Contemporary House with Vernacular Elements 
Effect on Natural Ventilation in Tropical Climate 

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ABSTRACT

Most design of houses in tropical area today still considers natural ventilation as their main ventilation approach. However, proper understanding on how natural ventilation reacts towards variety of building designs is very important in taking advantage of the potential. Based on previous researches, vernacular buildings show good natural ventilation potential by providing good indoor air movement. Therefore, the research was done to see how vernacular building elements applied on contemporary design houses may affect their natural ventilation performance. Two case studies of houses were chosen according to design criteria identified. In both cases, the ventilation performance was identified by collecting data of the air movement via the wind speed and air temperature at several points determined inside and outside of the houses. The result shows the high ceiling double volume house known as Rengit House of Case Study 2 shows a better natural ventilation performance compared to another high ceiling double volume house of Case Study 1 known as BP House. The Rengit house roof is high using Malay traditional roof element with ventilation openings, while the windows are positioned in order where they may capture the maximum cross ventilation at the site. However, in BP house, instead of having numbers of window openings, the slim elongated design of the windows shows a lower performance in capturing the air movement into the house. As predicted, the double volume area of Rengit house which is larger than the BP house also recorded a better vertical air movement. The improper positioning of openings in BP house also show interruption on the vertical air movement which defy its ventilation potential.

Keywords: Natural ventilation, Air movement.

1. INTRODUCTION

Nowadays, energy crisis has become an important global issue. Poor passive thermal design in building construction makes the issue more critical. Almost 68% of the energy usage is used for Heating, Ventilating and Air Conditioning Systems (HVACs) [1]. Aware by the problem, people nowadays have started to opt to green building materials and design features that can save energy. The role of a building design is important to provide good thermal comfort of indoor environment. There are two approaches in providing a good thermal environment in a building which are the passive and active design approach. Natural ventilation is a passive approach based on openings such as windows and other ventilation openings to allow the air to enter and leave the building naturally. The air movement within buildings is necessary to remove any undesirable odours, contaminants, moisture and also to provide cooling in summer for human thermal comfort [2]. By relying on natural ventilation, the air
movement process can be achieved without depending on mechanical air ventilator.

Natural ventilation occurs based on two different principles which are cross ventilation and stack ventilation. The common way to obtain natural air supply in the buildings is through the cross ventilation. This natural ventilation system needs good wind pressure and it depends on the wind direction [3]. Therefore, building design should integrate proper building elements and proper building orientation to gain excellent cross air ventilation [4]. Meanwhile, stack effect uses thermal buoyancy as a driving force to create the airflow. Principles of stack ventilation are based on temperature differences between the inside and outside of a building, height of space, stack throat and also the size of upper and lower openings. The warm air in the building will leave the building through the upper openings. While, cold air from outside will replace it by entering through the lower openings [5]. Whereas the cool air inside the building will leave the indoor area through the lower openings and replaced by outdoor air from the upper openings. Most designs of houses in tropical area today are still considering natural ventilation as their major ventilation approach. Based on previous researches, double volume stack throat or higher is an important element to move the air vertically in stack effect [6]. However, there are possibilities where the surrounding openings connected to the throat may give effect on the ventilation performance. While to shut the openings down may not be practical as in reality, cross ventilation and stack effect will perform concurrently in most cases. Hence, this research was done to make comparison on the performance of natural ventilation between two case studies of double volume houses with different layout and type of openings. The two double volume houses selected are based on their design that may have potential for natural ventilation. The houses are located at Batu Pahat and Rengit, Johor.

2. METHODOLOGY

2.1. Identification of Case Study

The case studies were chosen based on their design criteria which identified to be highly potential in contributing good indoor air ventilation to the buildings. It is named the physical architecture of the selected buildings. Both buildings are almost similar in size and height to minimize the limitation of the comparison study. Large opening of windows is the common criteria which allow maximum breeze through the building. Whereas double volume area with high ceiling may help the building to achieve a good indoor stack effect ventilation [4]. Besides that, openings at the roof level may also help in providing air ventilation under the roof which may bring cooling impact to the indoor thermal of the building. The physical architecture studied was categorized as shown in Table 1.

