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Bioclimatic design approach in Dayak traditional longhouse

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Abstract

The bioclimatic building design is essential for a building to adapt to local climates and to provide comfort for the inhabitants while encouraging energy saver features. Comfort inside the house can be achieved with less dependence on artificial lighting and mechanical ventilation, and the application of eco-friendly materials. Wood and bamboo are examples of eco-friendly materials which are excellent in absorbing heat and allowing natural ventilation thus giving comfort to the occupants. These materials are widely used in the construction of Dayak traditional longhouses in Sarawak, Malaysia. Therefore, a study has been conducted to assess the presence of bioclimatic building design approach in the Dayak traditional longhouse. In the study, observation and photo analysis were carried out at selected traditional longhouses in Sarawak. This study found that traditional longhouses practice bioclimatic building design. The traditional longhouse with its passive design for lighting and ventilation and materials contribute to its natural adaptation to the hot and humid weather conditions in the tropical climate. The findings are expected to generate ideas for bioclimatic building design for other modern houses in a tropical climate. In conclusion, the Dayak traditional longhouse in Sarawak, Malaysia is a good example of bioclimatic building design of the past.

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Keywords: Bioclimatic Design; Comfort; Eco-friendly; Traditional Longhouse; Tropical Climate

1. Introduction

Borneo Island is well known for its thick jungles and various indigenous tribes which are rich in cultural diversity. This tropical island is divided into three countries: Malaysia, Indonesia, and Brunei. Borneo Island is a tropical island with hot and humid weather throughout the year. This factor influences the design of the Bornean architecture to suit the weather and maintain the comfort level of the dwellers.

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Most Bornean traditional dwellings are built from local materials such as bamboo, ironwood, and sago palm leaves which have low thermal mass and are permeable [1]. The properties of the materials reduce heat gains and allow natural ventilation.

The longhouse is one of the traditional dwellings that can be found on Borneo Island. The dwellings belong to the Dayak community which can be found in Sarawak, Malaysia, and Kalimantan, Indonesia. Other than the Dayak community, the Murut and Rungus communities of Sabah are also dwellers of the longhouse [2]. This study will focus on the Dayak longhouse in Sarawak, Malaysia since they still strongly practice longhouse lifestyle and are being supported by the Malaysian government [3]. The Malaysian government supports the construction of new longhouses by giving loans and other financial assistance to the longhouse owners [3].

Even though the construction of new longhouses is being supported by the government, the concept of the longhouses is being modernized. The environmentally friendly and sustainable traditional materials are being replaced with modern materials such as concrete and bricks [4]. Some of the surviving traditional longhouses are also being affected by modern influences. Metal roofing, laminated boards, asbestos boards, and plywood are being used to repair certain parts of the longhouse as an alternative to timber shingles for roofing and wood for the wall. The reasons for the use of these materials are their availability and lower prices [5]. The use of modern materials does not match with the traditional features of the longhouse hence damaging the aesthetical value.

It is important to study the existing traditional longhouse to determine the traditional building elements that still survive and possess sustainable features. The findings can be proofs of bioclimatic design approach in traditional longhouses and thus used to generate ideas for bioclimatic design in conventional housing. During the olden times, the traditional longhouse does not have electricity thus mechanical lighting and ventilation were not possible to be used. The traditional longhouse depends on its passive design and materials to provide solar protection, natural ventilation, and natural lighting. Materials for the traditional house are based on local materials available and the technology used in the traditional house design depends on the climate of the places [6].

2. Traditional Longhouses of the Dayaks in Sarawak

The Dayak community in Sarawak comprised three main ethnics: the Iban, Bidayuh and Orang Ulu. The Iban is known as the Sea Dayak and the Bidayuh is known as the Land Dayak. The terms Bi-dayuh itself means the people of the hill or land. The Bidayuh people can be divided further into a few dialect groups such as Jagoi, Singgai, Biatah, Biannah, Bukar-Sadong, Selakau and Lara. The Bidayuh populations can be found mainly in the Kuching, Samarahan and Serian division. The Iban community is the largest ethnic that inhabits Sarawak with 713, 421 people according to the 2010 census [7]. In contrast with the Iban and the Bidayuh, the Orang Ulu is a political term used to describe a few minority ethnics that live in the upriver areas. Kayan, Kenyah, Lahanan, Berawan, Kejaman, Bukitan, Ukit, Lun Bawang, Kelabit, Penan and Punan to name a few of the minority ethnics that can be found in the Sarawak upriver areas [8]. The longhouse design between the ethnics is quite different from one another which depends on the structure of the society and the longhouse locations. The Iban and Bidayuh longhouses are simpler and have almost the same spatial elements; while the Kayan and Kenyah longhouses are larger and more decorative [1, 9]. The Kayan and Kenyah people of the Orang Ulu group strongly practice a stratified society where they have the maren, panyin and panyin lamin classes [1]. Maren is the aristocrat class and it is common for the Maren's apartment to be larger than the rooms of the other classes [1]. Panyin is the ordinary freemen and panyin lamin is the slaves to the Maren [1]. In this modern times, the practices are not significant anymore as compared to the past.

