EFFECT OF COURTYARD POSITION IN CREATING INDOOR THERMAL COMFORT

(Pengaruh Posisi Courtyard dalam Mewujudkan Kenyamanan Thermal dalam Bangunan)

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Abstract

The courtyard existance that has been recommended in some publication may need to be promoted and hence prioritized on every Rumah sederhana Sehat (RsS) development. In order to support the courtyard promotion initiative, evidence based on research into RsS courtyards' characteristic that inform the maintenance of optimal indoor thermal comfort, needs to be acquired. This paper examines the issue of the RsS courtyard's position as one of the factors that is effective in both establishing and maintaining each house's indoor thermal comfort. The research is conducted with Ansys 14.5 Fluid CFD simulation. The unit model itself is a 9 x 9 m^2 unit house. A 3 x 3 m^2 courtyard, in 9 different placements, is tested for its effectiveness in maintaining the RsS model's indoor thermal comfort. Based on the results and the discussion, it can be concluded that there are 5 courtyard positions that provide the RsS houses and their residents with comfortable indoor temperatures. Therefore, these five positional options can be proposed as viable courtyard placements, especially the two positions that show superior performance to the other three acceptable courtyard locations.

Keywords*: CFD simulation, indoor temperature, natural ventilation*

Abstrak

Eksistensi courtyard yang direkomendasikan oleh beberapa artikel perlu dipromosikan sehingga menjadi prioritas pada pengembangan Rumah sehat Sederhana (RsS). Untuk mendukung hal tersebut, pembuktian berdasar penelitian terkait karakter courtyard pada RsR yang menunjukkan bagaimana menjaga kenyamanan thermal perlu disosialisasikan. Artikel ini mengkaji dampak posisi courtyard sebagai salah satu faktor yang efektif dalam menghadirkan dan menjaga kelangsungan kenyamanan thermal dalam rumah tinggal. Penelitian untuk paper ini dilakukan dengan simulasi Ansys 14.5 Fluid CFD. Berdasarkan hasil dan diskusi, dapat disimpulkan bahwa terdapat 5 posisi courtyard yang dapat memberikan kenyamanan thermal bagi pengguna RsS. Oleh karena itu 5 posisi terebut perlu diajukan sebagai pilihan penempatan courtyard, terutama 2 posisi yang menunjukkan kinerja yang lebih baik dari 3 posisi courtyard lainnya.

Kata kunci: simulasi CFD, suhu dalam ruang, penghawaan alami

Introduction

In order to provide affordable housing, the Indonesian government offers a modest house known as *Rumah Sehat Sederhana* (RsS). As the family grows, involving the need for spatial development and the financial expense related to improvement, the RsS can be transformed to satisfy the occupants' demands. Some rooms from the initial design can be widened and re-arranged, and some new rooms might be added (Aryani et al., 2016). The kitchen is the area that is most often widened and re-arranged. However, similar modifications also happen to bathrooms and the guest room(s). The bedroom, as a part of the initial room program, is the room that is most often added, as one is rarely enough. A multifunction room and an open space inside the house, which can function as the clothesline area or courtyard, are the second most frequently added facilities. This couryard addition is known for its benefit in maintaining indoor thermal comfort (Dili, Naseer & Varghese, 2010; Asfour, 2008; Sadafi et al., 2011; Zakaria and Ismail, nd).

As there are too many programs relating to rooms that can, or actually need, to be added (Aryani, Mulyadi & Wahyuningsih, 2016), such a richness of options may cause the eager occupants to use the entire available space, including the front, side and back of the house (Aryani, Mulyadi & Wahyuningsih, 2014). Such an ‘all-inclusive’ option will almost certainly have the unwished-for effect of decreasing the house’s ventilation performance and thermal comfort quality (Sasongko et al., 2015). Therefore, the courtyard’s existance that has been recommended and chosen for use with some transformation designs (Aryani et al., 2016) may need to be promoted and prioritized for every RsS development. In order to support the promotion of courtyards, research data on the RsS courtyards’ optimum characteristics for maintaining indoor thermal comfort need to be gathered. This article examines the courtyard’s position as one of the factors that informs the quality of the RsS’s indoor thermal comfort.

