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VERNACULAR APPROACH IN PROVIDING PASSIVE HEATING SYSTEM FOR HOUSING IN TROPICAL GAYO HIGHLAND

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ABSTRACT
Gayo Highland is a district located in the middle of Aceh province. It has different micro-climate from the flat and coastal area in Aceh. However, the traditional house seems to bear no differences from any other Acehnese traditional house. Without ignoring such similar performance which can be derived from the same traditional philosophy, this study conducts an assessment on vernacular house design in providing slight warmth which is thermally sensed as comfortable by Gayonese. The study found that earlier people provided warmth by building the bedrooms in the middle row of the house. The openings such as windows and doors do not face the cool external environment directly but instead to other spaces. Those spaces are the surrounding areas such as gathering and kitchen space working like sun space functioned to trap the heat gained during the day and released in to the internal room during the cold night and early morning. There are some more adaptive house designs to produce the warmth,some of which are still utilized up to now which is discussed in this study through figures and descriptive analysis.

Keywords: Passive heating system; Tropical highland; Vernacular house

1. INTRODUCTION
1.1. Background and Objective of The Study
For centuries humans have known how to build houses that utilize the elements to achieve comfortable living conditions (Beagley, 2011). Lechner (2004) explained that heating, cooling and lighting contribute to the comfort. Hence, they influence the design of the house elements. As a result, vernacular housings all over the world perform significantly unique design to obtain the comfort. Houses in tropical areas have thermal comfort elements to cool the internal space. The elements are such as the use of local materials, the house orientation, high pitch roof-as stack effect function and as solar shading devices, raise on stilts-to capture high-velocity of air movement, and plenty of windows and openings-to allow more natural lighting and natural ventilation (Nordin, 2005). The characteristics are aimed at supplying fresh air movement to create comfortably cool sensation. However in some areas of the tropics due to the influence of its geography, distance from the sea and shape of the land (topography) of the local climate is slightly different from each other.
This paper focuses on the houses in Takengon, a district located in Aceh province, Indonesia which has been widely known to be tropics. Broadly speaking, most of districts in Aceh province have similar climate to the capital city of Aceh i.e Banda Aceh which has latitude of 5.51, longitude of 95.41, with an average altitude of 8 metres. Based on data from the meteorology office in Banda Aceh (BMKG, 2008) the

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average air temperature and humidity in Banda Aceh are 27^0C and, 78% respectively. The average precipitation in the given year was 100.6mm with the highest rainfall occurring in November, December, January and March. The prevailing wind predominantly blows to the south east with an average wind speed of 2 m/s (Sari, 2010). The slightly warmer months, and hence those with lower relative humidity, are April, May, June, July, September, and October; the air speed and cloud cover remained almost the samethroughout the year.

Figure 1 Takengon surrounded by mountains and LautTawarlake (http://36.82.105.7/nusapedia/Aceh/ID/place/265/kota-takengon-serpihan-surga-di-tengah-bumi-aceh)

Takengon however has slightly different local climate from Banda Aceh. The topography is about 100-2600 m above the sea level. Due to such high topography it has lower air temperature (Sari, 2015). The warmest month of the year is May, with an average temperature of 21.4 °C. At 20.2 °C on average, whilst September is the coldest month of the year (http://en.climate-data.org/location/27764/).
From the general performance, the traditional house in Takengon looks similar to any other Acehnese house. Therefore, people will generalize that Aceh has only one similar form of traditional house. However it is not exactly similar. Hence, the objective of this study is to assess the house elements in traditional house in Takengon called Gayonese house or *Umah time ruang* in providing warmth. It is thermally sensed as comfortable which contrast to the preference of thermal sensation of Acehnese people living on the flat land such as Banda Aceh.

1.2.Overview of Gayo Traditional House

Gayonese traditional house is commonly called *Umah Time Ruang* which means the house with balance lay out. It is a long house sheltering a number of patrilineally related families. SnouckHurgronje (1903) and Kreemer (1922) described the Gayo house as resembling the Acehnese house which is being elevated, built on post and divided into three parts. The Gayo house is occupied by more than one family in contrast to the Acehnese house which is inhibited by a single family. The house was east-west oriented, while most of the openings face north-south. The Gayo house also looks different from the Acehnese house from the presence of the staircase and veranda called *lepo* at the entrance which was located on one of the short sides, generally the eastern one. Two doors as the main entrance were located in the veranda to access the male

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living rooms on the left and the female living rooms and kitchen on the right side. Bedrooms (*umahrinung*) which are located in the middle row surrounded by the living rooms (*serambi*) are occupied by the married children (figure 2). The Gayo house is 2 to 2,5 meters raised above the ground. Such raised floor was intended to protect the householders from the wild environment.