The traditional longhouse consists of four main spatial elements: the long gallery, the open veranda, the apartment, and the loft. The long gallery and open veranda are shared among families in the longhouse but maintained by each family [10]. The long gallery is a covered long space located in front of the apartments of the longhouse dwellers. The gallery acts as a place for welcoming guests, the place for bachelor men to sleep, for socializing and event celebrations. The open veranda is the uncovered long space outside the gallery that functions as a place to dry paddy, commodities such as black pepper and cocoa, and a place to dry clothes. The apartments are the place for every family in the longhouse to carry out their daily chores, for resting and preparing food. The apartments are privately owned and maintained by the different families in the longhouse [10]. The loft is the space located on top of each apartment. The loft is used to keep family possessions, paddy and even as a sleeping place for the single women or girls of the family [4].

3. Bioclimatic Design Approach

Nowadays issues such as global warming, ozone depletion, energy wastages and pollution have woken up the housing and construction industry to implement sustainable and green solutions. Various research has been done to determine suitable green solutions to be implemented in new constructions. One of the solutions is by applying the bioclimatic design approach. Bioclimatic design is a sustainable design which makes use of the passive design of a building or house to achieve a certain comfort level with as minimal use of energy as possible and low carbon emissions [6]. Bioclimatic design approach is used to minimize the usage of mechanical ventilation, artificial lighting, and air conditioning which consume high energy. The traditional house is among the past architecture that is found to be practicing bioclimatic design. The reasons for practicing bioclimatic design in the past were due to lack of electricity and absence of modern technology [6]. Every traditional house was built using environmentally friendly local materials and architectural design that allow natural solar protection, natural ventilation, and natural lighting. The traditional house was designed according to the local climate to provide comfort to the dwellers without the presence of modern cooling technology. The traditional longhouse of the Dayak people in Sarawak is no exception. The longhouse has its own design that is used to provide comfort to the longhouse dwellers. Even though nowadays the longhouse is no more a hundred percent having the original form but some bioclimatic design approaches of the traditional longhouse still survive and function.

Modern architecture focuses more on the function-shape concept while traditional or vernacular architecture focuses on the shape-energy concept [6]. Modern buildings such as terrace houses and apartments are built to gain monetary value rather than focus on energy saver features. Modern buildings are built to not exceed certain costs and this causes poor implementation of the energy saver features. While for the traditional house, the importance is to apply solutions to achieve comfort level by using passive design since no modern technology was available then. The rural house also depends on passive design to maintain the thermal comfort in the house due to the inability to afford air conditioner installation or lack of electricity supply.

The implementation of bioclimatic design approach for thermal comfort needs to focus on four factors that are: wind orientation, climate, solar radiation, and materials [6]. The best orientation of the house to achieve maximum natural ventilation is whereby the openings such as windows need to face the direction of the wind. A site study must be made to determine wind directions to design the orientation of the building and the location of openings. In terms of solar radiation, the north-south orientation is an option since east-west orientation receives maximum solar radiation [11]. A study conducted on the climate of the site can assist the process of implementing suitable bioclimatic design and materials selection. Materials selection is also based on the availability of local materials.