Research Method

The research is conducted by using a Computational Fluid Dynamic (CFD) simulation; a method which has been used by many researchers. Shi (2013) used CFD to examine the role of the courtyard as it related to the wind. Yasa and Ok (2014) employed CFD to observe the energy efficiency of buildings with courtyards; in particular the relationship with courtyard form and thermal comfort levels. Tablada et al. (nd) used CFD and added a wind tunnel experiment to identify the wind’s movements. Tablada et al. (2005) used CFD again to compare the different geometric forms of courtyards relative to the wind movement’s characteristics and velocity inside the room, in order to observe the thermal comfort of the rooms that faced the courtyard. Rajapaksha, Nagai and Okumiya (2002) observed the effect of wind movement on buildings with courtyards. Aryani et al. (2018) ran the CFD simulation to test the courtyard’s location to identify the yard’s optimal placement for maintaining occupants’ indoor thermal comfort, based on wind velocity analysis.

Simulation and Modelling

The simulation is run with Ansys 14.5 Fluid CFD. The conditions assumed are 34°C (304°K) indoor temperature and 25°C (298°K) outdoor temperature. The wind blows on 0.9 m/s. Observation is at the 2 meter height.

The unit model itself is a 9 x 9 m^2 unit house without any interior partitions; a design that enables researchers to easily visualize wind movement. The unit is facing to the west and functioning as the only access for the induction of natural ventilation. This type of model is informed by the tendency of house transformation design that in many cases uses the entire site (Aryani, Sasongko & Wahyuningsih, 2017; Aryani, Mulyadi & Wahyuningsih, 2014); hence the only place for any ventilation intake has to be at the front part of the house.

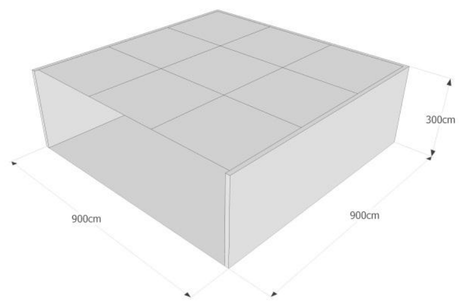

Figure 1. Modelling Unit
(Source: Aryani, Susanti, Sasongko, 2018)

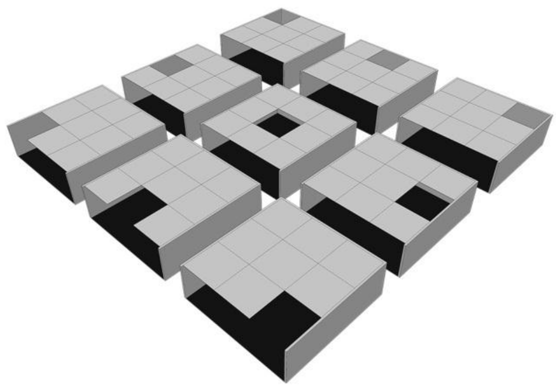

Figure2. Variety of The 9 Courtyard Placement
(Source: Aryani, Susanti, Sasongko, 2018)

The 3 x 3 m^2 courtyard, with 9 different placements, is tested for its effectiveness in maintaining indoor thermal comfort. This approach may differentiate from other studies that only observe 1 courtyard position (Sadafi, 2011), most often placed in the middle of the site (Shi, 2013; Zamani, Teleghani & Hoseini, 2012; Rajapaksha, 2002; Asfour, 2008; Myneni, 2013).

Result Reading

The simulation results are presented by color gradation as there is no strict difference in the thermal condition at each of the observed spots. The colors themselves represent the thermal levels in the range of 297°K – 304°K. However, as every simulation result has a different temperature range, the colors from one result may not represent the same degrees of temperature as recorded in another simulation result. Therefore, the color parameters need to be viewed with particular care.

