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# The Effect of Natural Ventilation on Indoor Air Temperature and Relative Humidity in Traditional and Modern Iban Longhouse in Sri Aman, Sarawak

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**Abstract**: Iban Longhouse or *"rumah panjai"* is an Iban's residential building that symbolize of Iban ethnics in Sarawak. Nowadays, the effect from modernization brings changes towards the uses of material of Iban Longhouse, which the modern Iban Longhouse now are using high thermal mass material in construction compare to traditional Iban Longhouse. The aim of the study is to identify material use of traditional and modern Iban Longhouse and to compare the indoor air temperature and relative humidity of traditional and modern Iban Longhouse. The field measurement has been carried out in traditional and modern Iban Longhouse in Sri Aman, Sarawak for 3 days and observed in daytime (6:00 am to 6:00 pm) and nighttime (6:00 pm to 6:00 am). The investigation was measured with Thermo Recorder TR-72U for air temperature and relative humidity. The sensor was placed vertically 1.5 meter above the ground in living room and bedroom for both Iban Longhouse. Finding shows that, indoor temperature in traditional Iban Longhouse is hotter by 7.3 and 7.6°C air temperature difference compared to outdoor temperature during day. During nighttime, the indoor temperature almost at the same state by 1.3°C and 1.4°C compare outdoor temperature. Meanwhile in modern Iban Longhouse, the indoor temperature is cooler by -2.5°C and -2.8°C air temperature difference compared to outdoor temperature during day. During nighttime, the indoor temperature is warmer by air temperature difference 7°C and 7.2°C compare outdoor temperature. The findings of the study have found that different built materials may affect the indoor thermal performance in the Iban Longhouse. The significance of this study will give benefits to the society considering that materials used in building construction plays important roles in indoor air temperature and relative humidity towards the building.

**Keywords**: Iban Longhouse, Natural Ventilation, Indoor Air Temperature, Relative Humidity

## 1. Introduction

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One of traditional house in Malaysia is Iban Longhouse. Iban Longhouse or *"rumah panjai"* is an Iban's residential building that symbolize of Iban ethnics in Sarawak. Iban ethnic are still lived in Iban Longhouse until today. Iban Longhouse consisting of one long room which design consist of *"tanju"* (balcony), *"ruai"* (covered balcony), *"bilik besai"* (living room), *"bilik panking"* (bedroom). The traditional Iban Longhouse usually made from bamboo or timber [1]. The longhouse structure between the ethnics is also very different from each other which depends on the nature of the culture and the longhouse places [2].

Nowadays, the effect from modernization brings changes towards the uses of material in the building of Iban Longhouse, which the modern Iban Longhouse now are build using high thermal mass material. It was reported that modern houses made form brick and concrete tends to have higher indoor air temperature especially during daytime which it can be more than 29°C [3]. Natural ventilation is a traditional way in order to maintain the heat loss and heat absorption through the building such as window opening, door opening and roof height. However, in a modern Iban Longhouse, the natural ventilation method maybe not adequate to provide comfort due to warm indoor characteristic provided using modern construction material [2]. This will probably lead to the use of mechanical ventilation for cooling, thus will increase the energy consumption by the households. Therefore, it is important to investigate the changes that occurred in the indoor thermal environment of the modern Iban Longhouse compared to the traditional type.

The usage of material in building is important in order to maintain the thermal performance in the building, so the efficiency of the energy in the building can be improve. This assessment is to determine and make a comparative of indoor thermal environment in variation of indoor air temperature and relative humidity between traditional and modern Iban Longhouse. From this study were able to identify the characteristic of material use that suitable for building to achieve suitable indoor thermal that suits occupant. In order to assess the Iban Longhouse design elements that still survive and have sustainable characteristics, it is important to identify the current traditional and modern Iban Longhouse. In order to provide solar protection, natural ventilation, and natural lighting, the conventional longhouse relies on its passive nature and materials. Traditional house materials are based on available local materials and the technologies used in traditional and modern Iban Longhouse construction relies on the nature of the region.