4. Research Methodology

This paper presents findings from 16 longhouses studied. Site visits and observation have been done on 15 longhouses. Another one longhouse was studied by using secondary data from photos and interviews with its former residents as this longhouse has already been demolished. The longhouses are located all over Sarawak which comprised 5 Iban longhouses, 9 Bidayuh longhouses, and 2 Orang Ulu longhouses. The selection factors of the traditional longhouses were accessibility, transportation, location, availability, financial, time constraint, and manpower. Observation and photo analysis have been done to determine traditional bioclimatic design approaches on natural ventilation, solar heat protection, and natural lighting. A record card was used to record the availability of the bioclimatic features. The record card was divided into three sections: Section 1-Longhouse profile; Section 2-Longhouse plans, sections and elevations; and Section 3-Checklist on the bioclimatic design approach applied in the longhouses. Besides record card, a few interviews with some of the longhouse dwellers were conducted to obtain more information on the longhouse and the bioclimatic building elements.

5. Bioclimatic Design Approach in Traditional Longhouse

Bioclimatic design approach in traditional longhouses was found to be implemented in the ventilation openings system, structural design, materials and daylighting system. The original designer of the longhouse allowed natural ventilation by providing large openings on the roof which is known as the *kamban,* and fixed transom on the upper part of the wall. The passive structural design of the longhouse provides solar protection to the longhouse interior by having high roofs and the presence of a loft space. The use of indigenous materials such as timber, bamboo, and sago palm leaves increases the effectiveness of the passive structural design and ventilation openings. The indigenous materials are known to have low thermal mass which insulates the longhouse from exterior heat [1]. Light tunnel and transparent roof coverings are used to provide daylighting to the dim longhouse interior especially the apartments that were built side by side. Figure 1 shows the bioclimatic design approaches that can be found in the traditional longhouse.

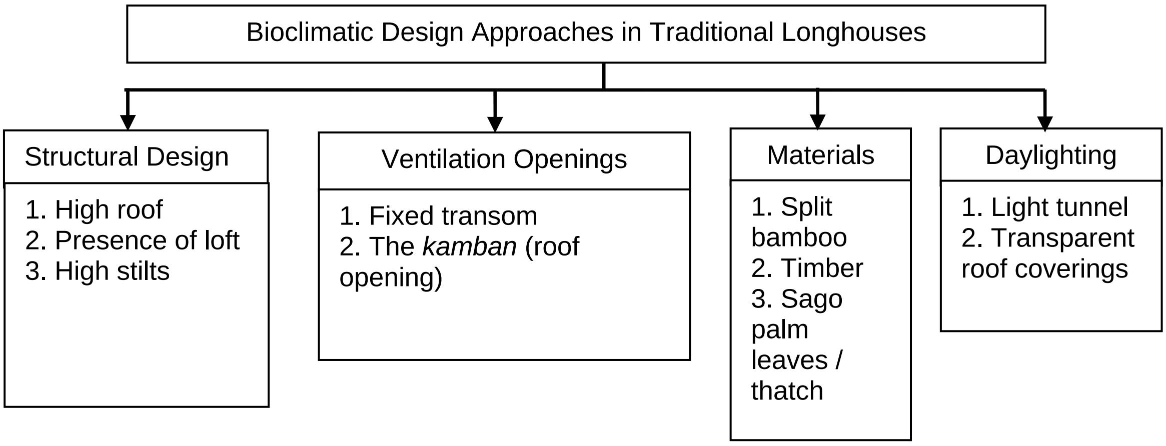

Fig. 1. Bioclimatic design approaches in traditional longhouses.

5.1. Ventilation Openings

In the past traditional longhouses depend on passive design to achieve thermal comfort by natural ventilation. Some of the features still survive and function until this day. From observation during the fieldwork, it was found that almost all longhouses had fixed transom on top of the apartment's front wall. The function of the fixed transom is more efficient with the presence of other passive ventilation features in the longhouse. For example, the original floor of the apartments and gallery of the Sebemban's longhouse was made of split bamboo before underwent renovation. The longhouse was built on stilts which still stand until today. The combination of the passive function of the raised floor, split bamboo and fixed transom were effective to provide ventilation to the apartment's interior where windows are limited. By applying the stack effect concept, cool air comes from under the raised floor through the split bamboo floor and hot air will rise and exit from the fixed transom and other openings on top. Having raised floor and openings on the floor will assist ventilation for the traditional house [12].

From the observation on the existing longhouses, almost all apartments have changed the split bamboo floor to wooden floor. Originally the materials of the floor for the long covered gallery and the apartments are from split bamboo and split areca palm. Presently, these materials are replaced with solid timber floor due to difficulty in maintenance and the availability of the bamboo plant. Only the covered gallery and open veranda in a few longhouses still have split bamboo as its materials. The replacement of split bamboo floor with solid timber floor reduces the effectiveness of the natural ventilation in the longhouse apartments.

