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PASSIVE DESIGN STRATEGY OF OPENING AND SHADING ELEMENTS ON BUILDING FACADES IN ACHIEVING THERMAL COMFORT

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ABSTRACT
Elevated temperatures are often resulting a problem of thermal comfort in hot humid climates, especially in urban areas that have high building densities. The lack of variety of window opening elements in utilizing natural ventilation often occurs in residential areas. This study aims to determine the combination of window opening elements and shading elements that can increase airspeed. This experimental research used CFD computer software to help simulate airflow. The results of this study found that the best combination is the use of sliding windows with 0.5m shading elements attached to the façade. However, the increase in airspeed in the room still does not meet the minimum speed standards based on the microclimate requirements.

Keywords: *Simulation; Facade; Openings; Shading; Airspeed.*

1. Introduction

The construction industry sector, the buildings sector, has an important role in energy consumption which uses 55% of the total energy needs [1]. Related to pandemic conditions that attack the world, the importance of the role of air conditioning in buildings is increasing. The selection of natural ventilation strategies is more suitable to use and recommended for use in pandemic conditions. In addition, the need for HVAC in buildings reaching 50% can be minimized with the use of natural lighting and natural ventilation strategies [2].

The condition of the city of Malang which is at an altitude of between 440-667 meters above sea level, provides a potential for the use of natural ventilation in a building, especially residential houses. However, Malang City which has a relatively high population level and has increased in recent times will affect HVAC energy needs in achieving thermal comfort in buildings. Indirectly, the large use of HVAC energy in buildings will hurt greenhouse emissions and global warming [3]. The building design has great potential in natural ventilation. The impact of openings as an important element in natural ventilation strategies is very significant [4]. In addition to openings, shading elements that also function as wind catchers also contribute to the results of natural ventilation systems in buildings [5]. The role of openings in buildings is often not taken into account in building planning, especially in residential buildings [6]. This will later bring more specific natural ventilation problems at the building occupancy stage. Thus, this study will investigate the influence of the design of openings and shade elements on building facades on natural ventilation performance.

Natural ventilation in buildings is divided into two mechanism systems, namely wind-driven flow and buoyancy-driven flow/stack effect [5]. The selection of this air conditioning mechanism is adjusted to climatic conditions and the local area. In addition to the mechanism of natural ventilation, the basic concept of natural ventilation conditioning is also an important part of the successful use of this passive strategy.

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There were two basic concepts of natural ventilation, namely single-sided ventilation which only has openings on one side of the building, and cross ventilation which has openings on both sides of the building [8]. The position of the openings also influences the performance of natural ventilation conditioning in buildings [9]. Openings facing the direction of the wind come from increasing the potential for natural ventilation performance [9].

2. Material and Methods

This research uses virtual experimental methods with the help of CFD (computational fluid dynamics) computer simulations. The case study was conducted on residential buildings in the city of Malang in the Blimbing sub-district area by the designation of the function of the area, residential. Before the simulation was carried out, Malang city climate data were analyzed first to determine the worst-case scenario. The variables to be used in this study include the type of opening used and the shading element. All input variables are obtained through a literature study.

CFD settings carried out in the simulation room include:

1. Time variation: steady state
2. Iteration:300
3. Solved problem: flow (speed)
4. Flow regime: turbulent RNG
5. Temperature: 32.80C
6. Boundary conditions:
    - Wind direction: perpendicular to the building
    - Wind speed: according to conditions at each time
    - Anemometer height: 2m
    - Land surface roughness categories: urban, suburban, and wooden areas
    - Surface roughness height: 0.03m

A steady state is a constant state, where it is assumed that there is no accumulation or loss of materials such as energy in the system. While the turbulence condition of the RNG (renormalization group) was chosen because the RNG model can improve accuracy for suddenly blocked flow, the RNG model can also be used to improve accuracy for swirl flow.