## 2. Materials Use in Traditional and Modern Iban Longhouse

Most traditional Iban Longhouse are constructed from locally available materials that have low thermal mass and are permeable, such as bamboo, ironwood, and sago palm leaves. The material uses decrease the solar heat and allow natural ventilation [2]. Meanwhile, on modern Iban Longhouse, there is a modification of the concept of longhouses which the traditional materials are replaced with modern materials such as using concrete and bricks. As an alternative to wooden shingles for roofing and wood for the wall, metal roofing, laminated boards, asbestos boards, and plywood are used to replace certain elements of the longhouse [2].

### 2.1 Bamboo

Bamboo is a plant that usually consider as a giant grass that consist of woody stems and suitable replacement of concrete for the existing materials for convention design such as steel and concrete [5]. Bamboo has the good and highest absorption of carbon dioxide. Other than releasing oxygen into the atmosphere, the growth of each plant of bamboo consumes an almost tons of carbon dioxide and it is adaptable to most forms of climate and soil conditions [6]. Besides that, bamboo is a plant that rapidly harvest and sustainable to the world, it may have a decent life span of 30 to 40 years. As we know, bamboo is sustainable materials that is suitable to use in the construction and can be used to build many components in the building such as wall, floor and wall panel [5]. It is an energy-efficient, low cost and environment friendly type of construction material [6,5]. When using bamboo as building materials, bamboo tends to reflect heat so it will produce more comfortable environment in the building. Apart from being flexible, it can withstand up to 3656kg/cm$^2$ and resistant to termites and fungus attacks [4, 6].

## 2.2 Timber

Timber is easy to find and easy to replant, it is a natural product that can grown and good for environment if logging is under control [7]. Timber has a high strength and stiffness, and much of it is used. In structures where it bears a huge amount of its own self-weight, effectively [8]. Timber not only have low thermal mass and permeable, it also controls the amount of heat flow into the longhouse which allows for natural ventilation. The main material for the longhouse is timber [9]. It is understood that most of Iban Longhouse are constructed using ironwood and are excellent for shielding the interior of the longhouse from external solar radiation. The composition of the ironwood, which is poor in heat conduction, makes it an ideal insulator, so it can be perfect for roofing [2].

## 2.3 Concrete

Concrete is one of the world's oldest and most common use as building materials due to it affordable prices, availability, long lifespan and ability to maintain harsh weather conditions [10]. It is the most functional and commonly used as building material widely by far, it can be constructed to meet a wide variety of performance requirements. Concrete is made from a composite material that consists of a binding material, such as a mixture of Portland cement and water in which particles or aggregate pieces are mixed. The thick concrete has a much higher thermal mass value of 1.4 W/m K, while the uncovered brickwork has a conductivity value of 0.84 W/m K [2].

## 2.4 Brick

Brickwork, is a composite of brick units connected together with mortar, is commonly used for building. Silica, alumina, lime, iron, manganese, sulphur and phosphates are mainly composed of clay of varying amounts. Crushing the clay during milling and mix with water to turn it plastic are one of the steps during manufacturing and the clay will molded dried and fired. The structural properties of the brick component, mortar and brick masonry such as compressive strength, elastic modulus, dry density, water absorption are essential aspects for masonry construction design [11]. The firing temperature for the production of bricks ranges from 900 °C - 1200° C, and the average density of the clay brick is 2 $Mg/m^3$ [8,12] Clay brick compressive strength is an important mechanical property that determines its loading capability and longevity, based on the clay composition, the production process of the brick and the degree of firing.

## 2.5 Ventilation opening in Iban Longhouse

The ventilation of the traditional house can be improved by providing elevated floors and openings on the building [2]. Both traditional and modern usually have the window at the covered balcony or *"ruai"* for a better ventilation (Figure 1). The longhouse are designed side by side, resulting in an insufficient amount of windows to provide natural daylighting and air flow [2].

