Progress in Engineering Application and Technology Vol. 3 No. 2 (2022) 203–210
© Universiti Tun Hussein Onn Malaysia Publisher's Office

PEAT

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

A Study on Maximum Natural Ventilation for a Modern Single-Storey House by Using Simulation Software

Muhammad Nursyahmi Md Sali[1], Nurdalila Saji[1]*

[1]Department of Civil Engineering Technology, Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 84600 Pagoh, Johor, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2022.03.02.020
Received 23 June 2022; Accepted 07 November 2022; Available online 10 December 2022

Abstract: In a nation like Malaysia, which is in a tropical climate, the issue of heat and humidity is one of the most critical challenges that must be addressed, particularly in residential buildings. Modern buildings are not planned with adequate cross-natural air circulation in mind but with an emphasis on aesthetics. Due to the warm climate, many homeowners choose air conditioning to reduce the indoor temperature, resulting in increased energy consumption. Hence, this study aims to analyse the wind flow in a house by using Computational Fluid Dynamic software and to compare the different size of windows for maximum natural ventilation in a modern single storey house. The location of this study is Bandar Melaka, Melaka, and the wind data collection was obtained from the Malaysian Meteorological Department (MetMalaysia). OnShape is the cloud-based software to construct the layout, and it is transferred to the simulation cloud-based software of SimScale to analyse the airflow in the house to gain thermal comfort. Four different sizes of windows are analysed following the standard size from MS1064:PART5:2001. From the result, it shows that the average velocity in a model for size of window for 1200 x 600 mm is 1.210 m/s, 120 x 1200 mm is 1.438 m/s, 1200 x 1800 mm is 2.486 m/s and for 1200 x 2400 mm is 3.839 m/s. The finding shows that the bigger size of the windows influenced the higher wind speed in the model. However, if the wind speed compares to the impact of occupants in MS 2680:2017, high wind speed in a building is not really suitable for thermal comfort. Hence, the dimension of windows of 1200 x 600 mm and 1200 x 1200 mm are the most suitable for the layout for the reason that the average wind speed is in the range of 1.5 m/s according to MS 2680:2017, and suitable with the climate in Malaysia especially is in Melaka where the study was conducted.

Keywords: Natural Ventilation, Cross-Ventilation, Cloud-Based Simulation Software

**Corresponding author: nurdalila@uthm.edu.my*
2022 UTHM Publisher. All right reserved.

1. Introduction

Southeast Asian nations have experienced rapid economic growth and urbanisation in recent decades, increasing energy use, especially in cities. According to the United Nations [1], households accounted for 27.00 % of worldwide power consumption. Residential buildings consume most of this energy. In Malaysia, space cooling accounted for 11.00 % of home power demand in 2016 [2], and outdoor weather affected energy consumption [3].

Modern structures are designed with an emphasis on aesthetics rather than proper cross-natural air circulation. Traditional structures are made in hot, humid environments, yet they seek natural ventilation to provide thermal comfort while reducing humidity. Traditional homes were built higher so that wind could readily enter and depart for ventilation. When the primary design goal is to maximise occupant thermal comfort, this significantly lowers the interior air temperature in homes. Natural ventilation is when confined rooms are ventilated without the use of active temperature controls or mechanical methods by utilising natural forces like wind and buoyancy to deliver enough fresh air and air change. Buildings require fresh air to get rid of odours and enhance the quality of the environment within. In a few of these situations, spill air from adjacent areas is sufficient to offer the needed air change and thermal comfort while consuming less energy. Natural ventilation systems rely on air flow through the space to equalise pressure.

At the end of the study, it will provide a layout of a single storey house with adequate natural ventilation. The layout suggested will follow the recommendation of cross ventilation as stated in Malaysia Standard MS2680:2017[4] - Code of Practice on Energy Efficiency and Use of Renewable Energy for Residential Buildings. Hence, several steps need to be taken before providing the layout. The steps or objectives are as follows:

- To analyse the wind flow in a house by using Computational Fluid Dynamic software.
- To compare the different sizes of windows for maximum natural ventilation in a modern single-storey house to know the impact of airspeed on occupants in a building.