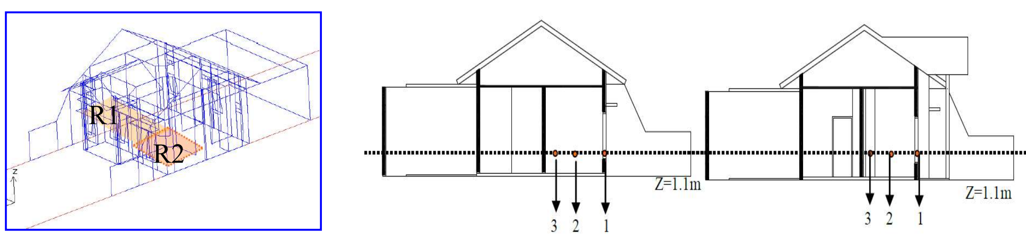

Figure 1. Observation points and room

The research stage starts from the formulation of the problem and continued with literature and field surveys to obtain research variables, physical data of objects, and climate data. The results of the literature survey and field survey are used further at the stage of simulation of existing models and alternative model designs. The simulation results were then analyzed based on natural ventilation theories and climate data on a bioclimatic chart [10].

The variation of façade design will be 9 models, which are derived from the combination of variables as follow:

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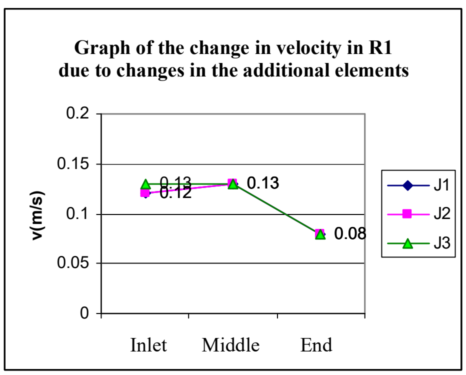
Table 1. Model's code for simulation

Model's Code	Opening type	Shading type
J1	Horizontal double pivot	1m horizontal shading
J2	Horizontal double pivot	1m horizontal shading with a 0.2m gap from the wall
J3	Horizontal double pivot	0.5 egg crate
K1	Sliding window	1m horizontal shading
K2	Sliding window	1m horizontal shading with a 0.2m gap from the wall
K3	Sliding window	0.5 egg crate
L1	Vertical pivot	1m horizontal shading
L2	Vertical pivot	1m horizontal shading with a 0.2m gap from the wall
L3	Vertical pivot	0.5 egg-crate

3. Result and Discussion



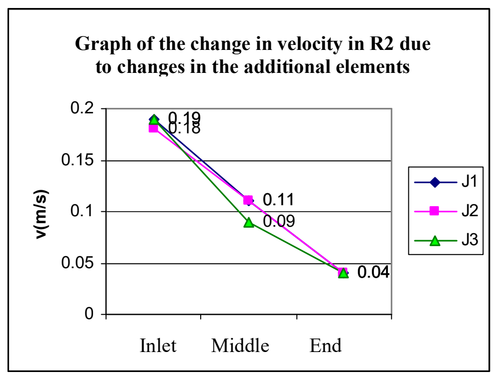


Figure 2. The change of airspeed in room 1&2 for models J1-3

From the comparison graph in the J1 to J3 alternatives, it can be seen that in the R1 area, the use of additional elements in the form of a 1m horizontal shading or egg-crate produces a higher air speed at the inlet than the use of spaced shading elements. At the midpoint and end of the room, the average velocity produced by these three additional element differences produces the same acceleration. However, in the R2 area it can be seen that the use of additional elements in the form of shading directly attached to the façade produces the highest relative speed at the inlet point but at the midpoint and end the resulting speed is the same as the alternative that uses shading, while the use of egg crate surrounding the inlet area of the inlet opening, produces the lowest speed both at the midpoint R2. So, in this alternative J, the treatment that can produce the highest airflow speed in space among alternative J is alternative J1 with a speed at the midpoint R1 of 0.13m/s or only able to reach 16.25% of the speed that should be required (0.8m/s) at a temperature of 32.8 0 C with a humidity level of 47%. in the R2 area the resulting speed at the midpoint is 0.11m/s or only able to reach 13.75%. But for the speed of airflow in the inner chamber to achieve a cool sensation (0.25m/s), at R1 it has reached 52%, and at R2 44%.

