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Natural Ventilation Design Attributes Application Effect on Indoor Natural Ventilation Performance of a Double Storey Single Unit Residential Building

Izudinshah Abd. Wahab[1] , Lokman Hakim Ismail[1], Abd Halid Abdullah[2], Muhamad Hanafi Rahmat[1], Nur Nasuha Abd Salam[1]

[1]Department of Architecture and Design Engineering, Faculty of Civil & Environmental Engineering, University Tun Hussein Onn Malaysia, MALAYSIA.
[2]Department of Building and Construction Engineering, Faculty of Civil & Environmental Engineering, University Tun Hussein Onn Malaysia, MALAYSIA.

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Abstract: In establishing a good indoor thermal condition, air movement is one of the important parameter to be considered to provide indoor fresh air for occupants. Due to the public awareness on environment impact, people has been increasingly attentive to passive design in achieving good condition of indoor building ventilation. Throughout case studies, significant building attributes were found giving effect on building indoor natural ventilation performance. The studies were categorized under vernacular houses, contemporary houses with vernacular element and contemporary houses. The indoor air movement of every each spaces in the houses were compared with the outdoor air movement surrounding the houses to indicate the space's indoor natural ventilation performance. Analysis found the wind catcher element appears to be the most significant attribute to contribute most to indoor natural ventilation. Wide opening was also found to be significant especially those with louvers. Whereas it is also interesting to find indoor layout design is also significantly giving impact on the performance. The finding indicates that a good indoor natural ventilation is not only dictated by having proper openings at proper location of a building, but also on how the incoming air movement is managed throughout the interior spaces by proper layout. Understanding on the air pressure distribution caused by indoor windward and leeward side is important in directing the air flow to desired spaces in producing an overall good indoor natural ventilation performance.

Keywords: Natural ventilation, Double storey house, residential building, fresh air

1. Introduction

Being in hot and humid climate surrounding with heavy rain and sunshine throughout the year, residential building in Malaysia faces its own unique challenge in maintaining a good indoor thermal comfort. The surrounding mean temperature is 27°C with 70%-90% relative humidity (RH) throughout the year [1]. The monthly mean of maximum air temperature ranged from 33.5°C in March and April to 31°C in December [2]. Meanwhile, the comfort level of tropical climate indoor spaces is ranged around 26°C to 29°C [3,4,5]. However, previous research shows that without proper design and good indoor ventilation flow, indoor air temperature may not reach the comfort level, especially during night time where trapped heat inside a building may cause higher indoor temperature than the outdoor air temperature [6].

In keeping the air comfort, ventilation is one of the important aspect for a building to provide fresh air for the occupants. There is no specific standard of air movement velocity required for house indoor due to variety of activities that may held at home, thus requiring variety level of air movement to cool the occupant. Commonly, 2m/sec air velocity is accepted as the minimum requirement of air movement to gain comfort [3,4,5] which may be achieved naturally or using mechanical devices. Due to the increasing awareness of sustaining the environment recently, people are becoming more concern in considering natural ventilation as the source of indoor air movement rather than depending on Heating, Ventilation and Air Conditioning (HVAC) system [7]. Based on previous researches, several building attributes were found closely associated with the natural ventilation flow into a building [8,9,10,11]. The air flow process into the building depends either way by cross ventilation or stack effect ventilation. However, the nature of natural ventilation flow on building that may switch between these two ways depending on air pressure difference may subjectively bring different impact caused by the building attributes. Therefore, this paper presents a research

*Corresponding author: izuddin@uthm.edu.my

finding on priority of significant building attributes that contribute the best to a good indoor natural ventilation based on case studies done.

2. Research Background

Ventilation is a process of supplying fresh air and removing heat and air pollution inside building to provide acceptable indoor air quality (IAQ). Towards sustainable living, buildings nowadays are expected to be less depending on mechanical system to generate ventilation. Meanwhile, natural ventilation relies on two principles of air movement which are cross and stack ventilation. Both scenarios depend on air pressure difference between two points to move the air from one point to another.

In general, cross ventilation moves horizontally and depends on wind blow. Wind blow occurs by air pressure difference between points in larger scale as the wind travel in distance. Therefore, the direction may depend on seasonal monsoon but is also highly influential by physical obstruction along the way. In smaller scale, air pressure difference also happens between walls of the building design. Air pressure in front of windward wall that faces the wind direction will be higher than at the leeward wall which against the wind direction. The condition creates air flow pattern surrounding the building. Good building design should be able to allow the flow into the building to ventilate the indoor spaces [11].