The sample layout proposed windows of different sizes, from the smallest to the largest, that will build and compared. The suggested house is about 900 square feet, which is about 84 square meters. This is the average size of a house in Malaysia. There will be one living room, one dining room, one kitchen, three bedrooms, and two bathrooms. The openings on the layout will also be the same number and size. OnShape will be the software that will be used in the cloud to build the layout. After the layout is turned into a 3D model, it will be sent to SimScale's simulation cloud-based software so that the airflow in the house can be studied to make it more comfortable to live in.

The importance of the study is not only to improve residents' thermal comfort, and the goal is to improve their energy efficiency and psychological acceptance of the building. The internal environment of the building is a key part of reaching these goals. The building needs a ventilation system to get rid of contaminants that come from the air. In the 21st century, countries that depend a lot on human capital and are trying to build a knowledge-based economy are realising how important it is to have good indoor air quality [6]

2. Literature Review

Air is one of the four basic elements, and humans cannot live without it. Even though it is important to have ventilation in a building, most people do not know that buildings need to have constant air exchanges. There is enough oxygen in the air, and people would only run out of oxygen in very closed environments. Ventilation is important for getting rid of smelly particles, volatile organic compounds (VOCs), and humidity, which are the biggest causes of problems with indoor air quality for people living there. Also, it is needed to dilute CO_2, which can make people feel unproductive (Passe et al., 2015). Ventilation is very important for people's comfort, health, and well-being.

Natural ventilation can save a lot of energy compared to mechanical ventilation systems when done correctly. Natural ventilation gets rid of heat by using pressure differences caused by temperature or wind. It also brings in fresh air by getting rid of or diluting humidity, odours, particle load, and Volatile Organic Compound (VOC) concentrations. Heat that has built up can be gotten rid of by air, or people have used natural forces to get rid of it [10].

When it comes to natural ventilation, wind or cross ventilation as in Figure 1 (differences in hydrostatic pressure) and the stack effect as in Figure 2 (density pressure differences). In urban areas, wind patterns and temperatures are different from those in open areas, so designer have to take a different approach. There are also microclimates and macroclimates to think about. How these forces, resistances, and obstacles interact with the flow direction is affected by how buildings are built and how they are connected to the environment around them. The speed and direction of the wind, as well as seasonal or daily trends, can have a direct effect on how rough or smooth a city is. Natural ventilation can only be used during the design phase of a building. It cannot be added on as a separate technology. For natural ventilation, it's important to think about the flow path's spatial make-up and the direction and strength of the driving forces [10].

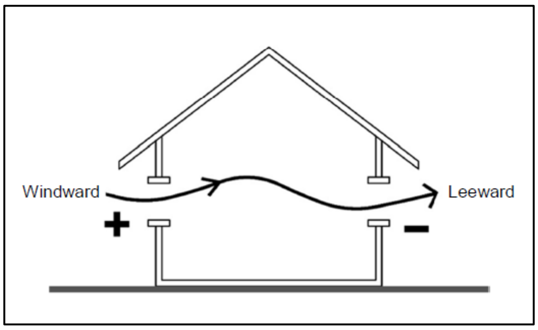

Figure 1: Cross ventilation

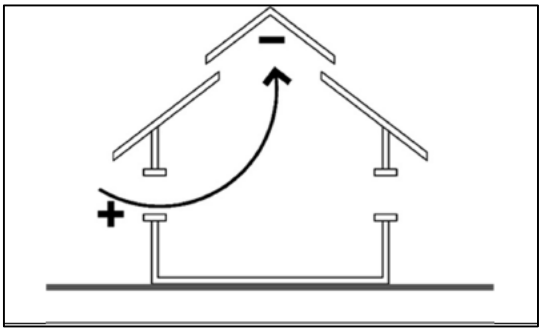

Figure 2: Stack ventilation

2.1 Passive Design

Passive design solutions imply the use of minimum, if any, mechanical or electrical means to accomplish both indoor thermal and optical comfort and energy savings. Residential buildings' principal purpose is to produce a suitable indoor and immediate outside environment for domestic activities. Architectural passive design is primarily impacted by a building's response to its site environment when it is designed. According to MS 2680:2017 [4], the designer should consider the following important factors such as listed below and one of the considerations taken for this study is natural ventilation.

