Investigation of Indonesian Traditional Houses through CFD Simulation

Suhendri¹, M D Koerniawan²

¹Asistant Lecturer, Department of Architecture, Institut Teknologi Bandung, Ganesha 10, Bandung, Indonesia
²Lecturer, Department of Architecture, Institut Teknologi Bandung, Ganesha 10, Bandung, Indonesia

Abstract. Modern buildings in Indonesia rely mostly on artificial lighting, heating, cooling and ventilation. It means more energy is used to drive mechanical appliances, and presumably not sustainable. Meanwhile modern buildings consume much energy, traditional architectures are known as the source of knowledge for sustainable, energy efficient and climate responsive design. Noticeably, one of the differences between modern and traditional buildings in Indonesia is shown in their strategy to provide thermal comfort to the user. Traditional buildings use natural ventilation, but modern buildings use mechanical air conditioning. By focusing on wind-driven ventilation, the study aims to investigate natural ventilation strategy of Indonesian traditional house, and their potential improvement to be used in modern Indonesian buildings. Three traditional houses are studied in this research, representing west, central, and east Indonesia. The houses are Lampung traditional house, Javanese traditional house, and Toraja traditional house. CFD simulation is conducted to simulate wind-driven ventilation behaviour and the temperature of the buildings. Concisely, the wind-natural ventilation of case study houses is potential to provide thermal comfort inside the houses. However, the strategy still can be optimized by adding some other passive design strategies: sun-shading; vegetation; or buildings arrangement in the traditional dwelling. Consideration about the roof’s shape and windows position to the roof is important as well to create a uniform air distribution.

1. Introduction

Indonesia is known for its diversity. This diversity is also found in its traditional houses. Most of traditional houses in Indonesia follow a certain rule in their local tradition, or culture-driven (Toe & Kubota, 2015). But, there are also some of the houses that only driven by needs and technical reasons. Nevertheless, traditional houses are known to its good thermal performance. It is because they are developed in response to the climate, availability of materials and techniques, and lifestyle specific to that region (Jayasudha, et al., 2014). The houses are known for its ability to provide thermal comfort with passive design strategies. Therefore, architectural community is now looking back to traditional to explore its diverse passive design strategies (Roaf, 2014).

Traditional houses, as mentioned before, are influenced by the local climate, and thus Indonesian traditional houses must be influenced by its hot and humid climate. In hot and humid climate like Indonesia, breeze has an important role to provide indoor thermal comfort (Feriadi & Wong, 2014). Breeze accelerates evaporation of sweat on human body, which is more need in high humidity. Webb (1959) states that the favourable wind speed to provide a pleasant thermal sensation for people in hot and humid climate is about 0.2m/s. Therefore, commonly Indonesian traditional houses have some windows in most of the building walls, which is categorized as wind-driven ventilation.
On the other hand, houses in hot and humid climate region nowadays are much different. Aflaki, et al. (2016) mention that in hot and humid climate region, most buildings rely heavily on air conditioning. This is due to insufficient ventilation and the inadequate circulation of fresh air into the buildings (Aflaki, et al., 2016). The solutions for this issue perhaps lie within the traditional and traditional architectures in Indonesia. There are number of studies show the advantages of natural ventilation in hot and humid climate. Two of the advantages are it can decline the latent and total cooling loads, as concluded by Hiranoa, et al. (2006), and could cut down air-conditioning energy use up to 24% as summarized by (Yik & Lun, 2010). However, there is still no systematic and quantitative research done for the traditional houses’ natural ventilation, for the traditional houses’ natural ventilation (Eduard, 2014). Hence, by focusing on wind-driven ventilation, the study aims to investigate natural ventilation strategy of Indonesian traditional house, and their potential improvements.

2. Indonesian Climate
Indonesia is located at latitude of about -11° to 6°, thus it experiences tropical climate. Specifically, its climate is hot and humid climate, because Indonesia is an archipelago that located between Pacific Ocean and Indian Ocean. The characteristic of hot and humid climate are high average temperatures, little day-night and seasonal variations, high humidity and heavy rainfall, also high and relatively diffuse solar radiation (Coch, 1998). In this type of climate the overheating is might not be the biggest problem, but it is bothered by high humidity that can restrain the evaporation potential (Szokolay, 2008).

