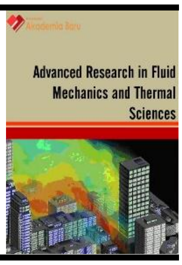
Journal of Advanced Research in Fluid Mechanics and Thermal Sciences 63, Issue 1 (2019) 144-153

Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



Stack Ventilation as A Design Tool to Improve Indoor Thermal Comfort of Duplex Studio at Soho High Rise in Hot and Humid Climate

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Tasneem Mostofa[1,*], Golnoosh Manteghi[1], Hasanuddin Lamit[2]

[1] Faculty of Architecture and Built Environment (FABE), Infrastructure University Kuala Lumpur, Malaysia
[2] Faculty of Built Environment & Surveying, Universiti Teknologi Malaysia, Malaysia

ARTICLE INFO

Article history:
Received 9 April 2019
Received in revised form 16 September 2019
Accepted 25 October 2019
Available online 18 November 2019

ABSTRACT

Natural ventilation can afford building occupants with thermal comfort and a healthy indoor environment. Ventilation approach (i.e. cross ventilation, stack ventilation, single-sided) is conceivably the key parameter that influences ventilation performance among all the design-related parameters. To improved energy and indoor air quality issues, the ventilation approach should be smarter and sensible. A significant smart and sensible ventilation concept is to enhance natural ventilation. Natural ventilation, that is dependable factors with the principles of sustainability and green energy, is widely acknowledged nowadays. Residential and Commercial office building of all major metropolitan cities of the world is characterized by high rise and high density. In this respect, this paper investigates the performance of a representative SOHO high rise building in the city of Selangor, Malaysia and evaluates the optimum solutions by using an optimization approach for that SOHO high rise. The study focused on a unit with single-sided ventilation (i.e. openings in just one external wall) and for stack ventilation only openings are the doors from the upper level and lower level. This pilot test will assess that air movement through the doors can improve indoor thermal comfort. A selection of unit is grounded on the orientation and mid-floor level of the building. The effects will demonstrate the amount of wind velocity passing through the doors can decrease the temperature from 32℃ to 30.3℃ and RH from 62.6% to 68.5%.

Keywords:
Air temperature; building orientation; stack ventilation; soho building

1. Introduction

The building is an enclosure for the help of human residence, work or refreshment. The success of a building depends on a better indoor environment that not only makes occupants thermally comfortable but it will resolve the energy consumption problem and led to its sustainability. A building dweller usually does not have the time, attention, or technical knowledge to optimize a building's thermal systems for comfort at all times. It is the responsibility of the architect to design a

* *Corresponding author.*
E-mail address: mtasnem@gmail.com (Tasneem Mostofa)

building that is comfortable for the dwellers without the HAVC system. Implementing passive designs or climate approachable strategies is an essential way for buildings to succeed in energy efficiency, especially for residential buildings [1, 2]. SOHO is a type of building which can be used as both small office and dwelling. Therefore, if these types of buildings are used as a small office, one has to spend most of his/her time in a day in the office. The problem arises when the indoor air is not sufficient and the building has a lack of ventilation. Even though the HAVC system is running all day long, but it is responsible for certain health and environment risks. The principal source of the problem is the absorption of solar radiation by the full-length glass window and the transmission of the heat into the non-ventilated attic space. The Malaysian architect and engineer would be able to encourage new design thoughts of housing that reveal the demand based on the current needs it is forecast by the construction industry. According to Real Estate and Housing Developers' Association of Malaysia (REDHA), the demand for SOHO is expected to remain strong for the next coming years. So, this is an accurate period to investigate the problem of existing SOHO and come out with a solution where we can provide healthy living by giving proper thermal comfort. The indoor thermal comfort can be maintained by providing proper ventilation which in turn depends on many factors like wind velocity, outdoor temperature, surrounding building structure, height, character, alignment, window opening type, size, and orientation. It is claimed by Aflaki *et al.,* [3] tropical regions like Malaysia, passive cooling method is one of the strategies to eliminate the air temperature heat which is blocked into the indoor environment. Among the above factors, window opening can be designed easily by the engineer and architect for good ventilation and thermal comfort and the rest of the factors could not be easily controlled. According to Osso *et al.,* [4] natural ventilation is a low-cost passive solution to guarantee both Indoor Air Quality and indoor thermal comfort of a building by reducing the demand for the mechanical ventilation system. Furthermore, global air temperatures would be increased with 0.2°C per decade in the coming century (Intergovernmental Panel on Climate Change - IPCC, 2007) [5]. Over the last few years, the indoor temperature of residential buildings in Malaysia has been widely studied by researchers. But in this paper, we will focus on air movement that can reduce temperature and enhance the thermal comfort of SOHO. Two principles which are cross and stack ventilation is the fundamental parameter of Natural ventilation. One of the common methods to acquire natural air supply in the buildings is cross ventilation [6]. The process of passive solutions permits a significant reduction of greenhouse gas emissions and addresses the emerging trend of Nearly Zero-Energy Buildings (NZEB), according to the 31/2010 European directive [7].