- site planning and orientation;
- daylighting;
- roof;
- façade

- natural ventilation;
- strategic landscaping; and
- alternative/renewable energy

3. Methodology

According to MS 1525:2017 [5], cross ventilation is the wind forces cool outer air into the structure via an inlet, while warm internal air is sent outside via an outlet. In this study, the layout is following the standard as stated in MS 1525:2017 [5]. The criteria that keep to the standards are as follows:

- Provide openings on opposite walls for optimum cross ventilation effectiveness. However, if this is not possible, openings can be placed on adjacent walls
- Have equal inlet and outlet areas to maximise airflow.
- Provide inlets on the windward side (pressure zone) and outlets on the leeward side (suction zone)
- Avoid obstructions between the inlets and outlets
- Design openings to be easily accessible and operable by the occupants.
- Locate outlet openings on the windward side at the occupied level.
- For cross-flow or two-sided ventilation, both window openings should be opened and the effective room depth is equal to or less than 12 m

3.1 Thermal Comfort for Comparison

Thermal comfort means being satisfied with the temperature by following ANSI/ASHRAE Standard 55-2010 [7]. Physiology and psychological variances make it impossible to meet everyone's demands. Conditions for thermal comfort should take into consideration of the following six significant concerns. The six significant concerns are as listed below and the impact of air movement to occupants are as shown in Table 1 are being compared to the result gain after the run of simulation.

- Metabolic rate
- Clothing insulation
- Air temperature
- Radiant temperature
- Air speed
- Humidity

Table 1: Impact of air speed on occupants [4]

Air speed (m/s)	Mechanical effect	Occupant sensation
≤ 0.25	Smoke (from cigarette) indicates movement	Unnoticed, except at low air temperatures.
0.25 - 0.5	Flame from a candle flicker	Feels fresh at comfortable temperatures, but draughty at cool temperatures
0.5 - 1.0	Loose papers may be moved. Equivalent to walking speed	Generally pleasant when comfortable or warm, but causing constant awareness of air movement.
1.0 - 1.5	Too fast for deskwork with loose papers	Acceptable in warm conditions but can be from slightly to uncomfortably draughty

> 1.5	Equivalent to a fast walking speed	Acceptable only in very hot and humid conditions when no other relief is available. Requires corrective measures if comfort and productivity are to be maintained.

3.2 Layout Design

The suggested house is about 900 square feet, which is about 84 square metres. The door in the model uses a single leaf door with the dimension of the door being 2100 mm in height and 900 mm in width, following the standard door opening size (MS1064:PART4:2001) [8]. Meanwhile, the windows in this model use only one type of window, which is the casement window. There are four dimensions use for the analysis that are 1200 mm (h) x 600 mm (w), 1200 mm (h) x 1200 mm (w), 1200 mm(h) x 1800 mm (w) and 1200 mm (h) x 2400 mm (w). All of the dimensions of windows follow the standard size of windows opening (MS1064:PART5:2001) [9]. The layout of the sample as shown in Figure 3.

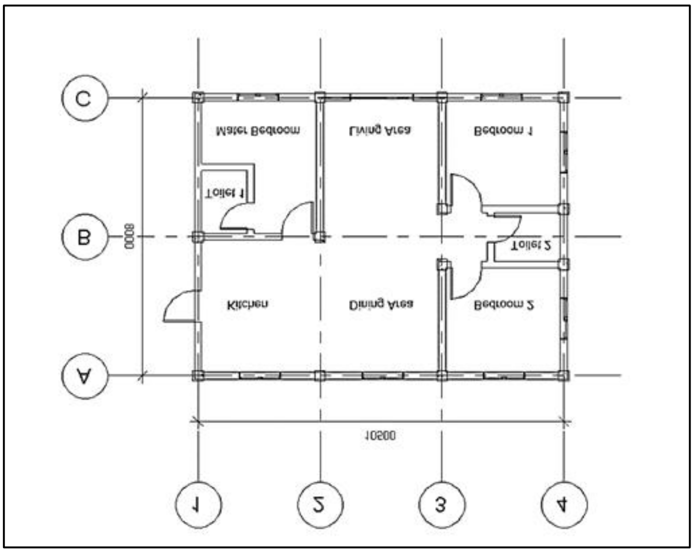

Figure 3: The layout of the sample

4. Results and Discussion

Since the wind speed will be the same, the size of the windows must be different in each layout model to get different results. The windows are only on the model's inlet and outlet, which are on the front and back sides, respectively. The windows are not on the right and left because it is not necessary while the simulation is running. The first objective of this study is to analyse the wind flow in a house by using ventilation simulation software. The example of wind flow in the model as shown in Figure 4.

