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AN EXPLORATORY STUDY ON THE POSITION AND SIZE OF NATURAL AIR OPENINGS AS A PASSIVE VENTILATION STRATEGY IN SPACE

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ABSTRACT

The issue of climate change in the world has become a serious problem until now. The excessive use of artificial air conditioning systems is one of the main contributors to climate problems in the world. Design solutions to help the world's climate problems through a design approach that creates optimal natural air conditioning performance. One of the things that affects the performance of natural ventilation is the placement of the opening position based on the Velocity of the airflow. Soori Bali designed by SCDA Architects was chosen as the object of study because the orientation of the building is designed to take advantage of the potential of the sea breeze as a natural ventilation strategy in its resort units. The method used is the simulation method using Autodesk CFD by evaluating several variations in the position and size of the openings placed horizontally from the left side to the right side of the building. The data collected included the airflow velocity (m/s), flow direction, and turbulence position to the layout of the room in each variation. The results of the simulation were compared to determine the most effective opening and furniture configuration configuration in supporting natural ventilation in tropical buildings. The results of the study showed that the 3 × 3 meter openings placed in the middle position of the room were able to produce an air flow of 1–3 m/s with a temperature distribution of 25–27°C, thus creating optimal passive thermal comfort in tropical buildings in accordance with the SNI 03-6572-2001 standard.

Keywords:Passive Ventilation, Opening Positioning, Autodesk CFD, Tropical Architecture

INTRODUCTION

The current global climate change has caused a significant increase in energy consumption in buildings, especially due to the excessive use of artificial air conditioning systems such as air conditioning (Kartikawati & Pramesti, 2024). These conditions exacerbate the urban heat island effect and dependence on fossil energy, so natural ventilation strategies are increasingly important as a passive design approach to maintain thermal comfort in spaces. However, in its application, many tropical buildings still do not achieve optimal natural air conditioning performance because the size and position of openings are not designed based on measured airflow performance. Soori Bali Resort is an example of a building designed to take advantage of the potential of the sea breeze as a natural ventilation strategy, but the performance of the applied openings still needs to be evaluated quantitatively to find out whether the indoor air distribution is even and meets thermal comfort standards according to SNI 03-6572-2001. Therefore, CFD simulation-based analysis is needed to test the effectiveness of position variations and opening sizes in improving thermal comfort in tropical resort buildings.

Passive ventilation utilizes the movement of natural air to lower and refresh the temperature of the room in the building without the help of mechanical systems. The use of this strategy is particularly relevant in tropical regions that have high temperatures and humidity every year. The results of other studies show that optimal natural ventilation design is able to improve the quality of thermal comfort and significantly reduce the risk of overheating in tropical buildings (Kartikawati &

Pramesti, 2024; Latif, 2020). However, the implementation of good natural ventilation requires a deep understanding of aspects of the design, such as size, opening position, building orientation, and indoor space configuration (Rachmalia et al., 2023)

In the architectural design of the archipelago, the principle of natural ventilation is applied effectively through the design of a ventilated roof and open space that allows it to be cross-air in buildings (Hildegardis, 2021). With the development of computing technology, computer simulations such as Computational Fluid Dynamics (CFD) have become an effective method in analyzing and evaluating natural ventilation designs in various building conditions and climates (Hanifah et al., 2023; Kartikawati & Pramesti, 2024).

Soori Bali Resort, a resort located on the southwest coast of Bali Island designed by SCDA Architects is the object of study in this study. This resort was chosen because it has a design approach that utilizes the flow of wind from the sea as a natural ventilation strategy in its units. Soori bali is specially designed in response to the orientation of the building that maximizes cross ventilation and utilizes large openings to capture the flow of air coming from the sea. The uniqueness of Soori Bali makes this resort a relevant case study to explore the potential position and size of openings in passive ventilation systems.