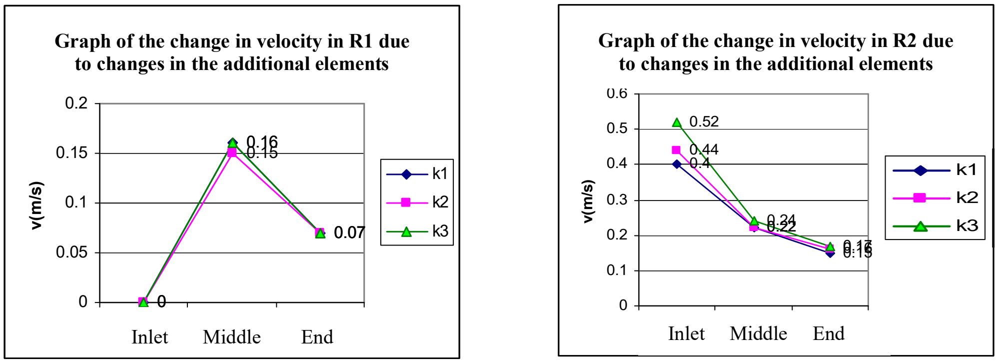


Figure 3. The change of airspeed in room 1&2 for models K1-3

From the graph of the speed change, it can be seen that the change in the use of additional elements does not have much effect on the speed at R1, but in R2 the use of eggcrate gives the results of airflow velocity at the midpoint and tip of the highest among other K alternatives. The use of spaced shading results in higher airflow velocity at both the inlet, middle, and outlet points of the room than the use of ordinary horizontal shading (without distance). The same thing happened to studies with inlets and outlets that were 100% open, showing the presence of fairly good airflow and increased thermal comfort in the room [11]. Eggcrate as vertical-horizon shading also acts as a wind catcher and has proved that it can improve thermal performance.

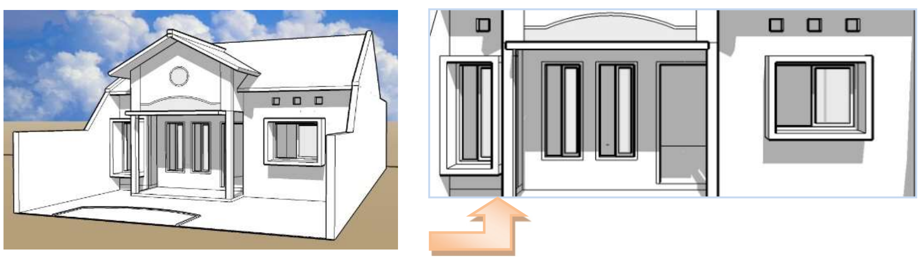


Figure 4. Alternative model K3

So, from the results of this K simulation, the alternative that can produce the highest airflow speed in the room is the K3 alternative, with the speed at the midpoint R1 being 0.16m/s or only able to reach 20% of the required airflow speed (0.8m/s) at a temperature of 32.80C with a humidity level of 47%. in the R2 area the speed at the resulting midpoint is 0.24m/s or capable of reaching 30% of the required airspeed requirement (0.8m/s). but to get a cool sensation, with the need for an airflow speed of 0.25m/s, at R1 it has reached 64% and at R2 it has reached 96%.

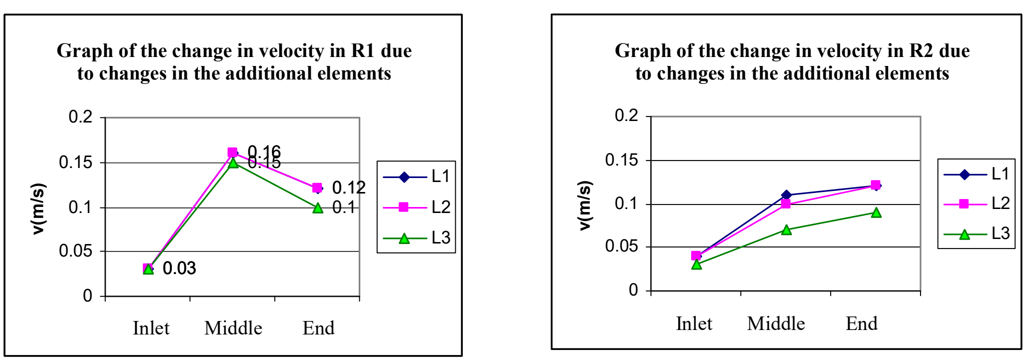


Figure 5. The change of airspeed in room 1&2 for models L1-3

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From Figure, it can be seen that at R1, the speed that occurs both at the inlet, middle, and end points of the room shows an increase from the inlet point to the midpoint and then decreases from the midpoint to the endpoint. The use of shading elements with both and without distance results in better speed than the combination of vertical pivot windows with egg crate shading elements.