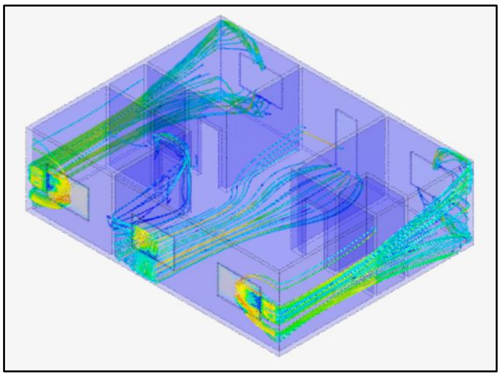

Figure 4: The wind flow in the model

4.1 Comparison Between the Average of Velocity at Each Windows for Outlet

According to Table 2, with the inlet wind speed of 1.610 m/s, the average velocity at each location and the size of the windows seems to be different. For Window 3, the average of velocity with the size of window of 1200 x 600 mm is 5.214 m/s, 1200 x 1200 mm is 5.452 m/s, 1200 x 1800 mm is 5.995 m/s and 1200 x 2400 mm is 6.021 m/s. Then, for Window 4, the average of velocity with the size of window of 1200 x 600 mm is 5.087 m/s, 1200 x 1200 mm is 5.160 m/s, 1200 x 1800 mm is 5.145 m/s and 1200 x 2400 mm is 5.059 m/s. Meanwhile, for Window 5, the average of velocity with the size of window of 1200 x 600 mm is 4.923 m/s, 1200 x 1200 mm is 5.324 m/s, 1200 x 1800 mm is 5.383 m/s and 1200 x 2400 mm is 5.694 m/s. As shown in Figure 5, the size of the windows and their average velocity, it shows that the bigger the size of the window, the higher the velocity in the model.

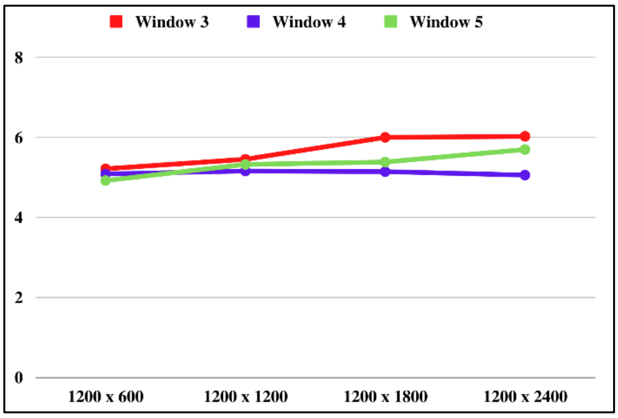

Figure 5: Graph to compare the size of window and average velocity

Table 2: The average value of velocity at each window for outlet

Location	Size of Windows (h x b) (mm)	Average Velocity (m/s)
Window 3	1200 x 600	5.214
	1200 x 1200	5.452
	1200 x 1800	5.995
	1200 x 2400	6.021
Window 4	1200 x 600	5.087
	1200 x 1200	5.160
	1200 x 1800	5.145
	1200 x 2400	5.059
Window 5	1200 x 600	4.923
	1200 x 1200	5.324
	1200 x 1800	5.383
	1200 x 2400	5.694

4.2 Comparison Between the Average of Velocity in a Whole Model with the Size of Windows and the Impact of Air Speed on Occupants

After the data on wind speed was gained from the analysis in the simulation software, the data was then compared to the impact of the wind speed on the occupants in a building. The comparison is made to fulfil the second objective of this study. Since the minimum value of velocity in a whole model is equal to 0 m/s, the average velocity is taken to make as indicator for comparison between the different size of windows. The average velocity in a model for size of window for 1200 x 600 mm is 1.210 m/s, 120 x 1200 mm is 1.438 m/s, 1200 x 1800 mm is 2.486 m/s and for 1200 x 2400 mm is 3.839 m/s. Based on the Table 3, the mechanical effect for the size of window of 1200 x 600 mm and 1200 x 1200 mm is too fast for deskwork with loose papers and for the occupant sensation it is acceptable in warm conditions but can be from slightly to uncomfortably draughty. For 1200 x 1800 mm and 1200 x 2400 mm size of windows, the mechanical effect is equivalent to a fast-walking speed and for the occupant sensation is acceptable only in very hot and humid conditions when no other relief is available. It is requiring corrective measures if comfort and productivity are to be maintained.