Literature Review

Hassan (nd) states that to ensure the courtyard's performance, both the orientation and the geometric form of the courtyard need to be considered. Tablada et al. (2005) support this statement by concluding that both the position and the orientation of the courtyard are the important aspects that influence the wind velocity and indoor thermal comfort. Similarly Heidari (2010) states that the potency of the courtyard as a passive design related to its composition in the building and the wind movement patterns and levels. Aryani et al. (2018) concludes that different courtyard positions offer different performance levels in maintaining wind velocity for a house's natural ventilation. Related to the courtyard orientation Zamani, Teleghani and Hoseini (2012) explain that the most efficient courtyard involves an east – west orientation.

Finding

The simulation results are categorized based on the courtyard's placement relative to the house: front, middle and back.

Front Part of The House Simulation Results

The simulation results from the front part of the house are not presenting the same range of temperatures. The 1st courtyard position shows a temperature range from 298°K to 299,67°K; the 2nd courtyard position shows a temperature range from 298°K to 304,00°K; the 3rd courtyard position shows temperatures ranging from 298°K to 300,63°K. Therefore, the results cannot be read directly based on the similarity of the colors, as they do not represent the same or identical conditions.

Below are the images of the courtyard placement at the front part of the house, named as the 1st, 2nd and 3rd courtyard, together with their simulation results.

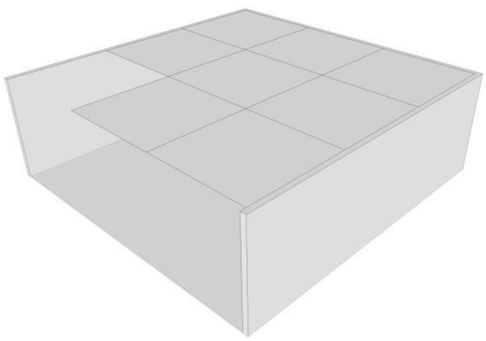

Figure 3. The 1st Courtyard Position (Source: Aryani, Susanti, Sasongko, 2018)

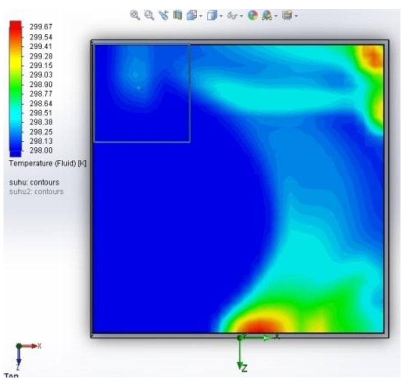

Figure 4. The Simulation Result of The 1st Courtyard Position (Source: Aryani, Susanti, Sasongko, 2018)

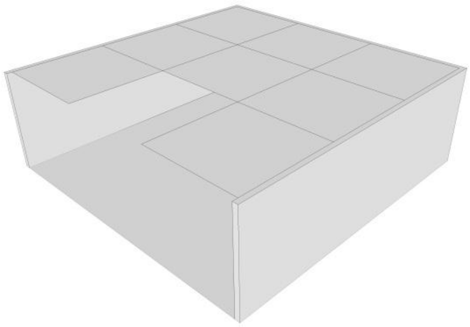

Figure 5. The 2nd Courtyard Position
(Source: Aryani, Susanti, Sasongko, 2018)

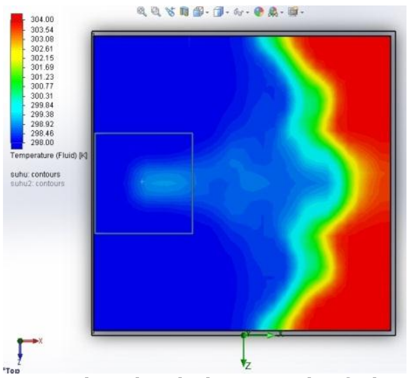

Figure 6. The Simulation Result of The 2nd Courtyard Position
(Source: Aryani, Susanti, Sasongko, 2018)