**Figure 1: Ventilation opening in Iban Longhouse**

## 3. Methodology

The field measurement was conducted in one selected traditional Iban Longhouse and one modern Iban Longhouse located in Sri Aman, Sarawak, Malaysia. Traditional Iban Longhouse is built from the timber structure element and place about 1 to 1.5 meter above the ground level. Meanwhile, for the modern Iban Longhouse majorly build from brick and concrete structures and placed on the ground level (Figure 2).

(a) (b)

**Figure 2: Traditional (a) and Modern (b) Iban Longhouse**

The field measurement that was recorded in this case study is air temperature and relative humidity. A TR-72U sensor is used to record the data during the measurement. The sensors installed specifically to get relative humidity ($RH_i$), air temperature ($T_i$) of interior of the room as shown in Figure 3 and Figure 4. In this assessment, the identification of material that used in the building is made and the measurement is conducted for 3 days in each longhouse. this assessment was conduct during daytime (6:00 am to 6:00 pm) and nighttime (6:00 pm to 6:00 am) in living room and bedroom and the time interval for the data obtained is 10 minutes. However, for outdoor air temperature data were using meteorology weather forecast with 30 minutes time interval. During the field measurement, the assessment was conducted under natural ventilation with an occupant and activity. The maximum, minimum, average, difference of air temperature in living room and bedroom for both Iban Longhouse were also determined and converted in table form and graph.

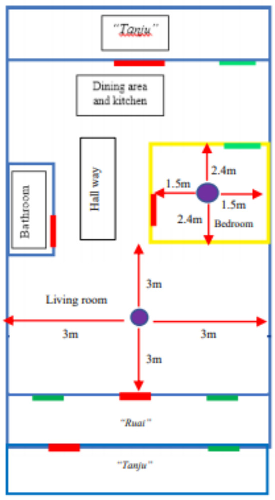


**Figure 3: Location of sensor in traditional Iban Longhouse**

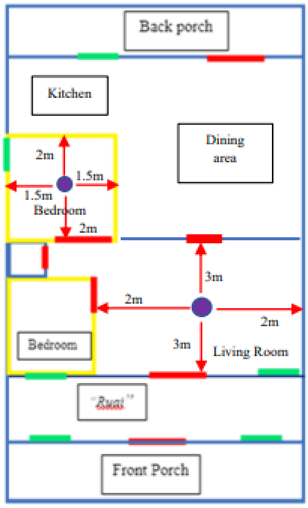


**Figure 4: Location of sensor in modern Iban Longhouse**

## 4. Results and Discussion

### 4.1 Identification of Materials Properties in Iban Longhouse

As shown in Table 1, both roofing system of Iban Longhouse are using zinc roof, but in modern Iban Longhouse are using it with insulation. The wall, floor and window for traditional Iban Longhouse are using timber and located 1.5 meter above the ground. Meanwhile, modern Iban Longhouse are using modern material such as red bricks and concrete for wall, concrete slab and ceramic tiles for flooring and aluminium glass window [2,9,13].

**Table 1: Materials use in traditional and modern Iban longhouse**

| Building Envelope | Traditional Iban Longhouse | Modern Iban Longhouse |
|---|---|---|
| Roof | Zinc roof | Zinc roof with insulation |
| Wall | Timber (0.13-0.15 W/m °K) | Red bricks (0.84 W/m °K) and Concrete (1.4 W/m °K) |
| Floor | Timber (0.13-0.15 W/m °K) | Concrete slab (0.8 W/m °K) and Ceramic tiles (1.10 W/m °K) |
| Window | Timber glass window | Aluminium glass window |
| Building Condition | 1.5 meter above the ground | Non |

### 4.2 Condition in Traditional Iban Longhouse

Figure 5 below shows the temporal temperature graph of indoor and outdoor air temperature in living room and bedroom in Traditional Iban Longhouse.

Maximum air temperature at living hall is up to 36°C and minimum is at 25.5°C on daytime. On average, indoor air temperature is 3°C higher than outdoor temperature. At nighttime, the maximum air temperature is up to 34.7°C and minimum is at 25.7°C. On average, the temperature is 3.3°C higher than outdoor temperature.

