author

As previously mentioned, that along with the times, the culture, habit and preference of community that lives in the Gayo highlands have changed. The traditional house has been demolished. Only some are maintained as the museum. Therefore, this study also studies on the current type of houses dealing with thermal comfort. From 53 respondents, we found that up to 70% of their houses are built from concrete, while 17% is made from timber and another 13% is half pemanent (concrete at the bottom part, and timber at the top part). The current house does not have the stilt floor anymore, instead, the floor is made from either ceramic tile or cement plaster. Various residential characteristics in the research object also use different materials and materials for walls, floors, and roofs. The use of wall materials from 53 respondents is 36 shelters (67.9%) used concrete walls and 9 shelters (17%) used wooden walls, and the other 8 shelters (15.1%) used semi-permanent walls. The use of floor materials consists of tiled floors and cast cement floors, 29 residences (54.7%) use ceramic floors, and the rest use cast concrete floors, 24 houses (45.3%). Roof material used from 53 respondents is 42 residences (78.8%) used zinc roofs, 8 houses (15.4%) used metal roofs and the remaining 3 shelters (5.8%) used bitumen asphalt roofs.

The old house did not have any problems with cold feet due to the wooden floor built raised from the ground. Cold feet is also a problem in dealing with thermal comfort that is caused by the cold floor. During observation, about 67% of the current house have 'Pepantaren'. This is a name for the raised floor which is commonly made from timber. This low raised floor is covered with rug or fabric to provide warmth. It functions as a multi-functional room such as sleeping, dining, relaxing, and chatting with

family. Pepantaren is normally located near the kitchen which is sometimes completed with a fireplace. In this study, about 34% of the respondents have fireplaces in their house which are commonly made naturally by burning wood to warm up the house.

Figure 8. The form of Pepantaren (raised floor section).
Source: Sari et.al (2016)

People's Habits

The people in Gayo highland performs some daily habits to achieve thermal comfort. The thermal comfort theory underlines that personal factor such as clothing and metabolic rate contribute to thermal sensation. The clothes used are measured in clo units (1 clo = 0.155 m2.K / W), while the activities carried out are measured in met units (1 met = 58 W / m2). In this study, we developed the question in the questionnaire asking the habitual actions performed to achieve warmth. The activity list contains questions about physical activity, food, and drink (hot or cold).

The behavior adjustment associated with the type of clothing used will result in the clo value, which can be seen in Table 3.

Table 3. Clo-value worn by Gayonese People

No	Type of Clothes	Number of Clo
1	Underwear	0.03 clo
2	Trousers	0.25 clo
3	Sarong	0.18 clo
4	Long Shirt	0.15 clo
5	Jacket	0.30 clo
6	Slippers	0.02 clo
7	Blanket	0.49 clo
	Total	1.92 clo

Table 3 shown the normal clothing worn during the night which is indicated as the coldest time. While during the day, as the majority feels fine with thermal environment, the clo-value is lower down to 0.75 Clo.

Another behavior carried out by the Gayo Highland community to achieve thermal comfort during the relatively hotter day, is opening the window to let the wind enter the dwelling. This activity was carried out by 41 people (77.4%) opening windows to achieve thermal comfort during the day, while 12 people (22.6%) did not open windows. For this condition various reasons stated by the Gayo Highland community, including 25 people (46.7%) were still feeling cold, 13 people (24.4%) for security, and 8 people (15.6%) using glass window, while 9 people (13.3%) answered other things.

In the Gayo Highland community, there are several types of traditional foods that are believed to provide warmth, namely asam jeng and pengat. Of the 53 respondents who answered, all of them ate this food. Apart from this traditional food, various other foods are also consumed by the Gayo Highland community such as Bakso, Durian and others. Whereas for the drinks they prefer warm drinks such as hot coffee and tea, ginger tea and other warm drinks.

CONCLUSION

The Gayo highland has a lower day temperature than the lowland. The local people feel dissatisfied with cool thermal environment during the night. To resolve this condition, the local people adapt themselves to the climate through several approaches. The house design shows how it provides warmth to the occupants. The sun-space concept such as in cold-climate building design the bedrooms are located in the middle row trapped by the living rooms to maintain the warmth up to the night. However, the house design has been changed, because the traditional one is not adaptive to the current life style anymore. The changes include the building material that has been converted to be concrete; and the lack of windows from the bedroom facing outside. The current adaptation of house design is by building the raised floor 'pepantern' near the fireplaces or kitchen. This shows that local architectural elements can provide comfort for the residents.

The local adaptations are also made by residents to the thermal conditions by wearing the high clo-value of clothings. The high clo-value will help the occupants to achieve their thermal comfort. This condition is particularly needed at night. The type of traditional food that are consumed by local people in the Gayo Highland is one of the personal factors related to the sensation of thermal comfort. Those local wisdoms such as foods, beverage are still maintained.

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