LITERATURE REVIEW

2.1 Natural Ventilation in Tropical Architecture

Natural ventilation is a process of air circulation without the help of mechanical tools that occurs due to differences in air pressure outside and indoors. This system uses natural phenomena such as wind flow and temperature differences to create thermal comfort in the room (Latif, 2020). In the context of tropical buildings that have high thermal conditions and significant humidity, natural ventilation has a key role to maintain air quality and occupant comfort (Nada Adiva, Tissa; Puspitasari, Popi; Rosnarti, 2022).

Effective natural ventilation in the tropics must be able to produce good cross-ventilation to accelerate the air circulation process (Hanifah et al., 2023). In addition, tropical architecture is required to respond to climatic characteristics by applying design principles that respond to the orientation of the building, the dominant wind direction, as well as the size of the dimensions and position of the opening.

The minimum standard for natural ventilation openings contained in SNI 03-6572-2001 is at least 10% of the floor area of the room in question to ensure the effectiveness of air circulation However, in practice, research shows that the existing minimum standards are often insufficient to create good thermal comfort, especially in extreme climatic conditions (Kartikawati & Pramesti, 2024). With an air speed standard that is in accordance with the Sni 03 - 6572 – 2001 standard at 0.1 m/s at $25^{oC\ to}$ 0.35 m/s at 27.2 $^{oC\ (}$Indonesian National Standard, 2001)

Thus, research related to natural ventilation in tropical buildings not only meets technical requirements, but also the application of a design that is able to adapt to the environmental context and user needs. This research reinforces the urgency of designing natural air conditioning that is not only present as an architectural element, but also as a comprehensive building sustainability strategy.

2.2 Factors Affecting the Performance of Natural Ventilation

The performance of natural ventilation in buildings is influenced by several main factors, including the position and size of the openings, the orientation of the building to the dominant wind direction, and the layout of the space and furniture in the room. The strategic opening position can produce effective cross-air flow, thereby accelerating the process of heat air exchange in the room. (Hanifah et al., 2023). The size of the opening that is too small or unbalanced with the area of the room also has the potential to inhibit airflow and reduce the effectiveness of natural ventilation.

(Latif, 2020) He stated in his research that the ratio of opening area to floor area must meet minimum standards, but to produce more effective air conditioning in tropical climates, planning that exceeds these standards is needed. The placement of openings in the opposite position or so-called *Cross Ventilation* has been proven to be superior to the placement of air vents on only one side or *Single-sided Ventilation.*

Therefore, the selection of position, size, and opening layout is an important aspect in designing building design in tropical regions that have high heat intensity and humidity every year.

2.3 CFD Simulation as a Natural Ventilation Analysis Tool

Computational Fluid Dynamics (CFD) is a computational-based simulation method used to analyze the behavior of fluid flow, including air in buildings. The use of CFDs in architectural planning is growing rapidly due to its ability to visualize airflow patterns and identify areas with good and bad air conditioning potential (Hanifah et al., 2023). CFDs allow the evaluation of various natural ventilation design scenarios without the need to create a physical prototype, thus reducing the time and cost in opening design planning. CFD simulations can measure airflow speed, pressure distribution, and turbulence areas that affect the quality of natural air conditioning in a room (Ananta & Suryabrata, 2024).

In natural ventilation research, the CFD result parameters should be compared with applicable comfort standards, such as SNI 03-6572-2001 which provides temperature limits and ventilation requirements in buildings, and ASHRAE Standard 55-2020 which establishes thermal comfort ranges, including indoor air velocity tolerance limits. In addition, previous studies have also shown that changes in the geometry and configuration of the aperture greatly affect the efficiency of air exchange, as well as emphasizing the need for model validation through wind flow experimental data (Vincent et al., 2021; Jauch, 2021).

RESEARCH METHODOLOGY

This study uses a CFD (*Computational Fluid Dynamics) simulation approach* to evaluate the effect of variations in size and opening position on the performance of natural ventilation in the bedroom of Soori Bali Resort located in a tropical coastal area. This method was chosen because it is able to provide accurate airflow modeling without the need for physical testing, making it more efficient in terms of time and cost.