Meanwhile stack effect ventilation moves vertically in common and relies on air pressure difference between two points at different level. In tropical areas, due to temperature difference, the air inside the building is either more or less dense than the air outside. The process of balancing the pressure may cause the air either to rise up or settling down. The effect is greater in building which allow a space for the vertical air movement. In situation where the building comes with an atrium, a natural air flow will be caused if there are openings at high and low level of the atrium. In tropical climate countries, where normally the air inside is cooler than that outside, the air will drain out the low opening, being replaced with a fresher air from outside through the high opening. Stack effect works best when the air intakes are as low as possible and the height of building spaces is as great as possible [12].

Ironically, the physic of natural air movement in both principles may contradict with each other [8,9,11]. In cases where there is a crossing wind flow, stack effect ventilation may be cancelled off due to the changes of air pressure difference. Therefore, without proper planning and understanding on the science of air movement, any openings may not contribute to the thermal comfort effectively. This demand a proper design solution on how to preserve and improve the temperature level of indoor air while at the same time encouraging the air movement in order to balance the humidity level.

3. Methodology

As also proven in previous researches [8,11], vernacular houses design was found to be effectively ventilated. Therefore, in determining the categories of houses for this research case studies, vernacular house stands its own category. Whereas other categories representing contemporary houses with vernacular elements and contemporary houses. The selection of the houses is as shown in Table 1.

Table 1: Categories of Houses and the Case Studies

Categories	Case Studies
Vernacular House	Tok Su House of Penang, Malaysia Sri Banai House of Kedah, Malaysia Batak Toba House, Indonesia Kalimantan Tengah House, Indonesia
Contemporary House With Vernacular Elements	Sri Merlong House of Rengit, Malaysia Sri Penggaram House of Batu Pahat, Malaysia
Contemporary House	Sekeping Seapark of Selangor, Malaysia Skudai Box of Johor, Malaysia

Fig. 1 Vernacular House Case Studies (Clockwise from top: Batak Toba House, North Sumatera House, Tok Su House & Sri Banai House)

Fig. 2 Contemporary House with Vernacular Elements (From Left: Sri Merlong House, Sri Penggaram House)

Fig. 3 Contemporary House Case Studies (From Left: Sekeping Seapark, Skudai Box)

Air velocity measurement were done in almost every space inside the houses together with the outside surrounding of the building. Spaces in the case studies were numbered as well as the indoor points surrounding the house. The reading was taken hourly using Portable Anemometers. At the same time, the buildings were observed on their design aspect.

In looking for the design effectiveness, nine natural ventilation attributes were listed based on previous design [8,9,10,11,13] as shown in Table 2. Each of every attribute was defined with proper specifications in order to objectively differentiate between each other.

Table 2 Specification of Natural Ventilation Attributes

Natural Ventilation Attributes	Specification
Wide Windows and Door Opening	Opening with size of 20% of the space floor area
Wind Driven Windows / Doors Design	Having window leaves or any other features directing the wind flow into building
Louver blades at opening	Having louvers at any angle which allow air to sip between the blades
High Openings	Central level of high window opening at 2/3 of the floor to ceiling height
Interior Layout	Open concept design to allow ventilation free flow
Low Opening	Opening with central height at 450mm from floor level or less
Wind Catcher element	Opening with orientation facing the wind flow at appropriate level
High Ceiling	Minimum 4000mm ceiling height from floor level
Raised Floor	Minimum 300mm floor level raised from the ground level

The indoor natural ventilation performance of each spaces in the case studies building was determined by the ratio of each particular mean indoor air movement velocity over the mean outdoor air movement velocity. This indicates how capable the spaces in allowing outdoor air flow into the building. However, theoretically, air movement may not only have influenced by the outdoor cross ventilation. There is other factor like stack effect which depends on the air buoyancy effect to move the surrounding air. Therefore, an over 1 unit ratio of indoor natural ventilation is also expected.

As for the analysis, the presence of the natural ventilation attributes specified earlier was identified in the spaces studied. Frequency of the attribute to present at spaces with good indoor natural ventilation performance may remark its significance.

4. Result and Discussion

As for the findings, all spaces with points measured more than 0.2m/sec of indoor air movement were listed. By comparison to each outdoor air movement velocity, the spaces were analyzed based on their indoor natural ventilation performance ratio.

Sri Banai, a vernacular house, indicates its significance by dominating nine out of 18 indoor spaces with ability to bring in 50% or more outdoor air movement into its spaces. While, it was Sri Merlong house that recorded the highest percentage of indoor air movement performance at Point 3 which located at the Serambi (open lobby). Being partly open, its performance was very well expected. However, it is also interesting to see Point 9 and 11 of Sri Banai house which located at its Family Area to record a high performance. Both Sri Merlong and Sri Banai cover 14 out of the 18 indoor spaces within the criteria, hence remark their design significance on enhancing indoor natural ventilation.