The typical thing happens with R2, but in R2, the combination of a vertical pivot window with a shading element attached to the wall (L1) gives a higher speed result at the midpoint than the combination of a vertical pivot window with a horizontal shading element at a distance from the plane of the wall. The lowest speed occurs when a vertical pivot window is combined with an egg crate. This is possible because the incoming air that tends to lead to the left side of the wall plane through the pivot window opening is very limited with a concrete cap element that covers the plane of the inlet opening. Other studies also mention that the ratio of openings was a significant effect on the performance of openings and airspeed in space [12].

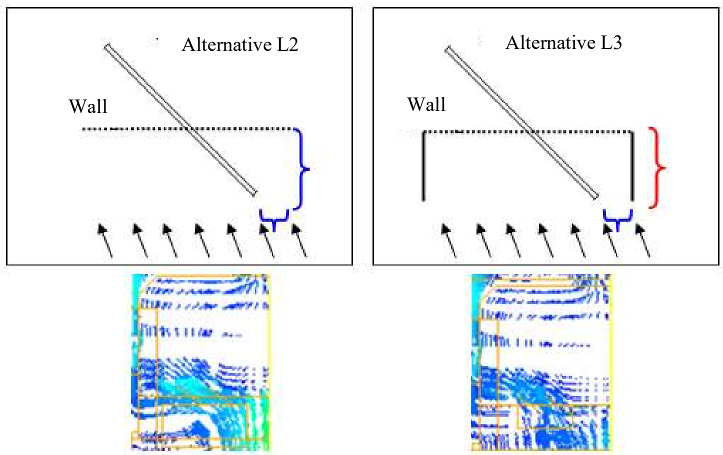

Figure 6. The air pattern for alternative L with vertical pivot window

So, in this L alternative, the combination of pivot windows with additional elements that produce the best airflow speed is the first alternative (L1), which is a combination of vertical pivot windows with shading elements attached directly to the wall plane. The speed at the midpoint at R1 is 0.16m/s or reaches 20% of the required speed (0.8m/s) at 32.80C with a humidity level of 47%. In the R2 area, at the midpoint of the space the speed occurs at 0.11m/s or reaches 13.75%.to achieve a cool sensation at a speed of 0.25m/s, in the R1 area it has reached 64% and in the R2 area it reaches 44%.

From the results of the simulated façade variation, three alternative types of façade variations were obtained that were maximum at R1, maximum at R2, and speed differences at R1 and R2 that were not too far. The most optimal façade alternative is the K3 design alternative. Overall, the alternative design produces better airflow speeds than existing models, but cannot meet standards according to microclimate elements or based on bioclimatic graphs. Similar results also occurred in previous studies, that the design of openings and balconies can increase the speed of airflow [13]. Other studies also mention a significant reduction in thermal discomfort with the right combination of façade designs [14]. The position of the opening plays an important role in increasing the speed of indoor airflow, the same thing happened in previous research by Moey, et.al who discussed the importance of the placement of openings [15]. By looking at all the simulation results, it can also be seen that the influence of the position of the inlet on the direction of the wind is also one of the contributors to the speed of airflow in the room [12].

4. Conclusions

The selection of the combination of opening type and shading type influences the resulting speed value and airflow pattern in space. In addition, the dimensions and placement or position of openings also affect the pattern of airflow and airflow speed in space. Placing openings that are too high from

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the floor level (in certain types of windows, such as overhead hangings and crepes) causes airflow not to lead to residential areas, causing low airspeed in space. The overall speed produced has not met the minimum speed limit to obtain comfort at the temperature at these times (e.g., 10:00 with a temperature of 31.6 0 C at a humidity level of 51%; noon with a temperature of 32.8 0 C at a humidity level of 47%: 14:00 hours with a temperature of 32.8 0 C at a humidity level of 50%), especially during the day. But in the afternoon (16:00 with a temperature of 26.7^{0}C at a humidity level of 69%), the average speed produced by selected alternatives was able to reach the minimum speed requirement needed.

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