3. Research Methodology
This research investigates quantitatively the effect of wind-driven natural ventilation on thermal comfort in some of Indonesian traditional houses. Two parameters measured are wind velocity inside the building and indoor air temperature. Computational Fluid Dynamics (CFD) is done to simulate the behaviour of the wind-driven natural ventilation. Three traditional houses are studied in this research, Lampung traditional house, Javanese traditional house, Toraja traditional house. The houses, its plan and sections simulated, are shown by Figure 2.

Figure 1. Location of the case study houses

The study scales only at building interior, and the only outdoor variable that affects the indoor condition is air velocity and temperature. Air velocity and temperature are two of physical variables of thermal comfort. The effect of surroundings (building, vegetation, etc) is neglected in this case, and the outdoor wind velocity is assumed to be constant. These conditions are design in order to minimize the effect of other variables in temperature changes. Wind velocity is set to 0.2 m/s, with outdoor air temperature 27°C similar to average temperature in the location of the houses (BPS, 2015).

More analysis can be done to the behavior of natural ventilation of the houses if the indoor temperature and wind velocity are not only seen by its value. Graphics of wind vector and temperature contour can be used to further the understanding. Hence, the analysis not only uses descriptive statistic but also visual analysis of wind vector and temperature contour images. As a sample for the velocity and temperature magnitude, some points at sitting level or about 90 cm above the floor are taken into
account. These measurement points are positioned at the windows, and every 1 meter started from the windows. Meanwhile, for the plan simulation, the measurement points are at the windows, and in the middle of the room.

Figure 2 The case study houses

4. Results
Some of simulation results for Lampung and Javanese traditional houses have been analysed and documented in accepted paper on Temu Ilmiah IPLBI (Indonesian Association of Built-Environment Researcher) 2016. Thus, some analysis of Lampung and Javanese traditional houses are quoted from the previous paper.

4.1. Lampung Traditional House

Figure 3 shows indoor air movement of Lampung traditional house. From section A point of view, it can be seen that cross-ventilation occurs inside the house. The air movement is mainly at the windows level or below it, with the average magnitude of the wind inside the room is lower than outside, between 0.16-0.25 m/s. This value is considered as still in the comfort range for wind speed, about 0.2 m/s. However, detailed view at the red-circle area in Figure 3 shows an escalation of wind velocity. It is likely caused by turbulence near the inlet windows, as shown by Figure 4. From the figure also can be deduced that the turbulence might be generated by the roof’s tilt angle and its position to the window. Due to its boost effect to the incoming wind, the turbulence is potential to create discomfort for the occupant if outdoor wind velocity is little bit higher.
On the other hand, section B simulation demonstrates a different result (Figure 5). There is no significant cross-ventilation occurs. Also, there is no air movement in the deep side of the room. Clearly, it is because the opening is only one-sided. Further, simulation of the plan of the building discloses the effect of one-sided opening for the whole room (Figure 6). If the wind comes simultaneously from all directions with similar speed, the air cannot move to the whole area of the room. The wind that comes from the front windows goes out from the side windows as shown by Figure 6(a). So, instead of becoming an inlet, side windows will more likely be an outlet. This causes indoor temperature higher than outdoor temperature. However, if the wind direction is preferable, the one-sided opening has no negative effect to the air movement inside the room. Therefore, indoor air temperature is more comfortable (Figure 6(b)).
Figure 6. Wind vector and temperature of Lampung traditional house plan

4.2. Javanese Traditional House

Figure 7. Indoor wind of Javanese traditional house, Section A (Suhendri & Koerniawan, Submitted 2016)

Figure 7 shows that cross-ventilation occurs inside the Javanese traditional house. Similar to the Lampung traditional house, the air movement mainly happens at the windows level or below. Wind speed inside the room is lower than outside within the comfort air speed range, with no significant turbulence. That is the difference; compare to Lampung traditional house, Javanese traditional house can provide smoother and more favorable indoor air movement.

Moreover, different from Lampung traditional house, Javanese traditional house also provides a sufficient condition for cross-ventilation to occur inside the room. Openings are located all at the 4-side of the building. Hence, the air movement covers the whole room (Figure 8). However, cross-ventilation behavior as displayed by Figure 8, does not automatically make indoor temperature of
Javanese traditional house much lower than outdoor temperature. From the Figure 8, indoor temperature is seen to be similar with outside temperature.