Based on the result, only Sri Penggaram house failed to be in the list. Figure 4 to Figure 10, showed all the rest of the case studies with red marked spaces indicating the significant spaces with good indoor natural ventilation performance.

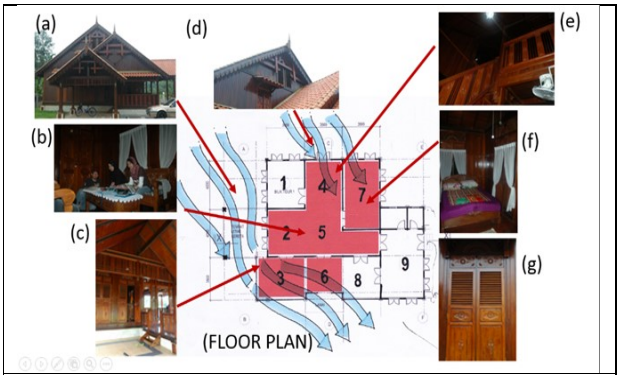

Fig.4 Sri Merlong house with significant spaces layout and the photos. Point 3 and 6 as the Serambi (open lobby), Point 2 and 5 as the Living Hall, Point 4 as the Family Area and Point 7 as the Bedroom

Based on the spaces analysis in Sri Merlong house and Sri Banai house, both houses are using high pitched roof which provide high ceiling for the indoors. Both also provides openings below the roof which may act as the wind catcher elements and high windows that may allow stack effect process. Direct flow through ventilation openings at small spaces such as at Point 13 and 14 do contribute to the scenario as expected.

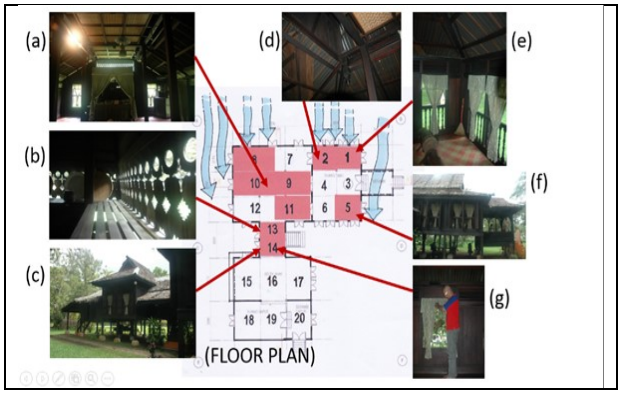

Fig. 5 Sri Banai house with significant spaces layout and the photos. Point 1,2 and 5 as the Living Hall, Point 8, 9, 10 and 11 as the Family Area and Point 13 and 14 as the Rest Area

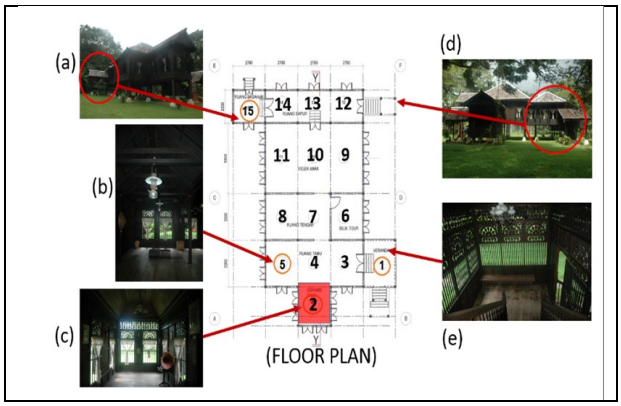

Fig. 6 Tok Su house with significant space layout and the photos. Point 2 as the Guest Area

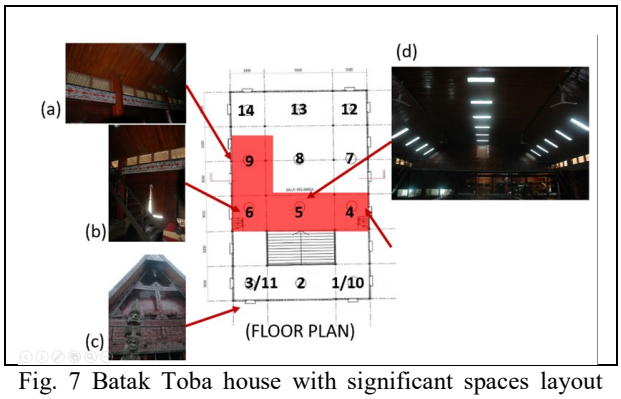

Fig. 7 Batak Toba house with significant spaces layout and the photos. Point 3 and 6 as the Serambi (open lobby), Point 2 and 5 as the Living Hall, Point 4 as the Family Area and Point 7 as the Bedroom

Ironically, vernacular elements in Tok Su house do not show obvious significant effect on good indoor natural ventilation performance. Being a small Guest Area with ample size of openings contribute to the result as expected. Meanwhile, Indonesian vernacular houses were found not to have such a wide window openings when compared to Malaysian. However high openings on both houses show possibility of the wind catcher attribute towards their indoor natural ventilation performance.