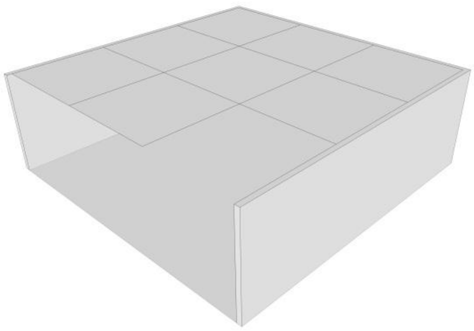

Figure 7. The 3rd Courtyard Position
(Source: Aryani, Susanti, Sasongko, 2018)

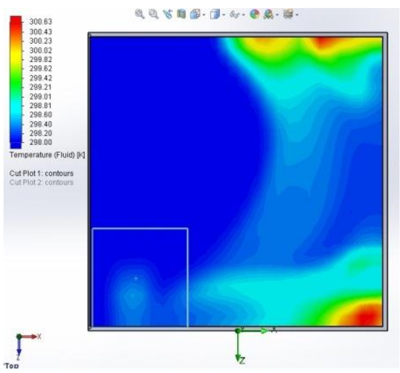

Figure 8. The Simulation Result of The 3rd Courtyard Position
(Source: Aryani, Susanti, Sasongko, 2018)

The table below summarizes the percentage of area with different temperature ranges.

Table 1: Percentage of area with particular temperature in the front part of the house

Position / Temperature	Court yard 1	Court yard 2	Court yard 3
298,15^0 K	43,8%	43,6%	46,1%
299,15^0 K	54,5%	18%	3,1%
300,15^0 K	1,6%	0,4%	4,7%
301,15^0 K	0%	8%	0%
302,15^0 K	0%	8%	0%
303,15^0 K	0%	5%	0%
304,15^0 K	0%	16%	0%

(Source: Aryani, Susanti & Sasongko, 2018: 6)

It can be seen that the 1st and 3rd courtyard positions are still in the thermal comfort zone as the indoor room temperatures are in the range of 298,15°K to 300,15°K. Only the 2nd courtyard position has a higher indoor thermal reading that exceeds the comfort zone, reaching 304,15 °K.

Middle Part of The House Simulation Results

Below are the images of the 4th, 5th and 6th courtyard placements in the middle part of the house; together with their simulation results

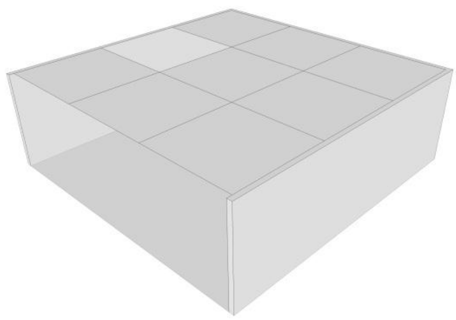

Figure 9. The 4th Courtyard Position
(Source: Aryani, Susanti, Sasongko, 2018)

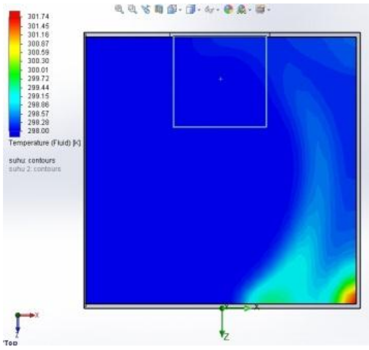

Figure 10. The Simulation Result of The 4th Courtyard Position (Source: Aryani, Susanti, Sasongko, 2018)

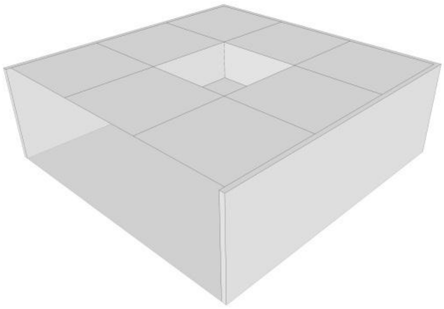

Figure 11. The 5th Courtyard Position (Source: Aryani, Susanti, Sasongko, 2018)

