Passive Building Design Approach in Iban Long houses

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Abstract: Passive Design is design that uses the advantage of the climate for maintaining the thermal comfort inside the room. Comfort inside the house can be achieved with less dependence on artificial lighting and mechanical ventilation, and the application of eco-friendly materials. Timbers and bamboos are examples of eco-friendly materials which are excellent in lessen heat flow and with proper inlet and outlet allow natural ventilation thus giving comfort to occupants. These materials are widely used in the construction of Iban longhouses in Sarawak, Malaysia. Therefore, a study has been conducted to assess the presence of passive building design approach in the Iban longhouse in Sarawak. In the study, site observation with photo analysis, experimental work and CFD simulation by Autodesk CFD software were carried out at eight selected Iban longhouses in Sarawak. This study found that Iban longhouses practice passive building design. Iban longhouse implements passive design strategies in achieving comfort for occupants. This contributes to 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 terrace 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.

Keywords: Passive Design, Long House, Thermal Comfort, Computational Fluid Dynamics

1. Introduction

Borneo is the third largest tropical island in the world after Green Island and New Guinea. Borneo Island is one of the tropical islands which experience hot and humid weather throughout the year. Its climate has influence the architecture design of the Bornean dwelling. In order to maintain the thermal comfort in dwelling, the architecture design was design to adapt the surrounding climate. According to J. Ting [1], most Bornean traditional houses are built from local low thermal mass and permeable materials such as sago palm leaves, ironwood and bamboo. These materials properties can reduce heat gains. Besides, the arrangement of these materials has allowed natural ventilation. Longhouse is one of the traditional buildings that can be found in Borneo Island. Longhouse is popular for Dayak, Murut and Rungus community dwelling. Research by H. Steiner [2] and T.T Sim [3] state that Dayak community lives in Sarawak and Kalimantan, Indonesia while Murut and Rungus community can be found in Sabah, Malaysia. Dayak community can be divided into two difference races which are Iban and Bidayuh. However, this study will focus specifically on the Iban longhouse in Sarawak. Furthermore, studies of indoor air movement and to proof that the Iban longhouse having passive design will involve computational fluid dynamics (CFD). The distribution of air flow and concentration can be simulating by using CFD. According to Zhang Lin et al [4] CFD have being used to solve building and environment problem for over 20 years ago. Besides, CFD was used to determine the optimal way of ventilation design to prevent smoke release by vehicle exhausts reach pedestrians. CFD simulation is very popular method to monitor the condition of indoor environment, inclusive of simulating airflow patterns, thermal comfort and pollutant concentration [5][6][7]. The modern techniques of conducting research and reliability, make CFD a powerful tool for simulation and the visualization of environmental problems.

The main objectives of this study are:

- To identify passive design of the existing Iban Long Houses.
- To validate the CFD simulation with the experimental data. (air velocity and indoor air temperature)
- To suggest possible passive design features in terrace houses.

2. Iban Longhouse

Sarawak are well known as the world's leading in producer of pepper, consists of fifty-four percent of its population lives in rural and remote longhouses according to [8] Sarawak has about 2000 longhouses [9]. The Borneo longhouse is an architectural form of building found throughout Sarawak. It can be found in various ethical forms, such as Iban, Bidayuh and Orang Ulu. A study by [10] found that majority of the Iban population is centralized around the Kapit district and along the Rajang River. The Iban also known as Sea Dayak and while else the Bidayuh ethnic group called Land Dayak. Similar to Iban, Bidayuh also lives in a longhouse west of Sarawak, in the province of Kuching.

The longhouses can be presumed as a village which consist of numbers of small family stay in family apartment set neatly beside each other. Iban longhouse usually found in "Route less" tracts of tropical rainforest. However, there is little access to their slash and burn farm or others longhouses [10]. Thus, every household own a long boat also known as "Perahu" and the river is the main transport system.

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 [11]. 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 [11].

3. Passive Design

Passive design is design that uses the advantage of the climate for maintaining a comfortable temperature range in the room. Passive design reduces or eliminates the need for auxiliary heating or cooling in a building that consumes about 40 percent of the world's energy production. As a result, dwelling produce about 40 percent of the sulphur dioxide and oxides of nitrogen that cause acid rain and the formation of smog. Building energy contributed 33 percent of all annual carbon dioxide emissions, significantly cause climate changes brought about by the accumulation of this heat-trapping gas [12].