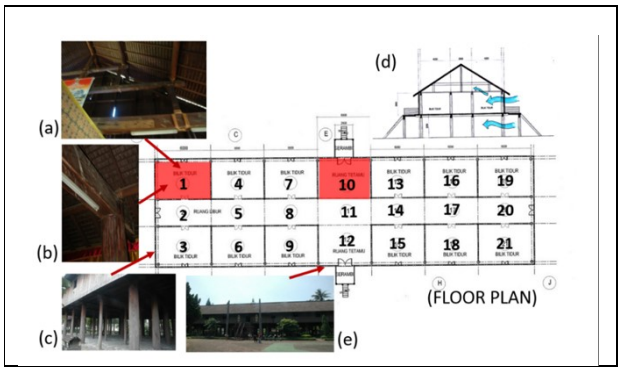

Fig. 8 Kalimantan Tengah house with significant spaces layout and the photos. Point 1 as the Bedroom and Point 10 as the Guest Hall

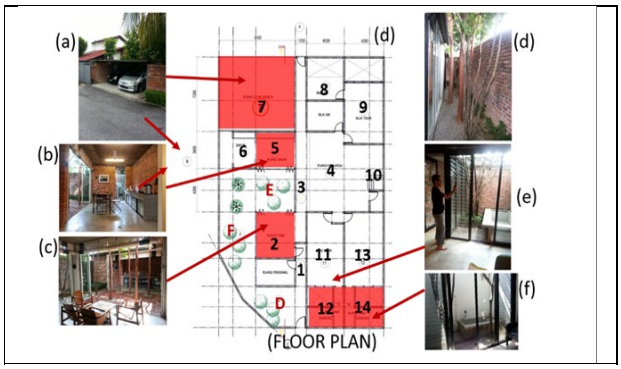

Fig. 9 Sekeping Seapark house with significant spaces layout and the photos. Point 2 as the Living Hall, Point 5 as the Dining Hall, Point 7 as the Car Porch and Point 12 and 14 as the Bedrooms

Fig. 10 Skudai Box house with significant spaces layout and the photos. Point 3 and 4 as the Dining attach Living Hall, Point 6 as the Kitchen

Meanwhile, besides of having open concept layout design, contemporary design houses, Sekeping Seapark and Skudai Box do show limitation on the indoor natural ventilation effect. As to provide privacy for the occupants, solid fencing wall were used as the site boundary, hence may block the crossing ventilation from reaching the house at certain level.

The frequency analysis on the presence of the nine attributes in all the case studies spaces is shown in Table 3. Based on the findings, wind catcher elements facing the wind flow orientation was found to be the most significant attribute. Being at higher level, such openings may stand a better chance to trap the crossing wind flow which obviously stronger at higher level. Wide openings were found to be significant as well. However, there was limitation especially at lower floor level, where the crossing wind may also interrupt by other surrounding objects as happened in Sekeping Seapark and Skudai Box. Besides that, it was also found that louvered openings do significantly contribute to the good air flow into the houses. Thinner valve for the flow may cause higher velocity of incoming air which help to push air movement further inside the building. Besides acting as blind to avoid sun glare, louvres may also help in directing the flow through the louver blades angle attack.

Besides the process of catching the outside air flow into the building, it is also important to manage the indoor air movement flow inside the building. Having walls inside a house may allow winward and leeward side of wall concept to occur in a building due to the air pressure difference distributed. Therefore, a proper planning with understanding on the physic of air movement may important to design the acquired air flow inside a building.

Table 3: Frequency of attributes presence in good natural ventilation performance spaces

Natural Ventilation Attributes	% Frequency being presence in good natural ventilation areas
Wide Windows and Door Opening	13.4 %
Wind Driven Openings	8.4%
Louver blades at opening	11.2%
High Openings	11.2%
Interior Layout	12.8%
Low Opening	8.4%
Wind Catcher element	18.4%
High Ceiling	9.5%
Raised Floor	6.7%

5. Conclusion

In this study, a list of significant attributes was developed in hierarchy based on their contribution toward a good indoor natural ventilation. While most attributes are common elements used since vernacular era, it is important to determine, which attribute do perform better than the rest. The knowledge may important to architects and designers in deciding priorities of the attributes to be applied during house design process and development.

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