<table>
<thead>
<tr>
<th>Building Orientation</th>
<th>Roof Design</th>
<th>Window / Door Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Cardinal direction on site</td>
<td></td>
<td></td>
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<tr>
<td>- Roof shape</td>
<td></td>
<td></td>
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<tr>
<td>- Roofing material</td>
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<tr>
<td>- Space layout</td>
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<tr>
<td>- Opening design size at roof level</td>
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<tr>
<td>- Window and door positioning</td>
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<tr>
<td>- Window and door design and size</td>
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</tr>
</tbody>
</table>

Table 1: Physical Architecture of the Case Studies

Figure 1: Case Study 1 (BP House)

Figure 2: Case Study 2 (Rengit House)
The measurement was done using Anemometer at various points inside and outside of the building. By using the equipment, the collection of data on the wind speed and the air temperature is possible to be done concurrently. A range of 10 minutes is set to be the maximum gap of time for the data collection at all the points within the same hour.

The measurement of outdoor air movement was conducted at four points surrounding the buildings at approximately 1800mm from building wall. While the measurement of the indoor air movement was done at most of the main spaces in the buildings. One point in each buildings was decided to be at the double volume area in order to identify any vertical air movement at the area.

The parameter used in the research is the wind speed in meter/second unit which was recorded using the multi-functionality anemometer. At the same time, the air temperature of the points was also taken using the same measurement gadget to see any correlation between the data. The measurement of the indoor wind speed was done simultaneously with the measurement of outdoor area attached to the space. The outdoor scale measurement became the comparative scale of measurement in order to identify the level of performance in the indoor natural ventilation. The time measurements were taken starting from 9 am until 6 pm hourly. The measurements were done in 3 days to get the average data of both Case Studies. The data on the air movement and temperature was then compared with the physical architectural analysis of both buildings in order to see any correlation.

3. RESULT AND DISCUSSION

3.1. The Case Study 1:
The first house selected as Case Study 1 is a double storey house with a double volume living hall. The house is located at Batu Pahat, Johor, so that was called the BP house. The building envelope is made of concrete structure with clay facing brick walls. The roof is covered using clay tiles. The windows are series of slim elongated windows. They are located at the living hall, dining area and all the bedrooms. Each windows width is around 500mm, sitting slightly 200mm above the floor with a total height of 2400mm. There are few ventilation openings at the roof gable using hollowed crafted wood. Theoretically, these openings are good for natural ventilation. There is an area at the front of the house called Anjung Tamu where the owners treat their guests. Instead of located at the front of the house, the area is enclosed with walls and sliding windows. The windows are 900mm above the floor with 1200mm height. The average ceiling height of the spaces at the ground floor is 3 meters. While, the height of the spaces at the first floor is 2.6 meters. The orientation of the building is shown in Figure 3.

3.2. The Case Study 2
The Case Study 2 is also a double storey house with a double volume high dining hall. The house is located at Rengit, Johor, so that was called Rengit house. The house is made of Chengal wood with elongated windows but wider compared to the first Case Study's windows. The windows are sitting 250mm above the floor level, where the bottom part of the windows are fixed.
with wooden louvres. The openable leaves are 900mm from the floor level. There are also roof openings at the gable. The Anjung Tamu is built with an open concept, surrounded by railings at the entrance part of the house. The windows are positioned in ways to allow cross ventilation through the areas. The double volume area of the house acts as a stack throat with 5 meters height of space bringing good ventilation (air movement) into the house. Meanwhile, the roof of the house is also covered using clay tiles. The average height of the rooms and spaces at the ground floor is 3 meters. While, the height of the spaces at the first floor it is only 2.1 meters. The house is elevated at about 450mm above from the ground level, but the space underneath the house is mostly covered with brickworks. The orientation of the building is shown in Figure 4.