Passive design considers a special way to control the internal environment of a building using air movement, passive solar gain, natural heat, and cooling to maintain good internal environmental comfort. According to Bansal N [13] by using passive solutions, the uses of a mechanical system can be eliminated or at least reduced by 80 percent. Other than that it also can reduce the emission of carbon dioxide.

The passive building is a building in which a pleasant indoor climate can be consistently maintained without mechanical automation system. Passive design is considered as a solution involving the design of properly oriented, shaped, ventilated and shaded buildings suited to the bioclimatic features of the site [14]. In other words, indoor thermal comfort is achieved naturally throughout most of the year.

4. Methodology

This paper presents findings from eight (8) Iban longhouses. A study has been conducted to assess the presence of passive building design approach in the Iban longhouse. In this study, site observation with photo analysis, experimental work and CFD simulation by Autodesk CFD software were carried out for eight (8) selected Iban longhouses in Sarawak. Seven of the Iban Longhouse are located at Sri Aman and remaining one (1) longhouse located at Santubong, Kuching. The longhouses were selected based on their accessibility, locality, occupants' ready ability, time and financial limitations. Data on the construction materials were taken while social spaces and sizes were measured. Traditional passive design approaches on channelling natural ventilation flow and controlling heat gains from sun light while harvesting for natural lightings were observed and relevant data were collected and analysed. Data on relative humidity also were taken for a period of time to understand their behaviour and differences if any.

Experiments were conducted at selected common rooms for data collection on the air flow, air velocity, temperature, humidity and light intensity of selected longhouses. These parameters were measured by using three different devices shown in Figure 1. Furthermore, the modelling involved one selected longhouse which is Rh Johnson. Rh Johnson represents the others seven longhouse as the result of experimental data among the longhouse show not much difference. Figure 2 show selected longhouse

This research on the later part simulates natural ventilation particularly from wind driven ventilation inside one of the selected house for a validation work. Experimental data were collected on the centre of selected space, at entrance and exit doors along at selected openings at selected height from the floor. This simulation begins with creating simplified computational 3D model of the room of the longhouse using CFD software. This dimensions than exported to Computational Fluid Dynamic (CFD) ANSYS Fluent 2019 where three boundary conditions were defined as the inputs of the simulations. These conditions are: a. Wind Velocity; used as an inlet boundary condition b. Pressure; used as an outlet condition c. Slip/Symmetry; this condition causes the fluid to flow along a wall instead of stopping at the wall, which typically occurs along a wall.

Figure 1: Calibrated Equipment for Data Collection

Figure 2: The selected Iban longhouse for data collection

5. Methodology

Passive Design Approach

Figure 3 and Figure 4 shows several common features in longhouse which contribute to thermal comfort. The main-purposed of the features in longhouses design is to provide the dweller with natural ventilation, day lighting and ideal temperature.

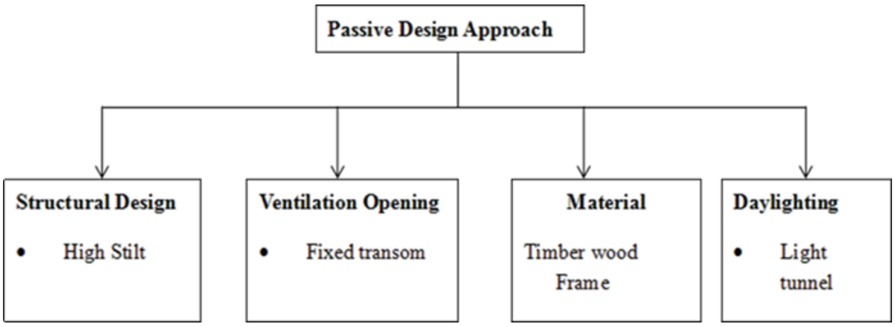

Figure 3: Passive Design Features commonly found at the Iban longhouses

Figure 4: Picture of Passive Design for the Iban longhouses

In term of structural design, high stilts were used in longhouse design because of several reasons such as increasing the occupants' security, which to protect against enemy, flood and securing from dangerous animals and to increase occupants' privacy [12]. Further, the use of high stilt creates passive design approach where it elevates the longhouse and allow wind to be caught at higher velocity [15]. At higher altitude, wind flows faster because there are no ground vegetations that can slow it down. Cool airs are also allowed to circulate beneath the longhouses which keeps the houses cooler in overall. Fixed transom windows at the longhouses allow air to circulate through the houses as well which is good for ventilation [15].