However, later in 1950s such lay out shifted to be single- house hold dwelling which is called *Umah Blah Bubong* (Bowen, 1991). Such single dwelling is described by If*ani (2015)* in figure 3. Nevertheless, such single dwelling can no longer be found in Takengon and the surrounding area any more. The only modified Gayo house that can be well seen recently is the one in Kung, Pegasing. However it has been dilapidated. The roof had been changed to corrugated iron. It has only six rows of four posts which had been reduced from its original size of ten rows. The positions of the bedrooms had also been shifted irregularly throughout the lay out (figure 4).

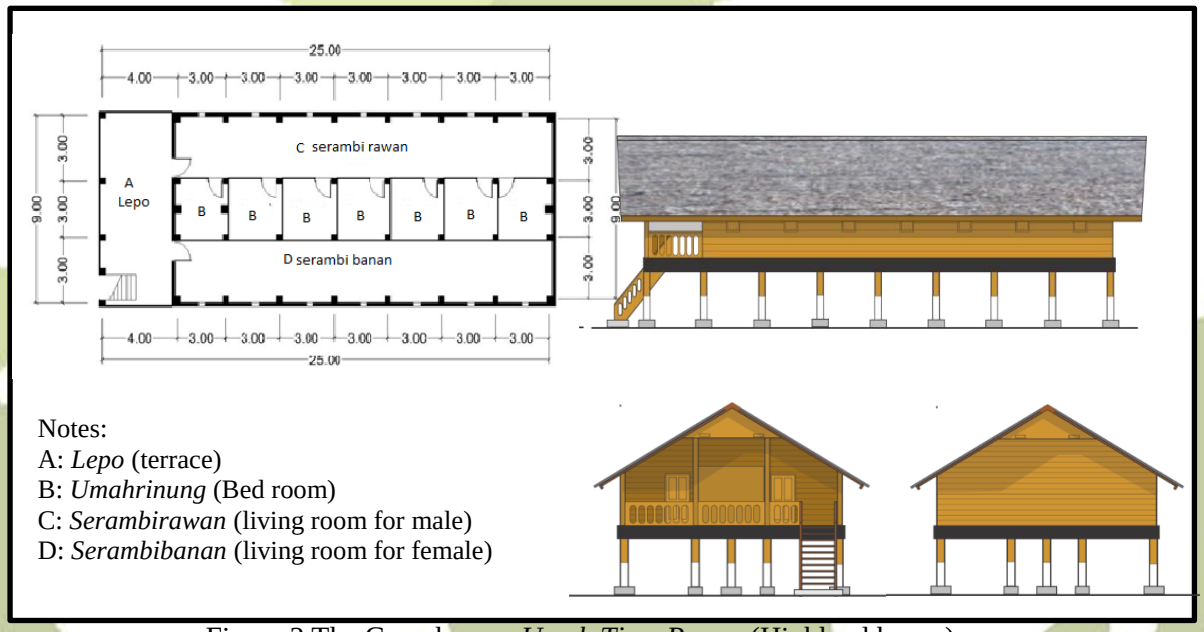

Figure 2 The Gayo house- *Umah Time Ruang* (Highland house)

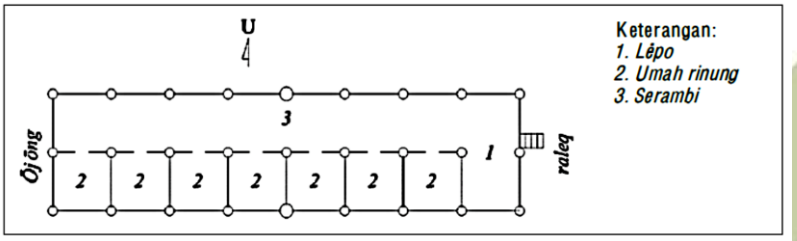

Figure 3 Single- house hold dwelling which is called *Umah Blah Bubong*(Ifani, 2015)