Fig. 2. (a) Sebemban longhouse covered long gallery; (b) One of the family apartments in Sebemban longhouse.

Fig. 3. Different styles of the fixed transom on top of the front apartment wall facing the long covered gallery in the longhouse.

Apart from the transom, traditionally a longhouse especially in the Bidayuh community has roof openings which are known as *kamban*. The function of the *kamban* is for natural ventilation and day lighting. During night time the *kamban* will be lowered to be at the same level with the roof and flapped to open during day time. A bamboo stick was commonly used to support the opened *kamban*. The roof coverings of the *kamban* were made from palm thatch. Sadly nowadays the *kamban* is nowhere to be seen. The Merian Bedup longhouse was one of the few longhouses from the past that still has the *kamban*. Unfortunately, the Merian Bedup longhouse was demolished in the year 2011. Fig.4. (a) shows the *kamban* at the roof of the longhouse. Each apartment in the longhouse has its own *kamban*.

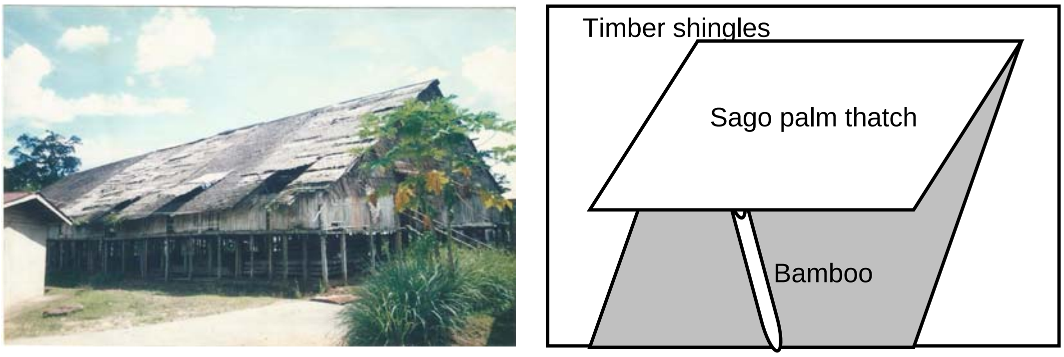

Fig.4. (a) The Merian Bedup longhouse and the *kamban*, the opening on the roof; (b) The *kamban* details.

5.2. Structural Design

Apart from the presence of ventilation openings, the design of the longhouse structure provides protection against solar heat (Fig 5). The high roof reduces heat gain into the longhouse interior. The structure itself needs to provide solar heat protection to the longhouse. For example the longhouses in Annah Rais in Padawan; Rumah Ahsoon near Sg Anap, Bintulu; Rumah Jimmy in Saratok; and Sebemban longhouse in Serian. The presence of the loft on top of each apartment reduces heat gain in the main living area underneath. A study on Minahasa House which has almost common features with the longhouse, found that high ceilings with roof openings create stack effect which allows cool air to enter from below and hot air to escape from above [12]. Previously, timber shingles and palm thatch were the main materials for longhouse roofing. The permeable properties of the traditional roof materials permit heat that arose from the lower levels of the longhouse to be freed and replaced by cool air.