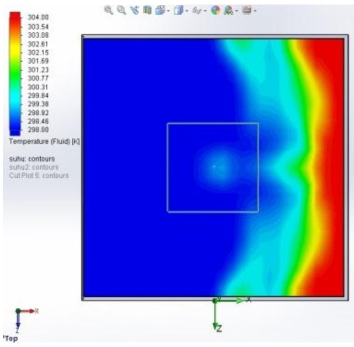

Figure 12. The Simulation Result of The 5th Courtyard Position (Source: Aryani, Susanti, Sasongko, 2018)

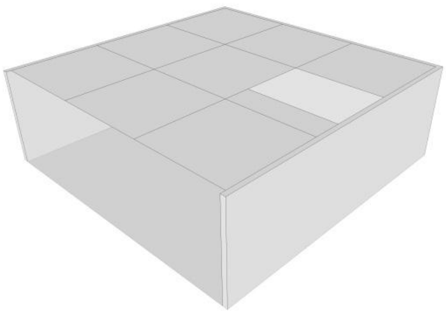

Figure 13. The 6th Courtyard Position (Source: Aryani, Susanti, Sasongko, 2018)

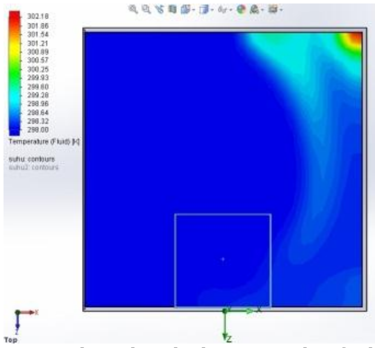

Figure 14. The Simulation Result of The 6th Courtyard Position (Source: Aryani, Susanti, Sasongko, 2018)

As with courtyard positions 1, 2 and 3 (above) the simulation results relating to the middle part of the house do not present the same range of temperatures; however, in this case the results may be able to be read based on the colors shown, as the differences are not too noticebale. The 4th courtyard position shows a temperature range of 298°K to 301,14°K; the 5th courtyard position shows temperatures ranging from 298°K to 304,00°K and the 6th courtyard position shows a range from 298°K to 302,18°K. The table below summarizes the percentages of areas in a range of particular temperatures.

Table 2. Percentage of Area With Particular Temperature in The Middle Part of The House

Position / Temperature	Courtyard 4	Courtyard 5	Courtyard 6
298,15^0 K	75,8%	57%	74,3%
299,15^0 K	20%	11,7%	16,9%
300,15^0 K	3,5%	12,8%	3,7%
301,15^0 K	0,5%	1,8%	4,9%
302,15^0 K	0,2%	3,3%	0,3%
303,15^0 K	0%	4%	0%
304,15^0 K	0%	9,3%	0%

(Source: Aryani, Susanti & Sasongko, 2018: 8)

It can be seen that 4th and 6th courtyard positions present better performance in creating indoor thermal comfort than the 5th position courtyard that touches 304,15°K. However, 4 and 6 both reached a highest temperature of 302,15

°K, whereas the side courtyard on the front part of the house only reached 300,15°K.

Back Part of The House Simulation Results

Similar to the front part of the house simulation results (courtyard positions 1, 2 and 3), the simulation results from the back part of the house do not present the same range of temperatures. The 7th courtyard position shows temperatures ranging from 298°K to 298,64°K; the 8th courtyard position shows temperatures ranging from 297,99°K to 298,71°K and the 9th courtyard position shows a temperature range from 297,99°K to 301,19°K. Therefore, the results cannot be read directly based on the similarity of the coloring, as similar colors do not represent similar conditions.
Below are the images of the courtyard placements at the back part of the house: the 7st, 8th and 9th courtyard positions and their simulation results.