In bedroom, during daytime the air temperature can spike up to 36.5°C and minimum is at 25.7°C. On average, bedroom is 3.2°C higher compared to outdoor temperature during daytime. At nighttime, the bedroom air temperature reach 34°C and can decrease to 26.2°C. On average, air temperature at bedroom is 3.2°C higher than outdoor temperature.

When compare the condition of living room and bedroom during daytime, it was found that both room is hotter on average difference of -0.2°C during daytime due to the heat radiation can easily transfer through zinc roof and increasing of temperature mostly occur at noon even thou timber is low thermal mass materials. However, during nighttime both rooms is having better indoor condition with minimum difference on average during nighttime. Means that, living room and bedroom is having cool indoor condition during nighttime due to the cool air transfer through the timber which is low thermal mass and indicating that timber do not let heat pass through it easily.

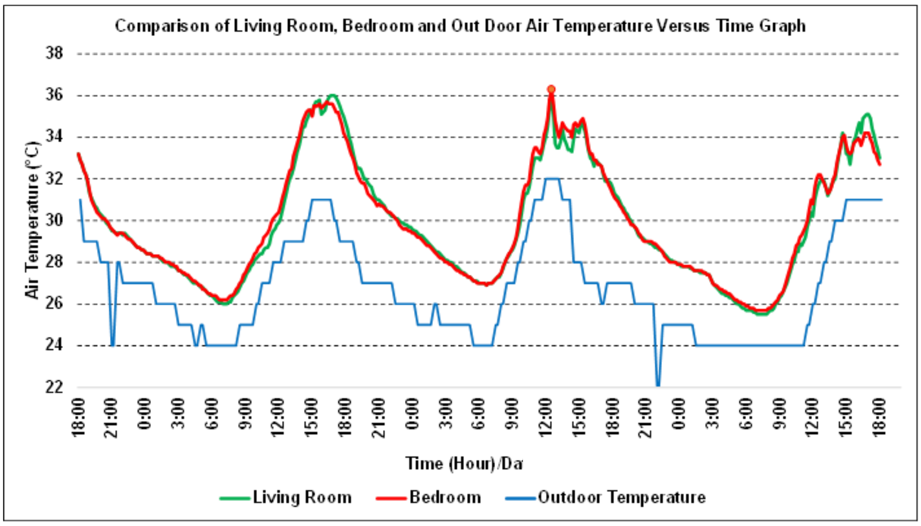


**Figure 5: Indoor and outdoor air temperature versus time graph for traditional Iban Longhouse**

4.2.1 Relative Humidity in Traditional Iban Longhouse

Figure 6 below show that the graph of relative humidity versus time for case 1 at Traditional Iban longhouse which conducted in the living room and bedroom.

During daytime, the relative humidity in living room was recorded ranging from 54% to 87%. On average relative humidity for daytime is 71%. Meanwhile during nighttime, relative humidity obtained range between 59% to 84% and the average relative humidity for nighttime at living room that had been recorded is 76%. At bedroom, the relative humidity obtained during daytime is range from 52% to 84%. The average for relative humidity in bedroom during daytime is 68%. During nighttime, the relative humidity in bedroom is 58% to 80%. The average relative humidity on nighttime at bedroom is 74%.

It shows that, the relative humidity in both living room during daytime and nighttime are high due to the human occupancy and surrounding environment at traditional Iban Longhouse. As stated, traditional Iban Longhouse are surrounded by green plants.