3.3. Air Movement Analysis:

The average data of the wind speed was identified and shown in Figure 5. Based on the data collection, the highest indoor wind speed level recorded in the survey on Case Study 1 was 1.0m/s at 10.00am at the first floor area (Point 6). It was higher than the average outdoor wind speed at that hour. At 11.00am, the indoor wind speed level at that point was also higher than the average outdoor wind speed. This condition may be influenced by the stack effect as the double volume area at the stairs may act as the stack throat to move the air vertically. Thus, through the process, the thermal buoyancy impact may become the force to move the indoor air faster than the outdoor air. At other hours, where the outdoor wind speed increase, the indoor wind speed level were found to be lower. This may indicates interruption on the stack effect by cross ventilation.

However, at other indoor points, the wind speed level was recorded at average of lower than 0.3 m/s. Despite of having numbers of windows, the indoor wind speed was quite poor even during the outdoor wind speed was high as shown at 12.00pm and 3.00pm. The narrow elongated windows may be the factors of the scenario due to the interruption of the wind flow by the window leaves. The improper positioning of the windows may also affect the wind flow into the building. Meanwhile, the fully enclosed Anjung Tamu that block the main entrance is clearly limiting the doors from receiving direct cross ventilation from outside. At 3.00pm, the indoor wind speed of the dining area (Point 3) was recorded to be the same with the outdoor wind speed at 0.7 m/s. This may be influenced by the wind flow direction towards the dining casement door.
Meanwhile, as shown in Figure 6, stack effect may also happen at Case Study 2. At point 1, which is a double volume area where the stairs is placed, the wind speed was recorded at 0.8 m/s at 11.00 am and 1.5 m/s at 7.00 pm. The higher measurement of the indoor wind speed at that point compared to the outdoor wind speed show the stack effect potential of the area.

The area consists of a large double leaves window at the ground floor but only having a small window at the upper floor. This may brought the neutral plane at a lower position that will pull the air in from outside with greater force at the upper level, thus giving a high wind speed condition in that area.

This phenomenon supports the previous finding on stack effect potential at a low neutral plane positioning in a building [7]. However, at nearby Point 7, the stack potential seems not to be as good as at Point 1. The closer the point with the window may give impact on the wind buoyancy.

While as for the indoor wind speed at other points, in-spite of not exceeding the outdoor wind speed, the air movement shows a quite similar pattern. This indicates the building ability to cater good cross ventilation through its openings. Wide windows at proper position facing the site cross ventilation may become the factor that provide good air movement into the building. Meanwhile, the consistent windy environment at 7.00 pm on the first two days has clearly affected the result. However, the rough windy situation at that time shows Point 1, 3 and 4 recorded a higher indoor wind speed compared to the outdoor wind speed. Therefore, it is predicted that the direction of the wind from North-East along with the combination of stack effect may cause that scenario.

3.4. Air Temperature Analysis
Based on the temperature result of Case Study 1 as shown in the graph above, the variations between indoor and outdoor air temperature was quite significant with previous studies on tropical building [8]. The average of the outdoor air temperature is higher than the indoor air temperature as a whole. The indoor air temperature of the Anjung Tamu (Point 1) was found higher compared to others. Enclosed walls with glass sliding windows of the area may cause the result. Besides Anjung Tamu, the indoor air temperature for other areas were shown significantly affected by the direction of sun path. This is based on by the high indoor temperature during morning till noon at Living Area (Point 2) and Room 1 (Point 4). The air temperature as recorded hourly started at 10.00am shows an overall above than 30°C, which is not under the range of an ideal comfort level.

The lowest indoor air temperature was recorded 28.5°C at the Kitchen area (Point 5), whereas the lowest average outdoor air temperature was recorded 29.4°C at 10.00 am. The small size of the windows at the Kitchen may contribute to the factor of slow heat penetration into the area. However, once the area was heated, slow movement of indoor air in the area as shown in Figure 5 may cause the indoor air temperature to remain high. At 11.00am, the Kitchen air temperature reached 33.5 °C and remain above 31°C till 5.00pm. The average outdoor air temperature was recorded above 32°C, except at 10.00 am and at 4.00 pm onwards.