![Wind velocity (m/s) vs Temperature contour (Kelvin)](image)

**Figure 8.** Wind vector and temperature of Javanese traditional house plan (Suhendri & Koerniawan, Submitted 2016)

Further analysis can be extracted from the difference of air movement inside the Lampung traditional house and Javanese traditional house. It is mentioned in advance that the reasons for the turbulence in Lampung traditional house are roof’s tilt angle and windows position to the roof. Both variables in Javanese traditional house are indeed contrast to the Lampung traditional house. Consequently, the air movement is smoother and more favorable.

### 4.3. Toraja Traditional House

![Wind vector vs Wind velocity magnitude (m/s)](image)

**Figure 9.** Indoor wind of Toraja traditional house, Section A

Simulation result of Toraja traditional house on section A is shown by Figure 9. Toraja traditional house differs from the two houses before in its windows proportion. The windows in Toraja traditional houses have a small window-to-wall ratio. Although, it still can deliver air movement to the room. Wind velocity at sitting level in Toraja traditional house varies from 0.024-0.17 m/s. Besides, there is an area of modest wind velocity at the different level floor near the outlet window. The floor
level difference as shown by red circle in Figure 9, somehow, makes an obstacle for the wind to get into the lower floor level.

Furthermore, it can be seen as well from Figure 9 that roof’s shape affects the movement of the incoming wind. Less wind received by the lower floor level is influenced by the roof’s shape of Toraja traditional house. Wind that get into the room is at steep direction to the higher floor level, so it then get reflected to the ceiling are by the floor. Therefore, lower floor level do not experience as much air movement as higher floor level.

Nevertheless, if there are openings in the area of lower floor level, air movement is still possible. Especially, because Toraja house is narrow in the Section B, positive air movement is supported by this narrow room. It is shown by Figure 10 that windows on Section B create a cross-ventilation, which is more delicate than air movement in Section A. Plan simulation results in Figure 11 supports this finding. Even, the openings at Section B side (right and left side of the house) are more influential in driving the wind than the front and rear windows.

![Figure 10. Indoor wind of Toraja traditional house, Section B](image)

![Figure 11. Wind vector and temperature of Toraja traditional house plan (Suhendri & Koerniawan, Submitted 2016)](image)
5. Conclusion

| Lampung | Javanese | Toraja |
|---------|----------|--------|
| • Limited cross-ventilation occurs at the windows level or below it. The limited cross-ventilation by mean the air cannot cross the room because of the one-sided opening that Lampung House has. | Cross-ventilation occurs at the windows level or below it, still in the comfort range for wind speed. Compare to Lampung traditional house, Javanese traditional house can provide smoother and more favorable indoor air movement. | Although the windows in Toraja traditional houses have a small window-to-wall ratio, it still can deliver air movement to the room. There is an area of modest wind velocity at the lower level floor near the outlet window. But, favorable air movement is still can be delivered by windows from the length side of the building. However, the floor level difference still somehow makes an obstacle for the wind to get into the lower floor level. The roof’s shape of Toraja house also influence the wind that get into the room. |
| • Based on the explanation above, air temperature inside Lampung House is likely to be higher than the outdoor temperature. | Javanese traditional house provides a sufficient condition for the air movement to cover the whole room. | |
| • There is turbulence near the inlet windows, which is potential to make occupants feel discomfort. | Cross-ventilation behavior as explained above does not immediately make indoor temperature of Javanese traditional house much lower than outdoor temperature. | |
| • The turbulence might be generated by the roof’s tilt angle and its position to the window. | | |

From the analysis of wind-driven natural ventilation of the three traditional houses, some conclusions can be derived. For instance, as it is shown in Lampung traditional house, one-sided opening is not appropriate to deliver a fresh air to the room. But, all of two-sided opening in the houses can create a cross-ventilation effect. Yet, from the results also can be deduced some considerations that should take into account for the opening design. Three houses demonstrate that roof’s shape and windows position to the roof influence the air movement. The effect from these design aspect varies from turbulence in Lampung house to the modest wind area in Toraja house.