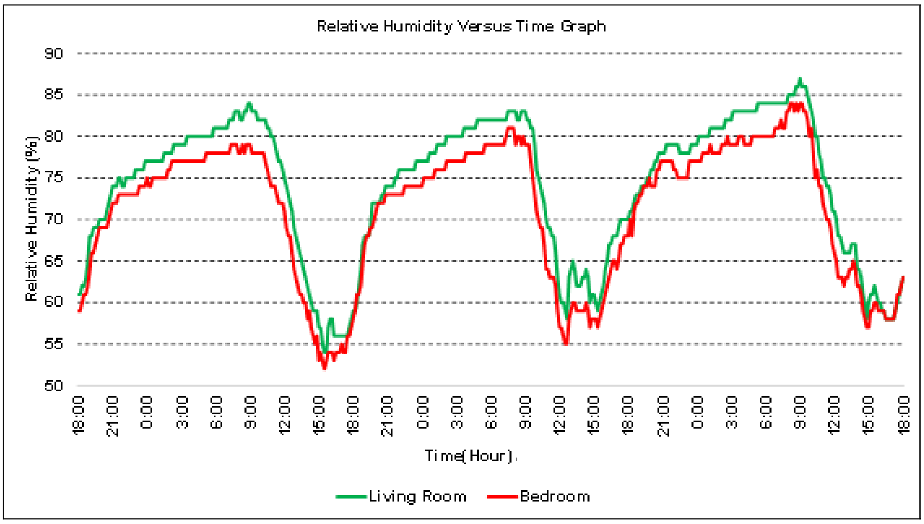


**Figure 6: Relative humidity versus time graph in living room and bedroom at traditional Iban Longhouse**

4.3 Condition in Modern Iban Longhouse

Figure 7 below shows the temporal temperature graph of indoor and outdoor air temperature in living room and bedroom in Modern Iban Longhouse.

Maximum air temperature at living hall is up to 32°C and lowest is at 28°C on daytime. On average, indoor air temperature is 0.3°C higher which almost at the same state as outdoor. At nighttime, the maximum air temperature is up to 31.4°C and minimum is at 28.2°C. On average, the temperature is 4.4°C higher than outdoor temperature during nighttime.

In bedroom, during daytime the air temperature can rise up to 32.8°C and minimum is at 28.3°C. On average, bedroom is 2.2°C higher compared to outdoor temperature during daytime. At nighttime, the bedroom air temperature reached 32.2°C and can decrease to 28.6°C. On average, air temperature at bedroom is 4.6°C higher than outdoor temperature.

When compare the condition of living room and bedroom during daytime, it was found that bedroom and living room is warmer on average difference of -1.9°C and -0.2°C during nighttime. It observed that the house was generally in poor conditions in the night hour. This is due to the building has a large thermal mass capacity which are built from high thermal mass material, it allows heat to be stored throughout the day and then re-radiated into the interior rooms until late at night [13].

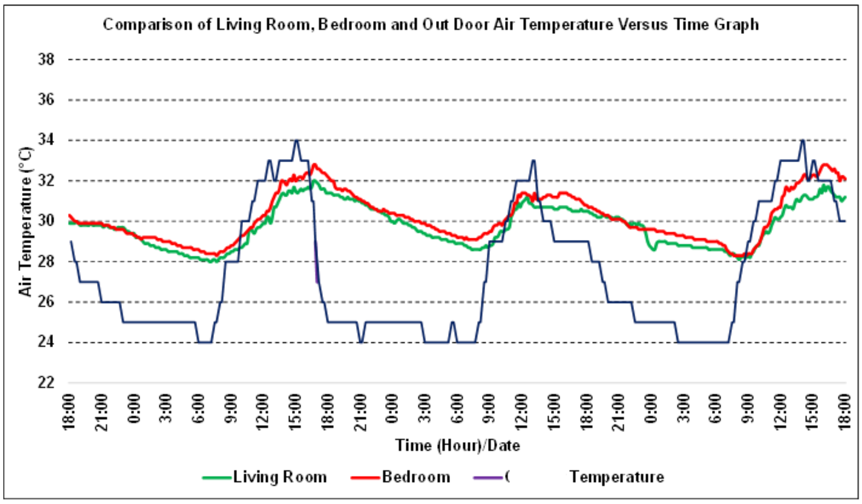


**Figure 7: indoor and outdoor air temperature versus time graph for modern Iban Longhouse**

### 4.3.1 Relative Humidity in Modern Iban Longhouse

Figure 8 below show that the graph of relative humidity versus time for case 1 at Traditional Iban longhouse which conducted in the living room and bedroom.

During daytime, the relative humidity in living room was recorded range from 59% to 82%. On average relative humidity for daytime is 75%. Meanwhile during nighttime, relative humidity obtained range between 55% to 82% and the average relative humidity for night time at living room that had been recorded is 72%.