2. Literature Review

Natural ventilation is one of the maximum effective methods, when weather permits, to reduce building cooling energy usage and increase indoor air quality. Experts have shown that the acceptable thermal comfort range for naturally ventilated buildings is greater than for buildings with standard mechanical HVAC systems [8]. In Ghana parallel analysis of the traditional and modern Architecture for this done by professionals [9]. Conferring to Subramanian *et al.,* [10] found the temperature measured in traditional indoor is varied from 28 °C-35 °C and in modern buildings it ranged from 31 °C-37 °C. According to Seppänen and Fisk [11], after reviewing 18 different studies on sick building syndrome (SBS) and ventilation systems, found the frequency of SBS symptoms was higher in air-conditioned buildings as incomparable to naturally ventilated ones from 30 to 200 %. In pursuance of calculating the naturally forced ventilation rates as, well as the related influence on building space temperatures natural ventilation design for buildings have a need for insightful awareness and precise forecast of airflow and heat transfer. Altering of air in an enclosed space is ventilation [12]. In the building codes of most countries, ventilation rate (time/hour) is a basic but very important criterion to judge whether a ventilation system is qualified. It means how often the indoor air volume is replaced by fresh air per hour. Better ventilation systems assist in providing fresh air and removing air temperature heat and air pollution. Sustainable construction theory for buildings depends more on natural ventilation to contribute to the improved indoor environment and thermal comfort to their inhabitants even though maintaining rational usage of energy. According to the standards in different regions, there are various limits to the ventilation rate. A ventilation rate of $0.5h^{-1}$ is commonly agreed upon in most European countries [13]. A questionnaire investigation was done in a few high-rise residences in the summer in Hong Kong. The results suggested that more than 70 % of the respondents felt stuffy because of the poor indoor air quality, while two-thirds of the respondents didn't know that a ventilation modification could be turned on to increase indoor air quality. Lack of knowledge of ventilation control devices was the major problem, indicating an urgent need for user education. Similarly Wong *et al*.,[14] in Singapore carried out a questionnaire survey and established that occupants in the middle part of the building be likely to be more uncomfortable with the thermal comfort, while the occupants on the top floor hold a more positive opinion about that. However, a percentage of residents on the top floor held the opinion that the wind was too strong [15]. As stated by Bajunid *et al*., [16] and Manteghi *et al*., [17] better conditions of life, precisely through the environment is a significant assignment of architects, designers, and urban planners. The decline of the quality of surrounding environments has a straight impact on humans or even alarming to the survival of civilization [18, 19]. Undoubtedly the most important and easily defined parameter of improving indoor environment quality is thermal comfort through passive ventilation. Their space requirements are to be thermally comfortable for living. Intended for inhabitants to produce to their full capability. Nonetheless, thermal comfort is grounded on the thermal adaptation of individual occupants which is correlated to parameters such as time of year, topographical location and microclimate, gender, race, and age [20]. The human body tries to maintain a temperature of around 37 °C. The temperature is maintained through heat exchange between the human body and the environment through convection, radiation, and evaporation [21]. Thermal comfort is subjective by six factors; four of them classified as environmental parameters consist of air temperature, mean radiant temperature, air relative humidity, and air velocity. These environmental factors are effortless can be controlled by natural ventilation. Though strong wind is usually annoying, it can also become a positive factor in such a hot climate in Singapore. In Kuala Lumpur, Malaysia, two high rise dormitory buildings were researched by onsite measurement. This research focused on the special character of a high-rise building. It was found that the temperature in the high-rise building rises with the height. The temperature is apparently higher on west side, compared with that on other sides [14]. The driving force for natural ventilation in a high-rise building is the same as in other buildings. Air pressure difference is the basic physical mechanism for airflow, and the pressure difference is generated by the effect of wind and temperature difference (which can lead to buoyancy). Therefore, natural ventilation can be categorized into "wind-induced" and "buoyancy-induced" [22]. There are many parameters affecting the performance of natural ventilation, but the effect weights are not equal. Natural ventilation mode is found to be the most influencing parameter in a high rise residential building, compared with other factors such as window type, window-to-wall ratio, window orientation [23]. It's necessary to study and plan for new cities and communities before their development, to guide them in management, designing and achieve sustainable societies [24].