The main material for Longhouse construction is timber wood frame. Because of its lightweight construction, timber-framed houses are more responsive to heating and cooling rather than buildings with higher thermal mass. These longhouses are situated in hot and humid climates which means nights are significantly cooler than days. The heat that absorbs by timber material during the day were released during the night. Since timber wood frame has lower thermal mass, the released of heat is much more rapid [16]. This makes the longhouses much cooler since it is not retaining heat.

The light tunnel that installed at every apartment unit in the longhouses will let the natural light to be illuminated into the houses. Less electricity will be used to brighten the space, and it is effective for energy saving and reduces electricity consumption.

Experimental Data

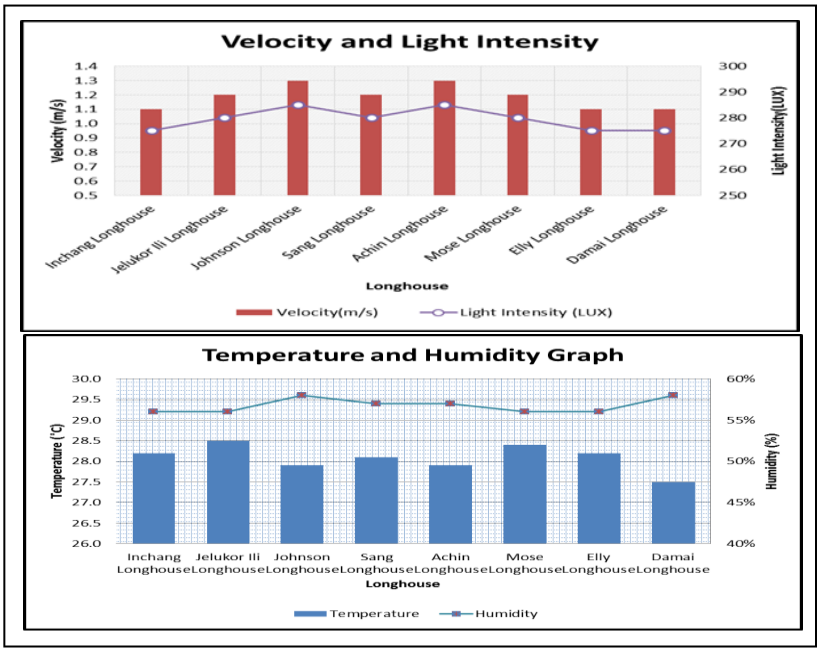

Figure 5: Graph of Air velocity, Light Intensity, Temperature and Humidity at longhouses

Study shows that during peak hot weather, during clear blue sky at 1pm until 130pm, at the longhouse social spaces the temperature gathered were still within the comfort range as shown in Figure 5

- Temperature in range 27-28.5 ° c
- Air Humidity between 60%-65%
- Light intensity in range 275lux-285Lux
- Air velocity is in range 1.1m/s-1.3m/s

Computer Fluid Dynamic Simulation (CFD)

The experimental data shows that all the sample longhouses sharing almost the same reading for air velocity, light intensity and temperature. As the data of the eight sample longhouse almost identical, Rh Johnson Longhouse was selected for CFD modelling.

This research used Computational Fluid Dynamic (CFD) ANSYS Fluent 2019, where there are many options when visualizing the results of a simulation. The plane feature was used to view the results within the same plane that the actual sensors were installed, cantered horizontally. Figure 6 and figure 7 used to present the result of simulation.