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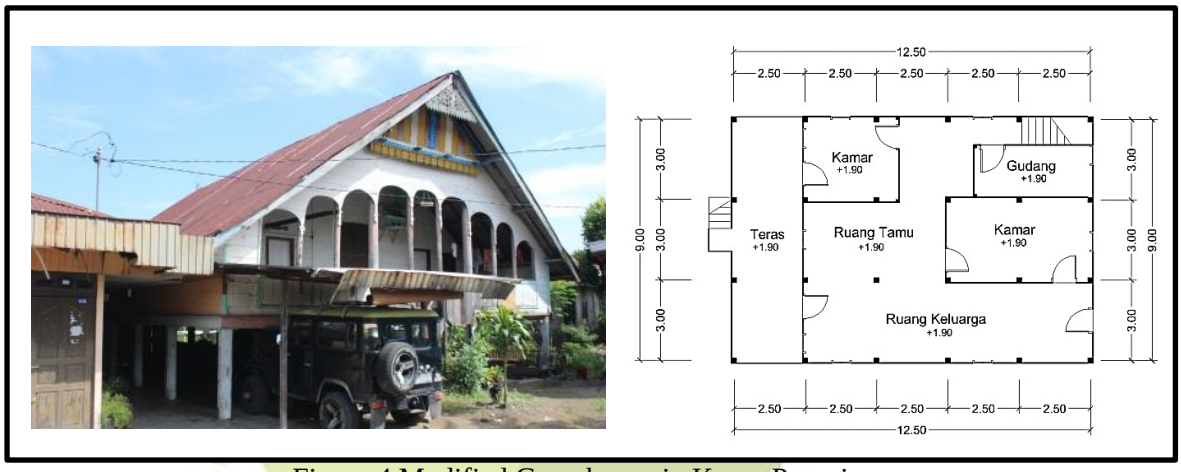

Figure 4 Modified Gayo house in Kung, Pegasing

2. METHODOLOGY

This data collection was carried out through observation, interview and comparison through study literature. The observation was conducted by assessing the house elements i.e house layout, wall, floor, ceiling/ roof, and building material. The observation was also conducted to assess the current typical house. Interview was done to the house owner to obtain the history and local wisdom behind the architectural form to provide comfort. On the field, the interview was conducted in open questions to an old villager which still has the traditional house and knows very well about the history of Gayonese traditional house; and to the owner of the currently typical house.

Final result was compared and referred to some significant readings related to this study, namely: the theory of passive heating referred to the book of Heating, Cooling and Lighting (Lechner, 2004). The observation was carried out to one traditional house and one current typical house. The two selected houses were purposive sampling which were chosen to represent the typical form of vernacular house design in performing vernacular approach in providing warmth.

3. RESULTS

Before discussing *Umah Time Ruang*, the traditional Gayonese house in highland area, it is noteworthy that this study will figure out the Acehnese traditional house in low land area. Figure 5 b shows that by tracing the average value of outside air temperature and relative humidity (red dot) on the Olgya's bioclimatic chart. The condition during the day is nearly out of the comfort zone (red dot 1) while the condition during the night falls is out of the comfort zone (red dot 2). The high air temperature during the day will be thermally sensed more comfortable by increasing the airspeed. Therefore, every room in the house was designed with apertures to circulate the air. The flatland house (Acehnese house) was also designed with shades. The raised columns also provide wider space for the height of a human being to occupy which is commonly occupied during the day.