At bedroom, the relative humidity obtained during daytime is range from 56% to 80%. The average for relative humidity in bedroom during daytime is 68%. During nighttime, the relative humidity in bedroom is 57% to 79%. The average relative humidity on nighttime at bedroom is 73%.

It shows that, the relative humidity in living room during are higher probably due to the human occupancy and surrounding environment by green plants and trees which release oxygen during photosynthesis process at night.

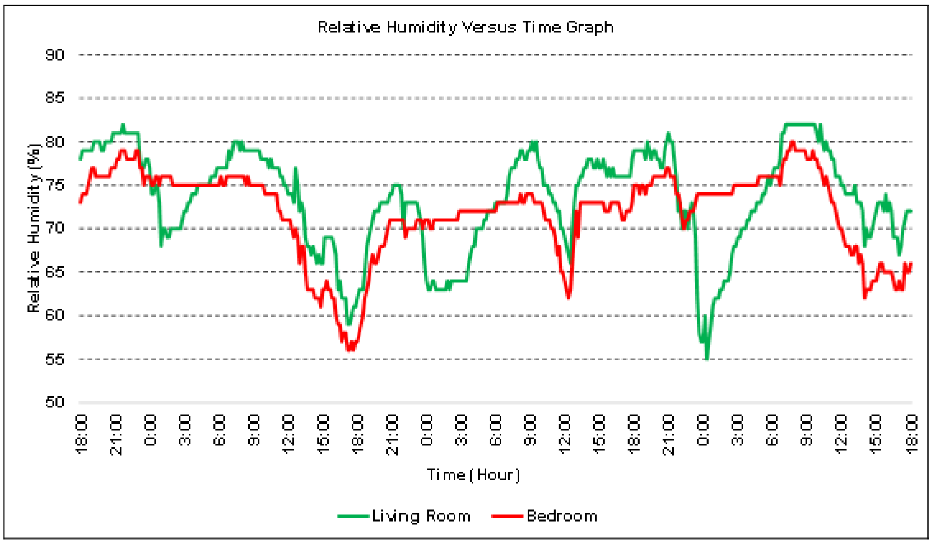


**Figure 8: Relative humidity versus time graph in living room and bedroom at modern Iban Longhouse**

### 4.4 Indoor and Outdoor Air Temperature Difference

The graph 9 and 10 shows the comparison of indoor and outdoor air temperature difference versus time graph for traditional and modern Iban Longhouse. From the graph, it shows that temperature differences at living room and bedroom at traditional Iban Longhouse is 7.3°C and 7.6°C higher during day compared to the outdoor temperature. This probably due to the usage of zinc roof is the factors that might contribute to the increases of indoor air temperature in the Traditional Iban Longhouse. Zinc roof is a highly heat absorbing material if it were used without any insulator. Zinc roof tends contribute to the temperature increase at the surface or space under the zinc covering. Meanwhile it appears to have cool indoor air temperature during nighttime by 1.4°C and 1.3°C due to the usage of the low thermal mass material as wall and floor.

However, in modern Iban Longhouse shows the increasing in air temperature at living room and bedroom during nighttime which is 7°C and 7.2 respectively when compared to traditional Iban Longhouse. Meanwhile during daytime, modern Iban Longhouse tends to have cooler indoor air temperature by differences -2.8°C and -2.5°C respectively during daytime. This condition probably due to the usage of highly thermal mass material such as concrete which usually trap heat during daytime and release the heat during nighttime.