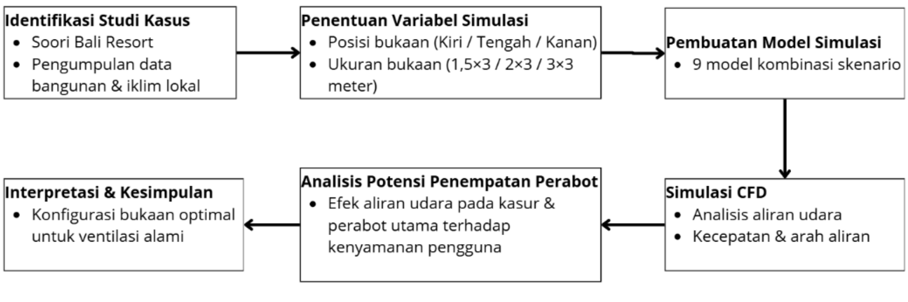

Figure 1. Research method flowchart

3.1 Natural Ventilation in Tropical Architecture

Data was collected through architectural documentation from the *Soori Bali Resort case study*, designed by SCDA Architects. Architectural information includes 3D modeling of resort unit layouts, especially in the bedroom that is the object of the simulation. Other supporting data in the form of the local climate of the Bali coast and the reference to thermal comfort standards in SNI 03-6572-2001 were used as the basis for the simulation parameters. The focus of the data consisted of two main aspects: (1) the relationship between the size and position of the opening to the pattern of air circulation in the room, and (2) the relationship between the size of the opening to the temperature distribution and air velocity, which was then analyzed using **a classification of four clusters** for each of these aspects. The classification groups air velocity data into: *Red* (>5 m/s), *Orange* (3–5 m/s), *Green* (1–3 m/s), and *Blue* (<1 m/s) clusters; as well as inward air temperatures: *Red* (>29°C), *Orange* (28–29°C), *Green* (26–28°C), and *Blue* (<26°C), with the principle that the higher the speed, is generally inversely proportional to the temperature in the area.

3.2 Data Analysis Methods

The simulation was carried out using *Autodesk CFD (Computational Fluid Dynamics) software* by creating nine model combinations that combined three opening position scenarios—(1) on the left side, (2) in the middle, and (3) on the right side of the building—with three variations in the size of the openings: 1.5 × 3 meters, 2 × 3 meters, and 3 × 3 meters. Each model is simulated to analyze the distribution of air velocity (in m/s), flow direction, as well as turbulence formation in space. The analysis of the simulation results was then used to identify the zoning of comfortable areas based on the distribution of speed and air temperature. The zoning is then the basis for providing recommendations for the placement of the main furniture such as mattresses, so that they are not in areas with direct blows or stagnant zones that can reduce the thermal comfort of the user.

Each simulation result is then classified based on **four speed and temperature clusters**, which allows for a more structured visualization of the relationship between thermal conditions and flow distribution. For example, in a small opening (1.5 x 3 m), the area near the opening tends to be in the Red cluster (high speed), but the temperature is in the Blue cluster (colder due to the fast flow), while the far side of the opening shows low speed and high temperature (Blue and Red clusters are in opposite directions). This is in contrast to the 3 x 3 m aperture, which actually shows the dominance of the Green cluster for both speed and temperature, indicating optimal passive thermal comfort. The simulation data were analyzed visually and descriptively to determine the most effective opening configuration in creating natural cross-ventilation, as well as the appropriate thermal conditions for tropical climates with high heat intensity and humidity.