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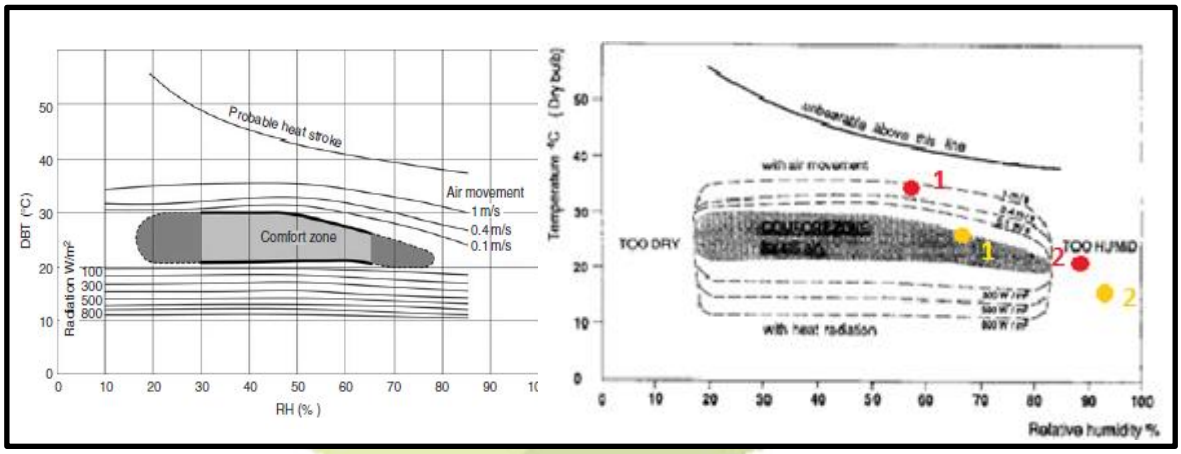

a. b.

Figure 5 a. Olgya's bioclimatic chart (Szokolay, 2004), b. Extensive Olgya's bioclimatic chart

Meanwhile, the average of day air temperature in Takengon is 29^0C, while during the night it drops down to 17^0C. The relative humidity is 96% during the low temperature and 64% during the high temperature. Those values are traced on the Olgya's bioclimatic chart to find out the position against the comfort zone. The condition during day (yellow dot 1) is nearly out of the comfort zone boundary- yet it is still in comfortable zone. Meanwhile the Condition during the night is out of the comfort zone (yellow dot 2). Such conditions require the house in Takengon to be designed to provide comfortable warmth during the night.

Based on the above figure and explanation, in analysing the performance of Gayo house in providing warmth as the major objective of this study, the discussion will cover the following scopes:

a. Building envelope and materials
b. Lay out and house construction

4. DISCUSSION

4.1 Building Envelope and Materials

The building materials of Gayo house are similar to the one in flatland house (Acehnese house). The overall house materials such as wall, floor, column, windows and doors are made from timber. Timber is strong, light and reliable making timber construction simpler and safer than steel or concrete construction. Building components and complete constructions of timber are simple and safe to erect, and cheaper to deconstruct or reuse at the end of a buildings useful life.

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Tabel 1 Thermal properties of common building materials in Indonesia

Material	Conductivity (W/m K)	Density (kg/m3)	Specific heat (J/kg K)
Softwood	0.130	610	1420
Hardwood	0.150	680	1200
Thatch (straw)	0.070	240	1420
Brickwork	0.840	1700	800
Concrete block, heavy	1.630	2300	1000
Metal deck	50.000	7800	480

Figure 5b showing the yellow dot 1 (the average of maximum outside air temperature, which happens during the day) is still in the comfort zone even though it is just on the upper boundary of comfort zone. This means that the inside air temperature should be at least similar to the outside air temperature or lower. But it does not require higher air speed Therefore we see that the material of the building envelope is just similar to the Acehnese house but with fewer apertures. With regard to thermal characteristic, wood is specified to have low conductivity and density compared with brickwork and concrete which is commonly used in current typical housing.

Roof materials which were commonly used were *lelede, kereteng, nunen* leaf. However they are not specified broadly in term of thermal properties. Therefore thatch (straw-kind of grass used as roof material) is referred in Table 1 instead of previously mentioned leaf. The very low value of conductivity of straws ensures that the roof will neither provide too high air temperature during the day nor too low air temperature during the night.

4.2 Lay out and House construction

The low air temperature during the night which is sensed as uncomfortable shown in figure 5b (yellow dot 2) is responded by the house design in providing warmth through the house plan (figure 2), and house structure section (figure 6 and 7). As the major rest activities in the bedroom take place normally from evening up to early morning, therefore the comfort should be supplied throughout the hours. In contrast, the activities during the day should be well maintained to be comfortable as well which has been discussed in the previous paragraph. Figure 2 shows that the bedrooms were arranged in parallel surrounded by female and male living rooms. While vertically the bedrooms are trapped by the attic which is utilised to store living utensils and the bottom air space under the floor along the bedrooms. Such design follows the characteristics of sun space in passive heating theory.