However, the average indoor air temperature was found to be below 32°C throughout the day. The indoor air temperature in all areas were recorded in the range between from 31°C - 33.4°C starting from afternoon. At the same time, it is interesting to find that the outdoor air temperature started to decrease at 4.00pm lower than the indoor air temperature. This shows the potential of the building to preserve the heat inside despite the surrounding cooling process. The longer the area is able to preserve the heat during this situation reflect the low potential of the building to maintain good thermal indoor surrounding in tropical area context.

Meanwhile, the variation between the indoor and outdoor air temperature was small in Case Study 2 as shown in Figure 8.

The air temperature was very much affected by hot weather and rainfall which was uncertain during the evening during the three days of data collection. At most of the time, the outdoor air temperature was recorded above 28°C. Starting from an average of 25.9°C during early morning, the outdoor air temperature started to increase to the peak of 35.5°C at 2.00pm, before decreased to an average of 28.2°C at 6.00pm. Although the indoor air temperature shows a same flow pattern throughout the days, there were still varieties of air...
temperatures between the indoor spaces. The temperature of all the indoor areas were also peak at 2.00pm with the highest of 34.2°C at the Kitchen area (Point 5), while the lowest average of indoor air temperature was recorded at 24.3°C at the Attic area (Point 8) as early at 8.00am. Besides the Attic area, the pattern flow of indoor air temperature at the stack throat area (Point 6) and the Hall area (Point 7) were also found to be lower compared to other areas. This may be caused by a small number and size of openings in that area. At the same time, a ample size and number of openings in other spaces at ground floor provide a good air circulation underneath the Attic area and push the cool air upward through the wide stack throat of the building.

Similar with Case Study 1, after 4.00pm, the outdoor air temperature started to decrease lower than the indoor air temperatures at certain areas. However, the decreasing of the indoor air temperature following the outdoor air temperature in Case Study 2 was closer compared to the decreasing pattern of indoor air temperature in Case Study 1. This indicates the ability of the building to release the day heat quickly in late afternoon towards night time.

4. CONCLUSION

A better indoor air movement and indoor air temperature at the double volume house in Rengit (Case Study 2) may be caused by several physical architecture factors. As the building floor is elevated at 450mm height from the ground, there is possibility on natural ventilation sipping through its wooden flooring from below. This scenario does not happen in BP house as it sit directly on the ground.

Orientation of both buildings may not influence the indoor wind speed as both locations are on flat land. Furthermore, there wasn't any consistent direction of air flow identified on both sites during the data collection on site. However, the orientation may effects the indoor air temperature which was recorded high at the areas facing direct sun light.

The most significant contribution of good indoor wind speed in Case Study 2 is may be from the ample size and good positioning of the windows along with having proper size of attic ventilation openings as shown in Figure 9. The application of double tiers Malay traditional concept of roof design on the house makes it possible to have a good positioning of the attic ventilation openings. By having much smaller size of the attic ventilation openings compared to the windows at ground floor, the neutral plane of the house is kept lower than half of the double volume indoor space height. This may contribute to slightly high speed of air coming in from the attic ventilation openings during daytime via stack effect ventilation process.

Besides that, an open concept layout of Living area, Dining area and Hall area without any wall may also help in enhancing better indoor air movement and circulation in Case Study 2. Open aired verandah called Anjung Tamu, in front of the Living and Dining area provides free flow of cross ventilation into the house without any obstruction.
However, placing multi ventilation openings so near to the double volume area which acts as the stack throat shows interruption on the stack effect ventilation process. In reality, both cross ventilation and stack effect ventilation may happen along together at the same time. At certain air flow speed level of cross ventilation, the flow may become so dominant cancelling of the stack ventilation process. However, during slower speed of cross ventilation air flow, the indoor natural ventilation of the double volume area with multiple openings shows passive air movement compared to other areas.

This combination can still give a good performance to enhance natural ventilation if are properly planned and designed. In hot tropical area, it is best to have a bigger total size of lower openings compared to the upper openings, which may help in lowering the neutral plane of the house [7]. This may create the isothermal jet to be happened at the upper openings, thus moving the air faster into the house during daytime.

**REFERENCES**