3. Research Methodology

Mechanical systems are commonly used to cool indoor environment to make it more thermally comfortable in tropical countries. The consequence of this is the energy load is increasing unconditional. Strategies of passive design can decrease a load of active systems if they are applied appropriately. Accordingly, the study was concentrated on examining the thermal condition of the indoor space of the SOHO type building. The evaluation started with a pilot study where one typical floor units were selected to represent the scenario of the existing and the potentials scenario. These two scenarios were based on the levels of radiation and the penetration of the sunlight into the units.

To collect the data, we turned on the Fan provided by the developers and switched off the air conditioner. Because our goal was to stimulate natural ventilation for achieving thermal comfort. We turned the Fan because of to measure the conditions as a true-to-life approach. In this pilot study, we considered the bright unclouded day time that is from 11 am to 6 pm. We collected data on unclouded 7 days. We ignored the stormy and rainy weather limit.

3.1 Research Scheme

Data logger center 310 series used for Relative Humidity and Temperature to measure for every particular location designed for the pilot test. Installed in between wall surface of the hot zone and cool zone/center of the room area at about 1.53 m above the floor level and data was recorded continuously 10 min interval. The result was a comparison of the ambient temperature difference and relative humidity for a particular location designed in the measurement.

3.2 Existing Scenario

For the pilot study we select a duplex unit type F of C block from SOHO high rise building in DE centrum City, this unit affected by direct and indirect heat penetration from East façade and North façade as shown in Figure 1(a) and (b). The unit is a single side ventilated studio apartment. East façade Figure 1(a) is designed with four full-length glass windows where the North façade Figure 1(b) is also designed with a full-length glass window in both lower and upper levels as shown in Figure 2(a) and (b). The schematic sectional diagram is given in Figure 3.

(a) (b)

Fig. 1. Direct and indirect heat penetration from (a) East face, and (b) North façade

Fig. 2. Design of (a) lower, and (b) upper floor plan

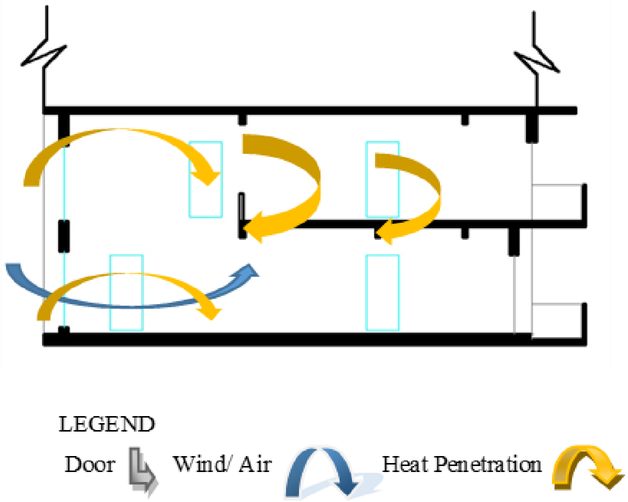

Fig. 3. Schematic sectional diagram

As an effect, the heat of air temperature penetrates from both façades beginning from late early in the morning and till midafternoon. And the North façade window has two operable sections which are a very minimum requirement for the whole unit. The unit is approximately 70 square meters where the operable window section is approximate 1.8 square meters. As a consequence, there is no provision for cross ventilation which has an impact on indoor thermal comfort though air temperature. Firstly in 1974 found by Rohles *et al.,* [25] in his research and recommended that the airflow had a great impact on indoor thermal comfort and the perimeter of airflow should be 0.8m/s. The study found that air velocity with a certain range, higher or lower airflow rate will lead participants satisfied [26]. Figure 4 and Figure 5 will observe the graph of air temperature and relative humidity of the unit for 7 days with the opening of the North façade window.