ANALYSIS AND DISCUSSION

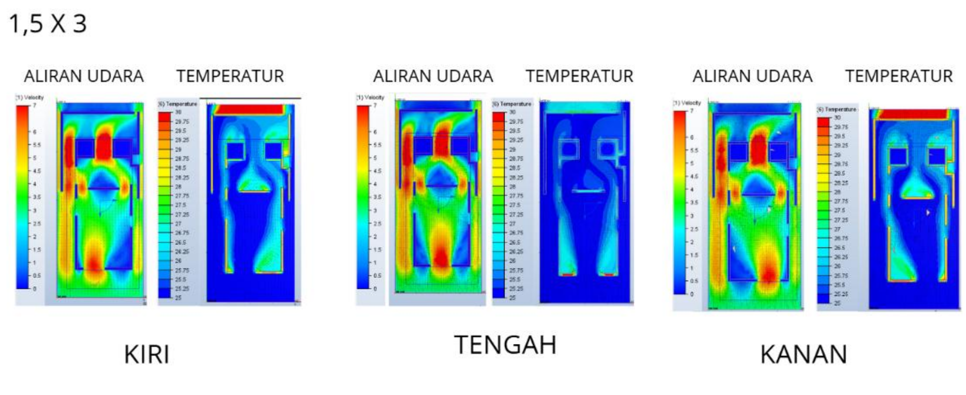

Figure 2. Size of 1.5m x 3m openings in left, middle, and right positions

Simulations conducted at the 1.5m x 3m aperture parameters showed the dominance of the red cluster for air velocity (>5m/s) in the area close to the opening, which was concomitantly lower in the blue cluster which had a temperature of < 26°C resulting in intensive cooling from the fast flow. On the other hand, which is an area far from the opening, the air tends to have a stagnant speed at <1m/s (Blue Cluster) and has a high temperature of > 29°C (Red Cluster). This extreme temperature difference shows a very uneven thermal distribution that results in temperatures being too cold on one side and too hot on the other, creating conditions that are far from the standard of thermal comfort. The magnitude of this flow results in very low temperatures in areas close to the opening, which is shown in the predominance of dark blue in the temperature simulation visualization. However, from the results obtained that these conditions are not ideal for human thermal comfort according to SNI, which suggests that the overhead air velocity should not exceed 0.25 m/s, and is more ideal if it is at a speed of less than 0.15 m/s. This means that at an opening of this size, air tends to cause a direct blowing effect that can interfere with comfort, especially when resting,

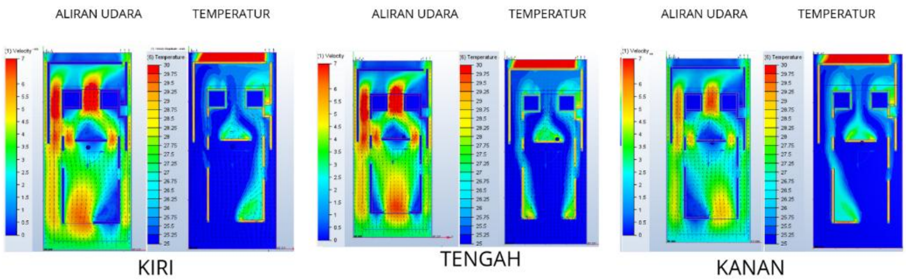

Figure 3. Size of 2m x 3m openings in left, center, and right positions

At the 2m x 3mm opening, the distribution begins to improve with the dominance of moderate air velocity at 1-3m/s (green cluster) and temperatures that tend to be in the range of 25–28°C (Green to Orange cluster). Around the opening, there are still areas with relatively high air velocities at 3-5m/s (orange cluster) which produces temperatures lower than <26°C (blue cluster), but the airflow is more horizontally spread so that it does not cause extreme turbulence of the area. The middle area is the most stable zone with a cool and comfortable flow, suitable for use as a rest area. The room temperature becomes more homogeneous, especially in the middle which shows a light blue color which is in the cool and comfortable category. Although the left side still has a relatively high flow, the area of turbulence is more controlled due to the wider size of the opening, allowing air to spread horizontally. The placement of the rest area on the central side of the room is recommended, as the temperature is within the effective and optimal temperature range of 22.8-25.8°C and the air velocity is close to the comfort standard according to SNI at 1-3 m/s.