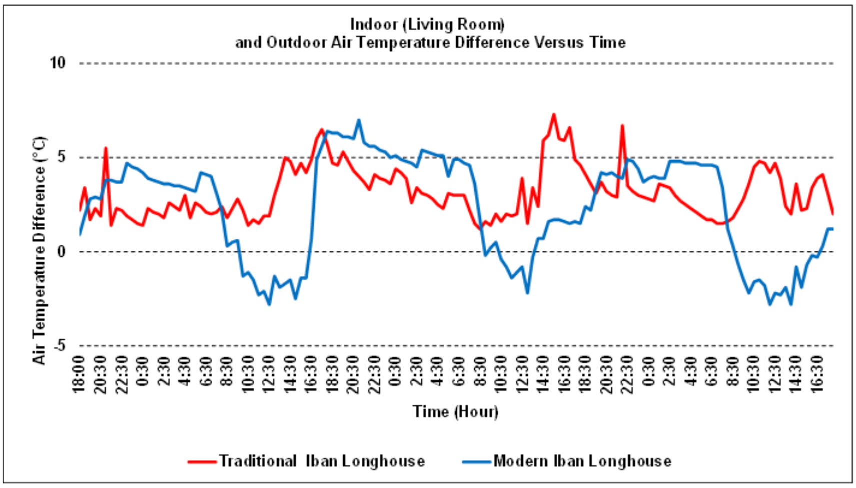


**Figure 9: Difference of indoor and outdoor air temperature versus time graph in living room at traditional and modern Iban Longhouse**

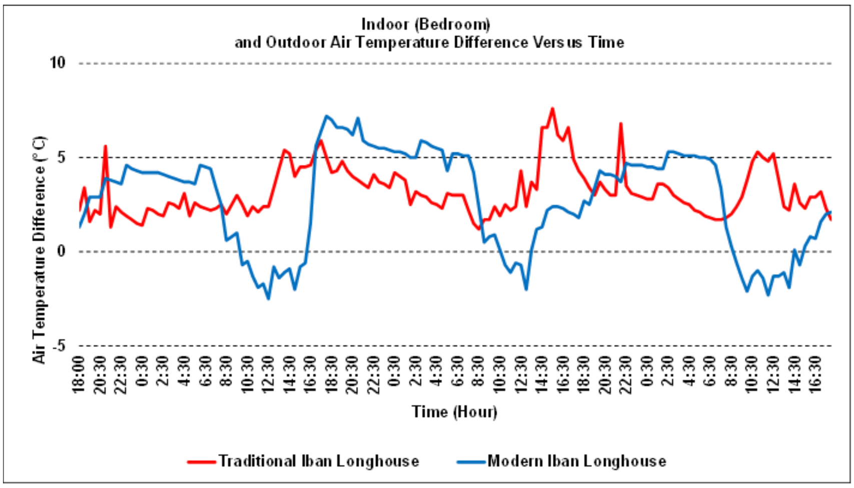


**Figure 10: Difference of indoor and outdoor air temperature versus time graph in bedroom at traditional and modern Iban Longhouse**

4.5 Discussion

The usage of material tends to affect the indoor performance in the building. Zinc roof might be one of the factors contributing to the increases of indoor air temperature in the traditional Iban Longhouse during daytime. Zinc is highly heat absorbing material if it were used without any insulator. Zinc roof tends contribute to the temperature increase at the surface or space under the zinc covering. Meanwhile, the usage of timber might be one of the factors which traditional Iban Longhouse having cool I indoor air temperature during nighttime due to timber is low thermal mass material which trap heat. It is recommended to use other roof material that can reduce the amount of heat such as concrete tiles roof or metal roofing with insulator and increasing the wall window ratio to allow cool air to enter the area.

In contrast, modern Iban Longhouse tends to have higher air temperature during nighttime. Modern Iban Longhouse were built from high thermal mass material, it tends to restore heat during daytime, it can cause the indoor have cooler air temperature during daytime. However, the high thermal mass materials will release the restored heat during nighttime which may contribute to the spike up of indoor temperature during nighttime [13]. It is recommended to use air conditioner or open the window during the nighttime to achieve suitable indoor air temperature for occupant.

## 5. Conclusion

To conclude the study, the usage of material is important in order to maintain the good indoor air temperature for occupant comfort. Indoor air temperature and relative humidity may be different due to the usage of material, occupant activity and environment surrounding. Usage of high thermal mass material may affect the indoor air temperature due to it trap heat during day time and will release or re-radiate to the indoor room during night time.

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