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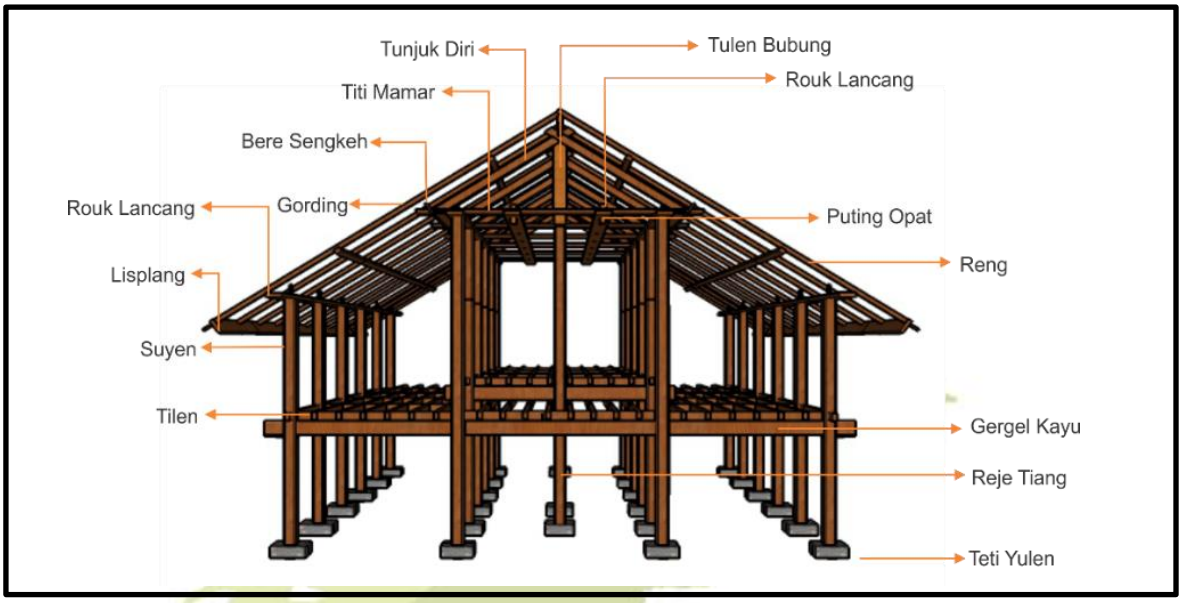

Figure 6 House structure section

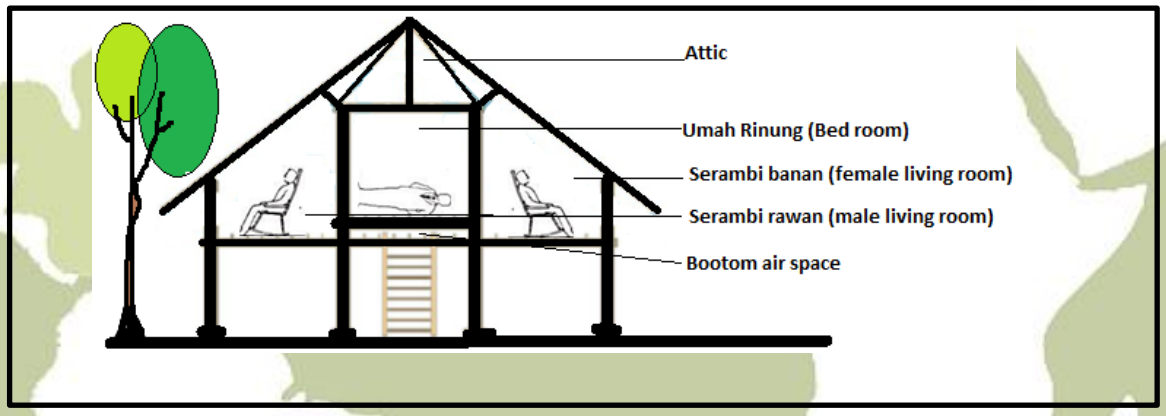

Figure 7 Rooms surrounding the bedroom (Adopted from Ifani, 2015)

In a basic design of sun space, sunlight passes through glass or other "glazing" and warms the sunspace. Thermal mass applied in sun space is either masonry material or water (figure 8).The passive heating in Gayo house is not exactly similar to sun space design because of the absence use of glasses and masonry material in Gayo house (*umahpituruang*). However the process of transferring heat through the openings such as windows and then absorbing heat and re-radiating it during the temperature drop works similarly to the sun space system. *Umahpituruang* was built from solid timber and left unpainted on its original dark colour. Solid timber has lower thermal densities compared with masonry material. Due to such character, the local wisdom located the bedroom wall indirectly to outdoor to avoid the rapid heat loss.