In conclusion, the wind-natural ventilation of three case study houses is potential to provide thermal comfort inside the houses. The research reveals that cross-ventilation can deliver better indoor air temperature. Although the temperature reduction is not significant, it is still preferable. But, the strategy still can be optimized by adding some other passive design strategies: sun-shading; vegetation; or building compound arrangement in the traditional dwelling. Consideration about the roof’s shape and windows position to the roof is also important to create a uniform air distribution.

This research can be a beginning of the same study for Indonesian traditional houses in all of its provinces. However, this study still can be improved such as by doing a field study of wind-driven ventilation of the houses. Or else, a similar study can be conducted by considering the effect of outdoor features or another physical thermal comfort variable such as solar radiation or humidity.

Acknowledgement

This research is planned to be conducted to traditional houses in all of Indonesian provinces. It is part of research in the roadmap of Building Technology Research Group, Department of Architecture, ITB.

References

[1] Aflaki, A., Mahyuddin, N. & Baharum, M. R., 2016. The influence of single-sided ventilation towards the indoor thermal performance of high-rise residential building: A field study. Energy and Buildings, Volume 126, p. 146–158. BPS, 2015. Suhu Minimum, Rata-Rata, dan Maksimum di Stasiun Pengamatan BMKG. [Online] Available at: http://www.bps.go.id [Accessed 13 September 2016].

[2] C.G., W., 1959. An analysis of some observations of thermal comfort in an equatorial climate. British Journal of Industrial Medicine, pp. 297-310.

[3] Coch, H., 1998. Chapter 4—Bioclimatism in vernacular. Renewable and Sustainable Energy Reviews, Volume 2, pp. 67-87. Eduard, A., 2014. Academia. [Online] Available at: http://www.academia.edu/ [Accessed 19 October 2015].
[4] Feriadi, H. & Wong, N. H., 2014. Thermal comfort for naturally ventilated houses in Indonesia. Energy and Buildings, p. 614–626.

[5] Hiranoa, T. et al., 2006. A study on a porous residential building model in hot and humid regions: part 1—the natural ventilation performance and the cooling load reduction effect of the building model. Building and Environment, 41(1), pp. 21-32.

[6] Jayasudha, P., Dhanasekaran, M., Devadas, M. D. & Ramachandran, N., 2014. A study on sustainable design principles: A case study of a vernacular dwelling in Thanjavur region of Tamil Nadu, India. Indian Journal of Traditional Knowledge, 13(4), pp. 762-770.

[7] Kinnane, O., Dyer, M. & Grey, T., 2014. Energy and Environmental Forensic Analysis of Public Buildings. Engineering Sustainability, Volume 167, pp. 143-156.

[8] OFFICE, 2001. Energy Efficient Office Refurbishment. London: James & James (Science Publisher) Ltd.

[9] Omer, A., 2008. Renewable building energy systems and passive human comfort solutions. Renewable Sustainable Energy Review, pp. 1562-1587.

[10] Roaf, S., 2014. Lessons From Vernacular Architecture. Architectural Conservation, pp. 1-2.

[11] Stavrakakis, G., Zervas, P., Sarimveis, H. & Markatos, N., 2009. Development of a computational tool to quantify architectural-design effects on thermal comfort in naturally ventilated rural houses. Building and Environment, pp. 65-80. Suhendri & Koerniawan, M. D., Submitted 2016. Investigasi Ventilasi Gaya-Angin Rumah Tradisional Indonesia dengan Simulasi CFD. Malang, will be conducted on 26-28 October 2016, IPLBI, p. Submitted.

[12] Szokolay, S. V., 2008. Introduction to Architectural Science The Basis of Sustainable Design. 2nd ed. Oxford: Elsevier. Toe, D. H. C. & Kubota, T., 2015. Comparative assessment of vernacular passive cooling techniques for improving indoor thermal comfort of modern terraced houses in hot–humid climate of Malaysia. Solar Energy, Volume 114, p. 229–258. Yik, F. W. & Lun, Y. F., 2010. Energy saving by utilizing natural ventilation in public housing in Hong Kong. Indoor and Built Environment, 19(1), p. 73–87.

[13] Yusran, Y. A. & Suryasari, N., 2016. Bolon and Lobo: Revealing The Stack Construction on Batak Simalungun and Kulawi Traditional House. IACSIT International Journal of Engineering and Technology, 8(3), pp. 187-192.