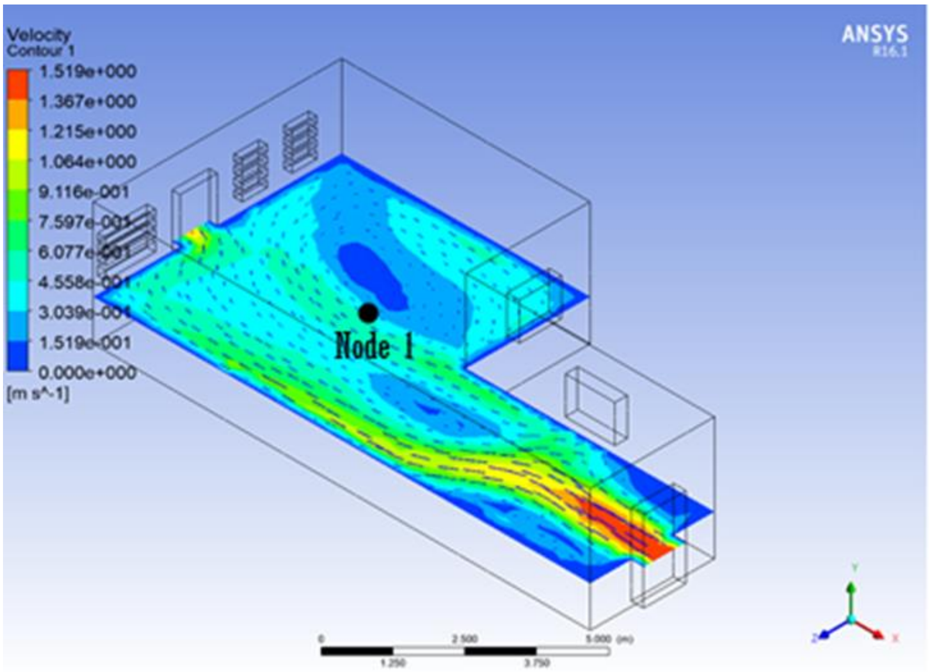

Figure 6.0 CFD simulation of indoor air velocity

Figure 6.0 shows the simulation of air velocity inside one of the apartment in Rh Johnson longhouse. It shows magnitude of air inside the apartment. The incoming air velocity is at the door of 1.5 m/s. The collected experimental data using anemometer at a located node point 1 in the middle of the room height 1 meter from the floor are at average 0.4 m/s which is lower than simulated value of 0.45 m/s. The difference is within the acceptable values of 12%.

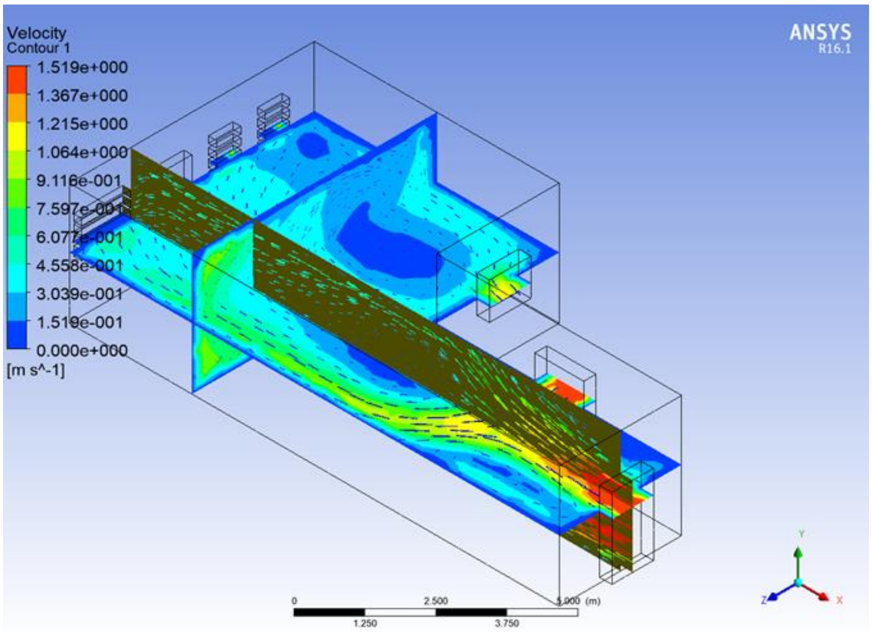

Figure 7.0 CFD simulation of air movement vertical plane

Figure 7.0 shows the pattern of air movement vertically in a selected plane inside the apartment. It shows the infiltration and exfiltration of air inside the room. Simulation indicate that the inflow of air at the front part of the house (gallery/ hall). The air then is distributed into the apartment later flown out through the back part of the door opening.

6. Conclusion

Study proves that Iban longhouses have practiced few passive design approaches to maintain comfort and provide natural daylight. A thermal comfort study on a naturally ventilated eight sample of Iban longhouse was presented. Actual measurements on the air temperature, relative humidity and air flow velocity show that the data achieved the thermal comfort zone standard.

CFD simulations were conducted on the representative models of the house. Using this method, we were able to observe naturally ventilated air flow conditions inside the house. The findings of this research can be used to generate ideas for passive design solutions especially for terraced houses where there are inadequate number of openings to provide daylighting and natural ventilation.

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