From Figure 4 and 5 we understand that in the afternoon the temperature is its pick point that is 33 °C to 37 °C and relative humidity is 44 % to 48 %. ASHRAE 55-set the maximum air relative humidity at 60 %. For instance, at low relative humidity, the increase in the evaporation rate may cause skin drying and irritation [27]. And from the pictures, plans and schematic sectional diagram we found that there is no air movement or there is no provision for cross ventilation. Based on the data shown in the chart, hot and humid air is likely trapped indoors for the whole day which caused high indoor temperature. Though the building is north-south oriented but only for lack of ventilation this scenario is taking place.

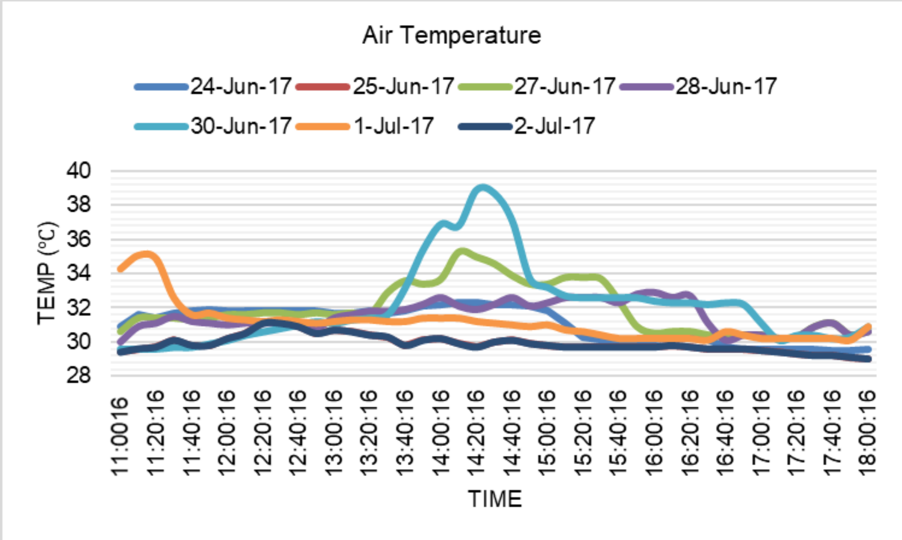

Fig. 4. Air temperature for seven days

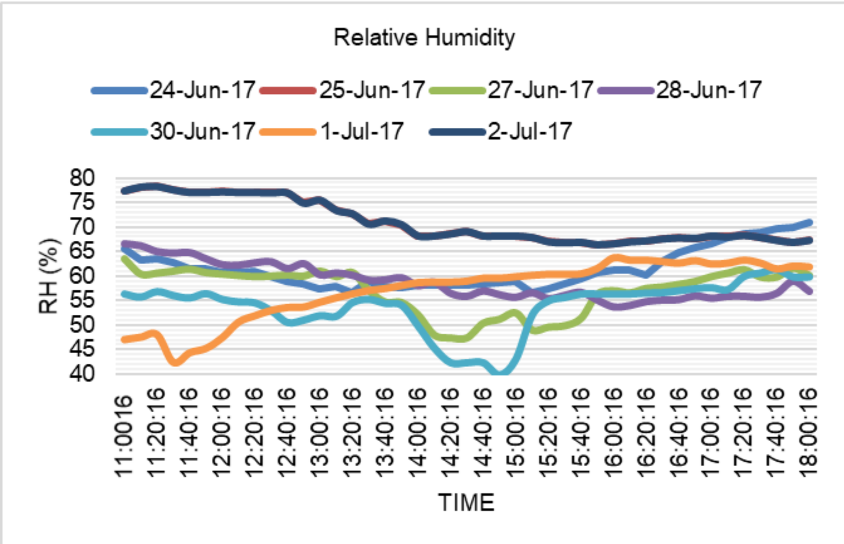

Fig. 5. Relative humidity for seven days

3.3 Potential Scenario

As per the weather of Malaysia is similar all throughout the year this pilot study was conducted for seven days in the month of July with different date. The time and time interval are ten minutes' interval as before. In this case, we open the door from the lower level and also from the upper level for cross ventilation and also have a little amount of stack effect. Generally, the air in the indoor environment is cooler than outdoor environments like hot and humid climate countries. It founded the air will drain out the low opening, being replaced with fresher air from outside through the high opening [28]. The greater number of openings in building generates fresh air intakes from outdoor of the building which creates better cross ventilation. In the pilot test, two doors and operable windows from the lower level and upper level are open to investigating potential scenarios. The resultant Figure 7 and 8 individually of air temperature and relative humidity are given below.

In the schematic sectional diagram Figure 6, we observe that wind is passing through from north to south as well vice versa because the door is placed on the south. In this context, Gao and Lee [29] evaluated the influence of opening configuration on the natural ventilation performance of the residential unit at Honk Kong and stated that the relative position of the two window opening groups (bedroom windows and living room windows) was the most affecting parameter. Similarly enhanced natural ventilation performance can be executed when the openings are situated in reverse direction or perpendicular to each other or they have height variations. According to Hassan *et al.*, [30] the influence of window amalgamations on ventilation characteristics for indoor thermal comfort in buildings. Once more in Figure 6 the openings doors are perpendicular and justify the above statement with additional enhancement by stack ventilation on the upper floor. However, in Figure 7, we found that when there are air movements in the unit the air temperature maintains a constant temperature which is 29°C to 32°C. Although in the afternoon the air temperature is in its pick which is 32°c to 34°c when there is no air movement. Furthermore, in Figure 8 relative humidity is also maintaining a percentage within 60 % to 72 %. Experts confirm that we can produce satisfactory wind speed by appropriate designing and urban planning which leads us to desirable development [31–36].