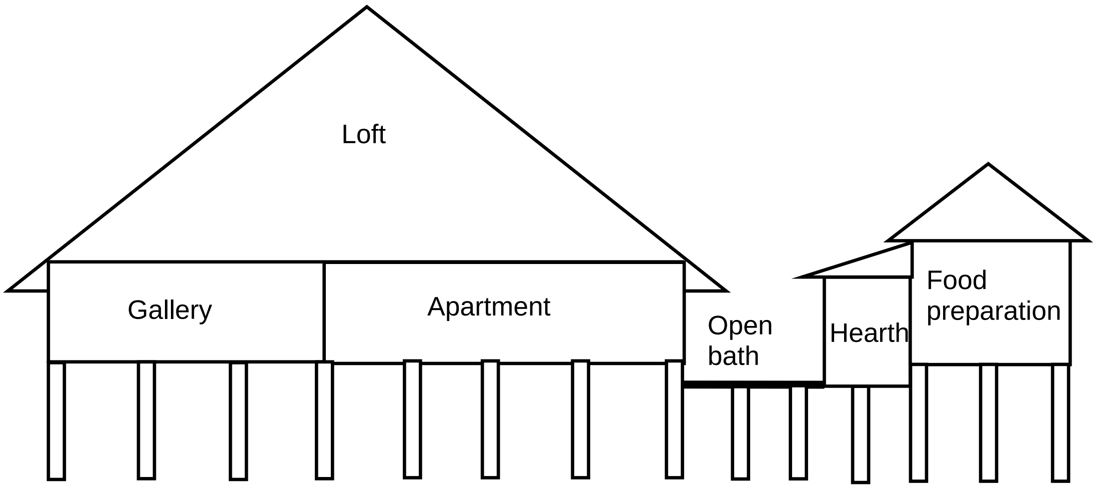

Fig.5. Cross section of the Merian Bedup longhouse before it was demolished in the year 2011. The roof was very high which provides a very good solar heat protection to the longhouse interior.

The traditional longhouse is categorized as one of the Austronesian house that can be found within the Austronesian region that stretches from South East Asia to the Indian Ocean territory. There are three key features of an Austronesian house: built on high stilts, high roof and decorative building elements [1]. One of the functions of the high stilts is to provide ventilation. Wind velocity is higher on a high place. The higher the stilts, the higher wind velocity can enter into the house [12]. The stilts are responsible to place the longhouse higher from the ground to receive more wind. Besides that, the high stilts allow the wind to enter from underneath of the longhouse as shown in Fig.6. A house with wall, roof, and floor openings together with higher stilts has high wind velocity of 154-173 mm/s as compared to a house that only has window openings and lower stilts where the wind velocity is only between 21-57 mm/s [12].

Fig. 6. High stilts of the Rasau longhouse, Serian. The longhouse does not depend much on mechanical ventilation where it was found that no mechanical ventilation or air conditioner were installed.

5.3. Materials

Timber homes can provide comfort against solar heat especially in the tropical areas that receive heat the whole year. Residents in the coastal areas which receive more heat still feel more comfortable in timber structure as compared to the respondents in the mountainous areas [13]. This shows that timber is excellent in protecting house dwellers from heat but not very good at protecting dwellers from cold [13]. In a tropical country like Malaysia, protection against solar heat is more important since the country experiences hot weather throughout the year. Timber is a poor heat conductor as compared to brick and concrete. Timber heat conductivity value is 0.13 W/m K for softwood and 0.15 W/ m K for hardwood according to CIBSE Guide [14]. However, dense concrete has a much higher thermal conductivity value of 1.4 W/m K while exposed brickwork has a conductivity value of 0.84 W/m K [14]. This shows that timber can be a good insulator to heat as compared to concrete. This property encourages traditional houses in a tropical country such as Malaysia to use timber as main materials. Not only that, timber can be found abundantly in the Malaysian thick rainforest.

Ironwood or *belian* in local term is a very hard wood that is used as the main structure of the longhouse such as the beam, stilts, and column. This ironwood is known to be hard and durable for a long time. Iban and Orang Ulu longhouses are known to be built using ironwood. Timber shingles are made from ironwood and it is excellent in protecting the longhouse interior from the outside solar heat. The nature of the ironwood which is weak in conducting heat made it an excellent insulator thus can be good for roof covering. In Merian Bedup longhouses (Fig 7), the apartment was an open living space with no partitions built. Only floor beams were visible as an indication for every space in the apartment area.