Hence, by referencing Table 3, an individual, contractor, client, supplier, or other party can refer to the dimensions of the windows that were analysed as well as the architecture of the model created to achieve thermal comfort in their building. Other elements, including as the metabolic rate of the occupants, garment insulation, ambient temperature, radiation temperature, and humidity, must also be considered. Then, in Melaka, where this study was conducted, it is recommended to consider window openings of 1200 x 1200 mm due to the findings of this study and the size's suitability in terms of aesthetics and cost.

Table: 3 The size of windows and its average of velocity to the impact to occupants

Size of Windows (h x b) (mm)	Average Velocity (m/s)	Mechanical effect	Occupant sensation
1200 x 600	1.210	Too fast for deskwork with loose papers	Acceptable in warm conditions but can be from slightly to uncomfortably draughty
1200 x 1200	1.438	Too fast for deskwork with loose papers	Acceptable in warm conditions but can be from slightly to uncomfortably draughty
1200 x 1800	2.486	Equivalent to a fast-walking speed	Acceptable only in very hot and humid conditions when no other relief is available. Requires corrective measures if comfort and productivity are to be maintained
1200 x 2400	3.836	Equivalent to a fast-walking speed	Acceptable only in very hot and humid conditions when no other relief is available. Requires corrective measures if comfort and productivity are to be maintained

5. Conclusion

The primary purpose of this study is to analyse the airflow within a house using ventilation simulation software. Thankfully, cloud-based technologies such as OnShape and SimScale can analyse models successfully. The second purpose is to compare the various window sizes for optimal natural ventilation in a contemporary single-storey home. The comparison indicates that the velocity or wind flow will rise if the window dimensions are increased. A building's natural ventilation performance is significantly affected by the openings' size, shape, and location. Additionally, the wind-generated pressure fields in the region and across the opening influence the distribution of air within the structure.

Therefore, window sizes of 1200 x 600 mm and 1200 x 1200 mm are the most suitable for the layout. It is Because the average wind speed is between 1.5 m/s and, according to MS 2680:2017, it is acceptable in warm conditions but can range from slightly to uncomfortably draughty and is suitable for the climate in Malaysia, particularly in Melaka, where the study was conducted. Therefore, this study is required for a building to obtain an appropriate wind speed or air velocity. Air velocity may cool a person's body through evaporation, directly affecting thermal comfort and enhancing tolerance for relatively higher air temperatures when air velocity is greatly increased.

For recommendation, the researcher in the future can create the model layout, either smaller or bigger than 900 sqft to provide varied results and suggestions. The future researcher can also conduct a study combining the wind speed and direction for a model layout.

Acknowledgement

The authors would like to thank Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its supports.

References

[1] United Nations (2018). Energy Statistics Pocketbook. https://unstats.un.org/unsd/energy/pocket/2018/2018pb-web.pdf
[2] Suruhan Tenaga Malaysia (2016), National Energy Balance 2016. http://meih.st.gov.my/documents/10620/9a9314a1- cf11- 4640- a9de- 3b31f336a416.
[3] Y. Zhou, C. Lork, W.T. Li, C. Yuen, Y.M. Keow (2019), Benchmarking Air-Conditioning Energy Performance of Residential Rooms Based on Regression and Cluster- ing Techniques, Appl. Energy 253.
[4] Malaysian Standard MS2680 (2017). Code of Practice on Energy Efficiency and Use of Renewable Energy for Residential Buildings.
[5] Malaysian Standard MS 1525 (2019). Code Of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings
[6] Cheong KWD, Lau HYT (2003). Development and application of an indoor air quality audit to an air-conditioned tertiary institutional building in the tropics. Build Environ2003 (38), 605–16.
[7] American Society of Heating, Refrigerating and Air-Conditioning Engineers, & American National Standard Institute. (2017). Thermal Environmental Conditions for Human Occupancy.
[8] Malaysian Standards MS1064 PART4 (2001). Guide to Modular Coordination in Building: Coordinating Sizes and Preferred sizes For Doorsets
[9] Malaysian Standards MS1064 PART5 (2001). Guide to Modular Coordination in Building: Coordinating Sizes and Preferred sizes For Windowsets
[10] Passe, U., Battaglia, F., & Taylor. (2015). Designing Spaces for Natural Ventilation: An Architect’s Guide. Routledge Taylor & Francis Group, Cop.