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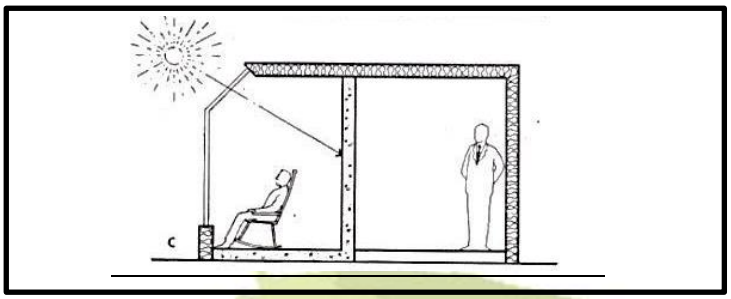
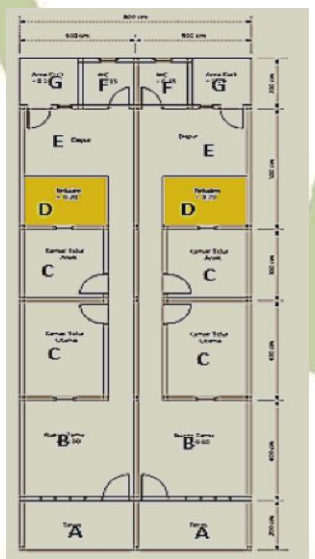


Figure 8 Sun space (Lechner, 2004)

4.3.Current Typical House

Contemporary house has been shifted in term of house plan and building materials. Most of current houses use heavy weight construction and employ typical 36m^2 house plan. It is quite common to see the couple house shown in figure 8. Such of this house was probably developed in 1950s (Bowen, 1984).The couple house also locates the bedrooms in the middle of the house plan. It can be either following the vernacular arrangement of the bed rooms or maximising the plot house size. However it looks similar to the sun space system (figure 8). The sun space will avoid the bed room in suffering the rapid heat loss during the drop temperature. The building materials are very significantly different from the old style. The wall is plastered by brick, the ceiling is by plywood and the roof is by zinc sheet. The floor is ceramic which is very cold to step on during the 24 hours especially during night and early morning. And the apertures are covered with the glass. The thermal mass gives the benefit of warmth which is released by the concrete material during the drop temperature. The cold feet is the problem for such house design. Therefore it has been common to see the current house aided with *pepanteren* (timber floor-shown in figure 9) utilised as sitting area, dining room and many other family activities area. Sometimes it is also built from concrete but covered with clothing carpet that will provide comfortable warmth while sitting.



Notes:
A.Terrace
B.Living room (especially for welcoming guests)
C.Bed room
D.Living room (for family leisure activities-usually completed with *pepanteren*)
E.Kitchen

Figure 9 Couple house (Semi-detached house)

Figure 10 Pepanteren

5. CONCLUSSION

This study found that The Gayo traditional house which is called *Umah Time Ruang* has the characteristic of being able to provide comfortable warmth. The house was built in timber which is similar to the Aceh traditional house. Timber, due to the character of low conductivity and thermal density is strategically designed through the house plan to provide warmth during the night and early morning. Horizontally, the bedrooms were arranged in parallel surrounded by female and male living rooms. While vertically the bedrooms are trapped by the attic which is utilised to store living utensils and the bottom air space under the floor along the bedrooms. Such horizontal and vertical arrangements avoid the rapid heat loss from the bedroom during the temperature drops. While in current typical house, the materials have been replaced with concrete work. Such building materials especially the use of ceramic floor cause the cold floor. People vernacularly have solved the problem through the use of *pepanteren* (timber floor) in sitting area. *Pepanteren* is also used for many family leisure activities such as dining, napping, watching TV etc. This simple approach gives large benefit in improving the indoor comfort. However it is recommended to have more extensive study which is completed with measuring the thermal comfort inside the two house types. Such work will show the natural phenomenon of air temperature, relative humidity and some other thermal parameters.

6. ACKNOWLEDGMENT

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