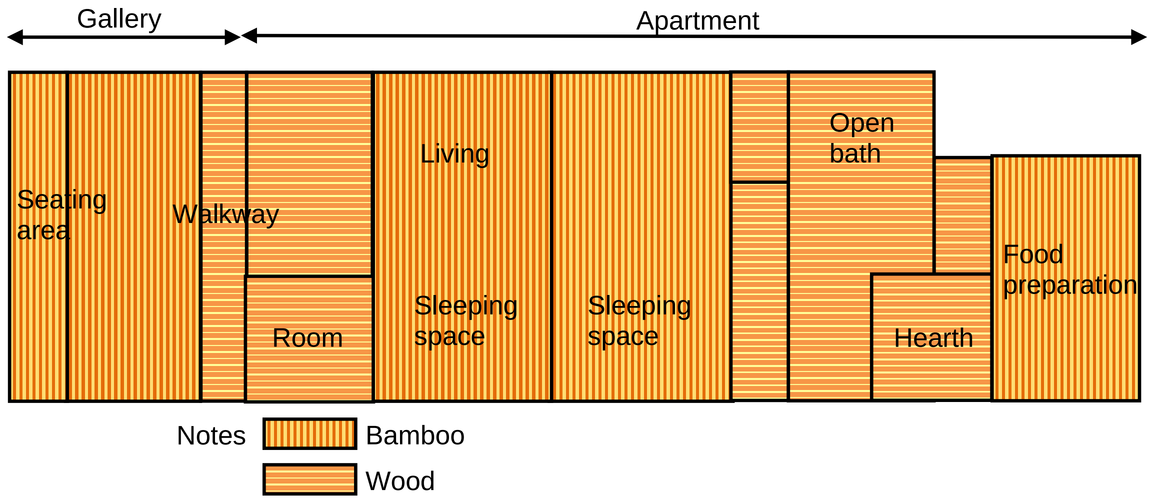

Fig. 7. The plan for Merian Bedup longhouse.

The Bidayuh longhouse is well known to use bamboo as its main materials (Fig 8). Bamboo is used for floors, walls, beams, trusses, supporting columns and supporting stilts. The permeable features of the split bamboo walls and floors allow the wind to enter the longhouse. The air can move freely between the loose split bamboos. From the observation and interviews, it was found that almost all Bidayuh longhouses have changed bamboo materials to more durable wood materials for the walls and floors. Only 5 out of 8 visited Bidayuh longhouses still retain bamboo but only for the covered gallery and open veranda.

Fig. 8. (a) Split bamboo walls of the Benuk longhouse; (b) Split bamboo floor of the covered gallery in Mongkos longhouse; (c) Split bamboo floor of the open veranda in Annah Rais longhouse. All three longhouses are Bidayuh longhouses.

Traditional longhouses also used sago palm thatch or its scientific name metroxylon sagu as roof coverings beside timber shingles (Fig 9). The photo of a Merian Bedup longhouse in Fig 4.(a) shows some parts of the longhouse roof used sago palm thatch. The environment-friendly material is waterproof where it is suitable to be used as roof coverings. However, the sago palm thatch needs to be changed on a regular basis as compared to timber shingles.

Before being used as roof coverings, the sago leaves are stitched together using bamboo or rattan and left under the sun to be dried. The green sago palm leaves will turn to brownish before they are ready to be used as roof coverings. Commonly the sago palm thatch is used as an alternative to timber shingles. It is also used as wall coverings. Low thermal mass in the sago palm thatch assists in reducing heat gain for the interior parts of the longhouse [1].

Fig. 9. (a) Timber shingles roof; (b) Wall coverings from sago palm thatch; (c) Sago palm thatch dried under the sun.

5.4. Daylighting

The apartments in the longhouse are built side by side which lead to an inadequate number of windows to provide natural daylighting. The approach taken by the longhouse builder was to construct roof light tunnel to focus daylight to the interior parts of the longhouse. This roof light tunnel provides lighting quality that is almost similar with the fluorescent lamp. Besides roof light tunnel, some parts of the roof are fixed with transparent coverings. The application of the natural daylighting system in the longhouse was found to be effective for energy saving and reduces electricity consumption (Fig 10).

Fig. 10. (a) The roof light tunnel as seen from the side; (b) The interior of the roof light tunnel; (c) The roof light tunnel lights up the living room of one of the apartments in the Rumah Ah Soon longhouse; (d) Transparent roof coverings allow natural daylight to light up the dim longhouse.

6. Conclusion

As a conclusion, traditional longhouses have practiced a few of the bioclimatic approaches to maintain comfort and provide natural daylight since a long time ago. Limitation in electricity supply and absence of ventilation and lighting technologies cause the longhouse builders to find solutions in maintaining the thermal comfort and provide daylighting to the longhouse. These solutions consume less energy and zero carbon emission which can be a good example from traditional dwellings. Each component of the longhouse from building design to materials play an important role in providing thermal comfort and daylighting to the dwellers. The materials of the traditional longhouse are environment-friendly and does not pollute the environment. The findings of this research can be used to generate ideas for bioclimatic solutions especially for terraced houses where there are inadequate number of openings to provide daylighting and natural ventilation.

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Rh Jimmy, Rh Medol, Rh Ah Soon, Rh Manja, Rh Ruma, Uma Kulit, Uma Belor and Kpg Merian Bedup.

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