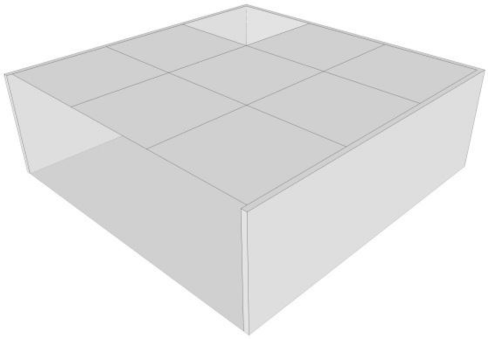

Figure 15. The 7th Courtyard Position (Source: Aryani, Susanti, Sasongko, 2018)

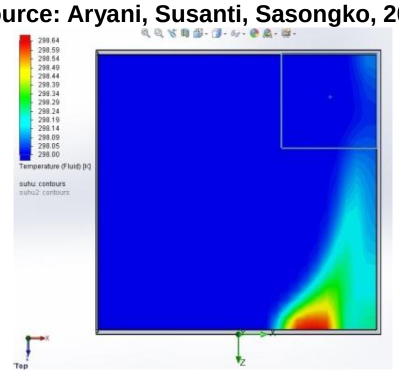

Figure 16. The Simulation Result of The 7th Courtyard Position (Source: Aryani, Susanti, Sasongko, 2018)

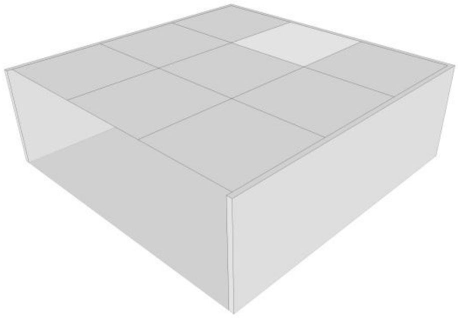

Figure 17. The 8th Courtyard Position (Source: Aryani, Susanti, Sasongko, 2018)

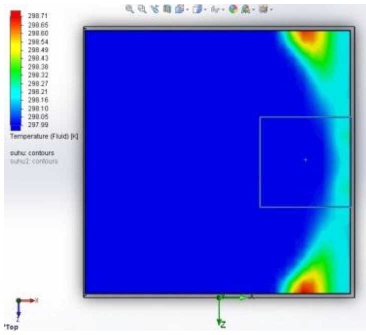

Figure 18. The Simulation Result of The 8th Courtyard (Source: Aryani, Susanti, Sasongko, 2018)

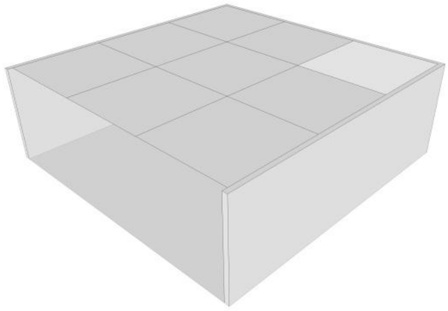

Figure 19. The 9th Courtyard Position (Source: Aryani, Susanti, Sasongko, 2018)

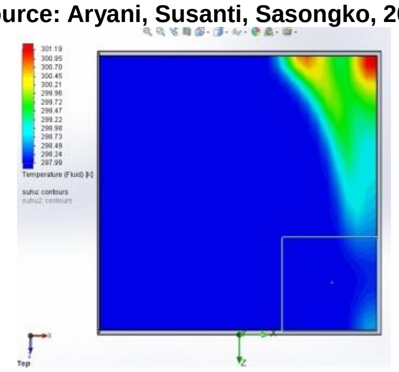

Figure 20. The Simulation Result of The 9th Courtyard (Source: Aryani, Susanti, Sasongko, 2018)

It can be seen on the table below that the 7th and 8th courtyards are still in the thermal comfort zone as the indoor room temperatures are in the range of between

298,15°K and 299,15°K. This condition is better than front part of the house simulation result that reached a temperature of 300,15°K. The worst courtyard position of options 7, 8 and 9 is the 9th location, even thought its performance is better than the 2nd and the 5th courtyard, which represent the worst thermal performances from each part of the house.The table below summarizes the percentage of area in a particular temperature range.