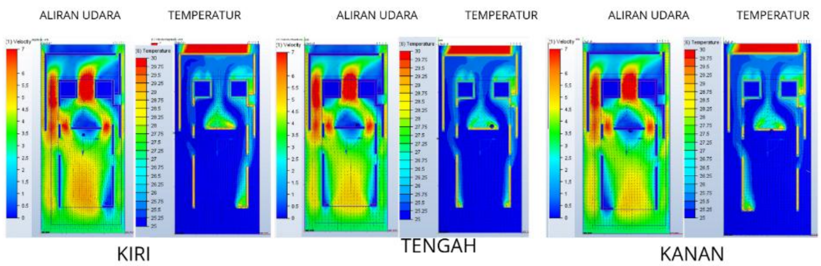

Figure 4. Size of 3m x 3m openings in left, middle, and right positions

Simulations at 3m x 3m apertures resulted in the most balanced thermal conditions. Most rooms are at an air speed of 1-3 m/s or in evenly spread green clusters, and produce temperatures at 26-28 °C (Green clusters), which correspond to the thermal comfort standards of tropical buildings. There are no areas of extreme speed or extreme temperature, as circulation works evenly throughout the room. This room reflects the ideal balance between airflow and temperature. It is not too cold and not too hot, and without direct blowing, thus providing maximum thermal comfort in passive ventilation. There are no hot zones or stagnant zones that can interfere with the thermal comfort of the room. This condition indicates that the room is in thermal conditions ideal for tropical climates, with the use of natural cross ventilation that runs without causing excessive areas of turbulence. With a temperature close to the effective temperature according to SNI 03-6572-2001, this room can achieve thermal comfort passively without the need for mechanical air conditioning. This underlies evidence that the use of appropriately positioned large openings is highly effective in improving thermal comfort in rooms in the tropics.

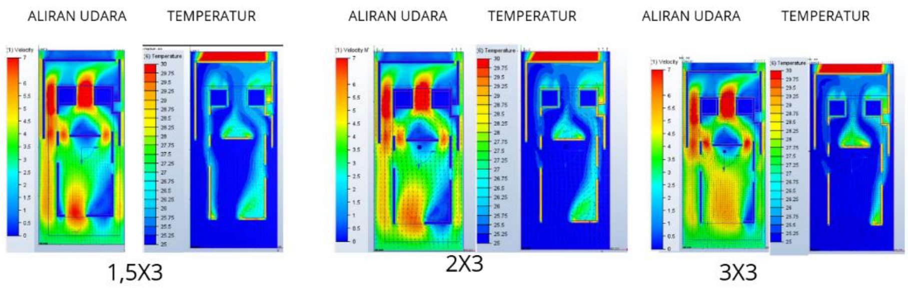

Figure 5. The position of the left of the opening relative to the size of the opening

When the opening position is placed on the left side of the room, the airflow tends to be concentrated on the left side of the building. The simulation shows a very low temperature in the position near the opening, with a dominant dark blue color, while in the right area there is a turbulence zone that produces a higher temperature and does not get enough circulation. This condition shows that the uneven temperature distribution, with only a small part of the space being effectively cooled, is not in accordance with the principle of thermal comfort in the SNI standard, which emphasizes the importance of even circulation with the air velocity in the activity zone in the range of 0.15 to 0.25 m/s so as not to cause a direct blowing effect.