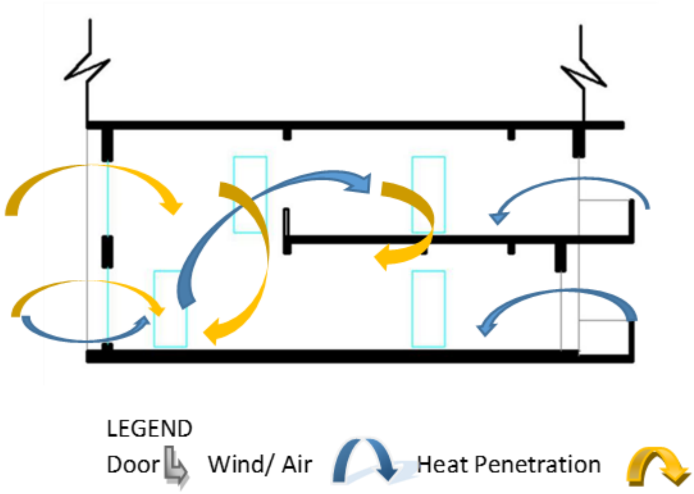

Fig. 6. Schematic sectional diagram

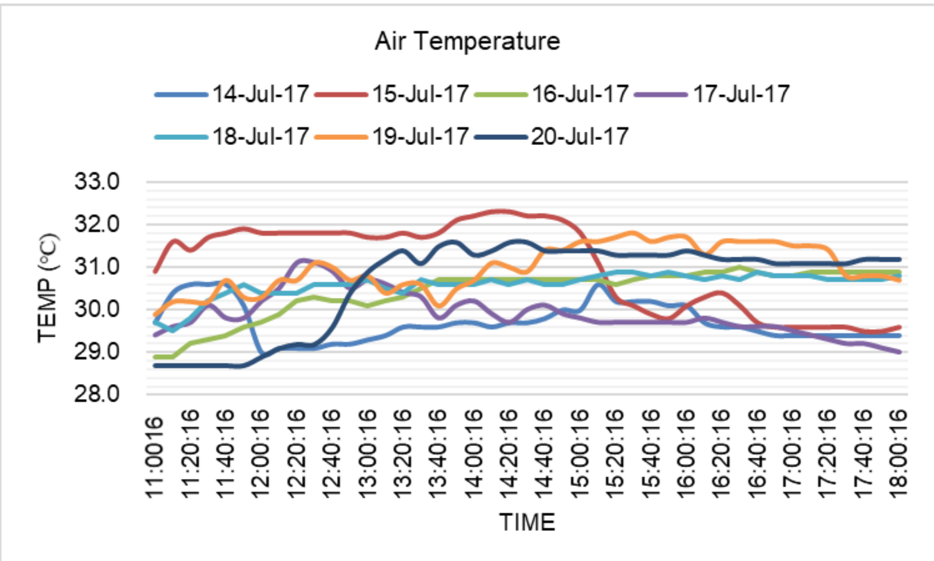

Fig. 7. Air temperature for seven days

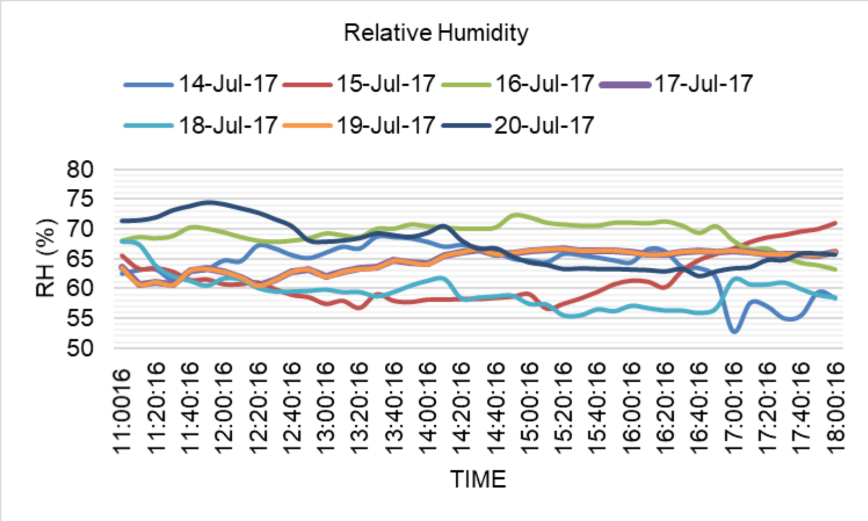

Fig. 8. Relative humidity for seven days

4. Results

For the equatorial region, north orientation might even be preferable to the south orientation while the east and west are the worst orientations [37]. But in this pilot study, we found that north-south orientation is preferable worthy when there is provision for ventilation. Again placing shorter opaque walls to the east and west (maximum solar heating) and longer transparent walls to the north and south (minimum solar heating) are an optimum strategy [38]. This statement will be justified when we have north and south orientation with a sufficient number of openings for cross or stack ventilation. But we found in the test that though the north façade has a longer transparent wall with a minimum operable window which not sufficient for passing the air. Again, the east façade has shorter opaque façade reference within the existing east façade but for penetrating heat it is sufficient besides the south façade with no openings. By the end of this pilot test, we derive a result that can help designers to improve the environment. The outcome is we have to consider north-south orientation with sufficient openings and east-west orientation prefer to be blind façade or very short opaque with shading elements.

5. Conclusions

This pilot study has provided a rough idea about how the thermal comfort level is distributed in a high-rise SOHO building through very indigenous techniques which inherited in every region of the world. Ventilation for any type of building is one of the essential features in providing a standard indoor air quality. Appropriate air circulation helps in providing fresh air and eliminating temperature and air pollution. Nevertheless, in sequence to operate the process, this passive ventilating process depends on natural forces such as wind accessibility and direction. This building design should be incorporated and focused on these parameters to avail of the proper ventilation.

Acknowledgment
The authors would like to thank the Internal Research Fund (IRF) Project ID: KLIU-ACD-AB-02 funded by Infrastructure University Kuala Lumpur.

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