Table 3. Percentage of area with particular temperature in the back part of the house

Position / Temperature	Court yard 7	Court yard 8	Court yard 9
298,15^0 K	89,5%	85,9%	82,7%
299,15^0 K	10,5%	14,1%	6,8%
300,15^0 K	0%	0%	9,2%
301,15^0 K	0%	0%	1,2%
302,15^0 K	0%	0%	0,1%
303,15^0 K	0%	0%	0%
304,15^0 K	0%	0%	0%

(Source: Aryani, Susanti & Sasongko, 2018: 10)

Discussion

It can be seen that the courtyards in the 4th, 6th, 7th, 8th and 9th positions show the best perfomances in creating thermal comfort, as they can maintain indoor temperatures in the range of 298,15°K to 300,15°K for most areas. The worst courtyard positions can be found in the 2nd and 5th courtyard positions, as they reached simulated temperatures of 304,15°K. This outcome shows similar results of courtyard effectiveness to those based on a simulated wind velocity analysis (Aryani et.al., 2018). Small percentages of areas appeared to reach 301,15°K in the 6th and 9th courtyard positions, which are on the south area. This result may support the conclusion other publications that suggest the importance of a courtyard's orientation, stated by Tablada et al. (2005) for the house on warm humid climate, Heidari (2010) for the house on desert area and Hassan (n.d) for the house on hot desert area, as well as the statement by Zamani, Taleghani and Hoseini (2012) that the courtyard located on the north area of a house in arid climate Isfahan exhibits low internal temperatures.

Closing Statement

Conclusion

Based on the results and the discussion, it can be concluded that the 4th, 6th, 7th, 8th and 9th positions can all be perceived as acceptable couryard locations as they provide comfortable levels of indoor temperatures.

Below is the chart that summarizes the simulation results.

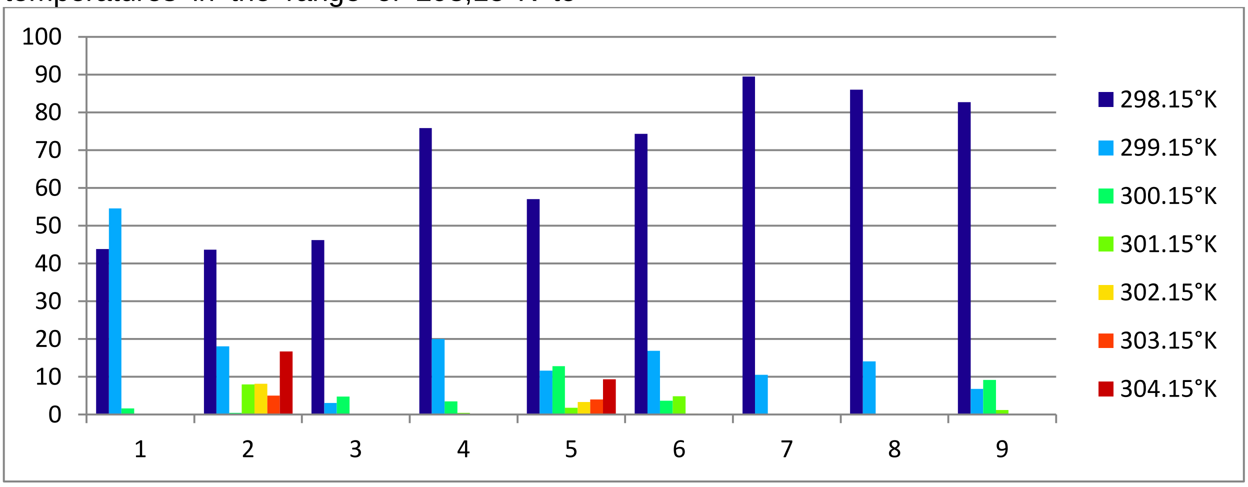

Figure 21. The Comparative Chart of Simulation Result for 9 Positions of Courtyard (Source: Aryani, Susanti, Sasongko, 2018)

Recommendation

Therefore the 4th, 6th, 7th, 8th and 9th positions can be proposed as optimal courtyard placements; especially the 7th and 8th options that show better performance than the other acceptable courtyard positions.

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