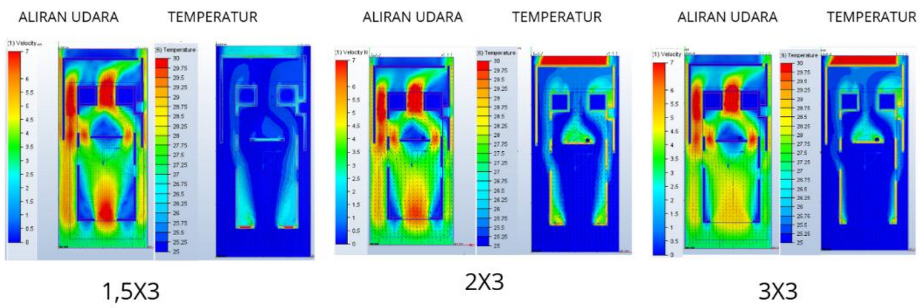

Figure 6. The position of the center of the opening relative to the size of the opening

When the berad opening is placed in the middle of the room, the airflow distribution shows a significant improvement in flow. The flow was more evenly distributed on 2 sides of the room, with the results of the temperature simulation in the blue cluster which was at 25-27 °C. This brings the temperature close to the optimal temperature standard listed in the SNI, which is between 22.8-25.8 °C. This position allows air to spread in a linear manner from the left and right without forming too strong currents, thus providing better comfort for the user's activities in it.

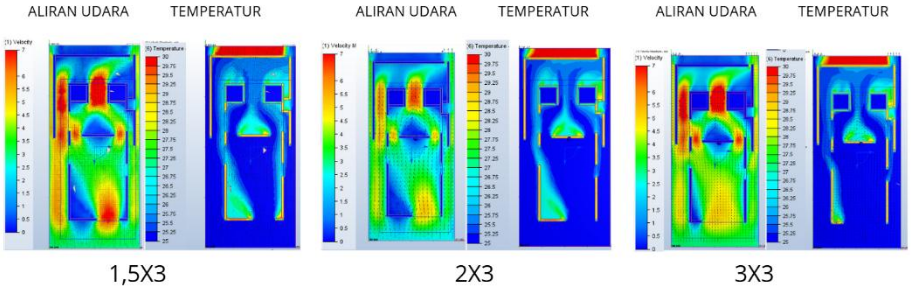

Figure 6. The right position of the opening relative to the size of the opening

When placing the opening on the right side, there is a distribution pattern and air temperature that is almost similar to the configuration of the opening on the left of the room, but in this position it occurs in the opposite direction. The area close to the opening becomes very cold, while on the left side of the room becomes hotter and stagnant. This causes temperature and airflow imbalances that occur in the space, and has the potential to cause direct discomfort to the user due to the occurrence of a direct blow that is quite strong.

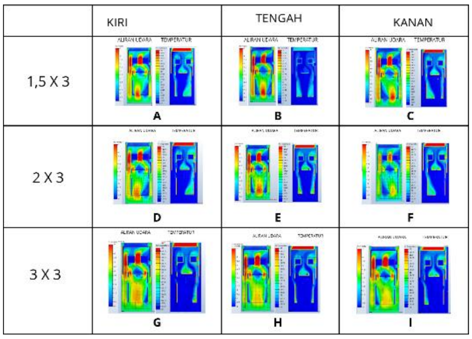

Figure 7. Simulation of the overall variable

The results of simulations of various opening positions show that the placement of the opening in the middle of the wall plane of the room is the most optimal configuration to create a balanced air distribution and a stable temperature. In the middle position, the air distribution spreads symmetrically evenly on the right and left sides, so that there is no extreme concentration of blows that can interfere with the thermal comfort of the user. In contrast to the right or left position, where the airflow is very focused on only 1 side so that turbulence zones occur and result in temperature imbalances and stagnant areas that can interfere with user activities. Thus the position in the middle of the room is recommended as the most effective design strategy for the distribution of air flow in the room supported by *cross ventilation* in tropical buildings, as it is able to distribute air and temperature evenly without causing excessive turbulence effects.

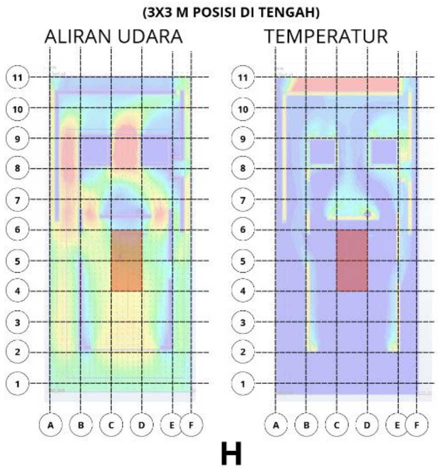

Figure 8. Grid helps determine the zoning of comfortable areas

Analysis of the simulation of the variation in the size of the opening showed that the size of 3x3 meters was the most effective configuration to create thermal comfort through evenly distributed airflow. The 3x3 size found that the air velocity was in the ideal range (1-3 m/s), while the resulting room temperature remained stable in the range of 25-27°C, which is in accordance with the thermal comfort standards for tropical climates. Thus, it can be determined that the zoning position of the comfortable area located on the grid **C4, D4, C6, D6** which has the criteria of airflow speed and air temperature is closest to the SNI 03-6572-2001 standard. So when combined with the analysis of the opening position, the size of 3 x 3 meters located in the middle of the room is the most effective option recommendation among other sizes and opening positions because it is able to produce optimal passive air conditioning conditions without the help of an artificial cooling system. Based on the mapping of the simulation results, areas with stable air velocities in the range of 1–3 m/s and temperatures of 25–27°C were identified as the zones with the highest level of comfort according to SNI 03-6572-2001. This zone is then used as a reference in determining the placement of the main furniture such as mattresses, so that it is not at a point that experiences direct air blowing or an area with stagnant flow that has the potential to cause thermal discomfort for the user.

CONCLUSION

1. The results of the CFD simulation process show that the large openings in the existing Soori Bali resort building, are able to create natural air conditioning performance that far exceeds the air speed standards accepted by humans in the space in accordance with SNI 03-6572-2001 when all openings are wide open. The existing opening at the resort is in the form of a sliding folding door with dimensions of about 3 x 3 meters, which when fully opened becomes the main path of air flow.
2. In this study, the size was used as one of the variables in the simulation, and a comparison was made with 2 alternative sizes, namely 2 x 3 m, and 1.5 x 3 meters. The results showed that the larger the size of the opening, the more even the distribution of air flow and temperature in the room, the 3 x 3 meter opening in the middle position produced the most ideal conditions with an air velocity in the room of 1-3 m/s which was categorized in the green cluster with a temperature of 25-27°C, indicating the achievement of passive thermal comfort.
3. Based on the simulation above, it is recommended that the planning of tropical buildings, especially resorts, villas, or beachfront residences adopt a large opening system that can be fully

opened, with a minimum size of 2x3 meters and has an ideal size of 3 x 3 meters to support natural cross ventilation.

4. The position of the opening also has a big effect on the distribution of air in the room: the opening placed in the middle of the wall plane tends to have a more symmetrical and stable air distribution than the position of the opening on the right or left side.
5. The placement of the rest area and other areas in the Soori Bali resort unit is a very appropriate configuration. The area is located in a zone with stable airflow and cool temperatures, and is free from turbulence zones and direct gusts, making it ideal for supporting the comfort of resting. Therefore, the large opening design approach with strategic spatial planning is one of the main aspects in creating a comfortable and efficient living space for tropical climates.

References

ARDIANSYAH, A., & Winasih, S. (2025). Kajian Liponsos Keputih Surabaya Sebagai Sarana Pemberdayaan Masyarakat Melalui Pendekatan Arsitektur Perilaku. *DEARSIP : Journal of Architecture and Civil*, *5*(01), 120-132. https://doi.org/https://doi.org/10.52166/dearsip.v5i01.9429

Hanifah, A., Sugini, Handoko, J. P. S., & Fauziah, I. Y. (2023). Pengaruh Tipe Bukaan Terhadap Kinerja Angin Dalam Ruang Pada Rumah Tinggal Di Dusun Mlangi, Sleman, Yogyakarta. *Seminar Karya Dan Pameran Arsitektur Indonesia*, *6*(2).

Hildegardis, C. (2021). Tinjauan Pengaruh Letak Bukaan Terhadap Persepsi Penghuni Pada Gereja-Gereja Di Indonesia. *Rustic*, *2*(1), 10–19. https://doi.org/10.32546/rustic.v2i1.1747

Jauch, C. (2021). Grid services and stress reduction with a flywheel in the rotor of a wind turbine. *Energies*, *14*(9). https://doi.org/10.3390/en14092556

Kartikawati, D., & Pramesti, P. U. (2024). Evaluasi Aspek Penghawaan Alami Terkait Sistem Ventilasi Bangunan Berdasarkan Standar Nasional Indonesia (SNI). *Gewang*, *6*(1), 53–60.

Latif, S. (2020). Sistem Ventilasi Alami Satu Sisi pada Kamar Kos dengan Metode Computational Fluid Dynamics (CFD). *Jurnal Permukiman*, *15*(2), 95. https://doi.org/10.31815/jp.2020.15.95-106

Nada Adiva, Tissa; Puspitasari, Popi; Rosnarti, D. (2022). *Tinjauan literatur sistematis bioclimatic architecture approach in term of energy saving in tropical countries , with systematic literature review*. 153–164.

Rachmalia, I., Romadhoni, N., Tarra, B. M., & Arfianti, A. (2023). Pengaruh Bukaan Terhadap Penghawaan Dan Pencahayaan Alami Pada Bangunan Terminal Joyoboyo Surabaya. *Seminar Nasional Arsitektur Pertahanan 2023 – UPN "Veteran" Jawa Timur*, 174–188.

Rambe, Y., & Tambunan, I. (2025). ARSITEKTUR SEBAGAI TERAPI : EKSPLORASI KARAKTERISTIK ANDRA MARTIN DALAM MENINGKATKAN KESEJAHTERAAN PSIKOLOGIS ANAK TERLANTAR DI MEDAN. *DEARSIP : Journal of Architecture and Civil*, *5*(01), 49-62. https://doi.org/https://doi.org/10.52166/dearsip.v5i01.8919

Rossa, A., Fajar Zakariya, A., & L. Punay-, A. (2025). KONSEP HEALING ENVIRONMENT DI RUMAH SAKIT DARMO SURABAYA. *DEARSIP : Journal of Architecture and Civil*, *5*(01), 35-48. https://doi.org/https://doi.org/10.52166/dearsip.v5i01.8104

SAnanta, B. S., & Suryabrata, J. A. (2024). *Pengaruh Konfigurasi Balkon pada Performa Kinerja Ventilasi Alami Dalam Ruangan Bangunan Rusunawa di Indonesia Impact of Balcony Configuration on Natural Ventilation Performance in Indoor Spaces of Social Buildings (Rusunawa) in Indonesia*. *8*, 37–50.

Sekarkinanthi, J., & Yunisya, A. (2025). KAJIAN PENATAAN ZONASI GEDUNG PARU DAN JANTUNG RSUD BANGIL DIMASA PANDEMI COVID-19. *DEARSIP : Journal of Architecture and Civil*, *5*(01), 108-119. https://doi.org/https://doi.org/10.52166/dearsip.v5i01.9432

Standar Nasional Indonesia. (2001). Tata Cara Perancangan Sistem Ventilasi dan Pengkondisian Udara pada Bangunan Gedung. *Sni 03 - 6572 - 2001*, 1–55.

Vincent, O. C., Uchenna, O., & Roy, O. O. (2021). CFD Analysis of Wind-Driven Natural Ventilation in Building Models. *International Journal of Engineering Research and Advanced Technology*, *07*(11), 01–08. https://doi.org/10.31695/ijerat.2021.3602