

Courtyard Placement for Maintaining Air Movement of Natural Ventilation inside a Transformed House

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Abstract. A courtyard has effectively induced fresh air into the interior of the house and hence is recommended for inclusion in an additional-room program in a house transformation initiative. However, because of the limited space and the vast choice of room programs that need to be considered in the transformation, it is necessary to formulate the right position of the courtyard. This article sets out the results of research that observed the most effective position of the courtyard. The research was conducted through Ansys 14.5 simulation. The 81 m² house was simulated as an open lay-out design without any interior partitions. The open layout based simulation is aimed to make the visualization of wind circulation clearly seen. The 9 m² courtyard is tested in 9 different positions. Based on the simulation, it can be concluded that there are 5 courtyard positions that give positive results for wind velocity, thereby promoting air circulation throughout the entire house area.

Keywords: Courtyard, simulation experiment, thermal comfort, wind velocity

1. Introduction

House design transformation or alteration of public housing units is actually expected by the Indonesian government, as the unit provider. Despite its potential benefits, there can also be a negative impact resulting from the self-help development. One outcome that often occurs is a decrease in indoor thermal comfort because of the preference to build over the entire back-yard, so blocking any outlet access for 'used' or stale air from within the house (Aryani, Wahyuningsih and Mulyadi, 2014). That finding became the background of the community service program for different public housing. Support is provided by giving assistance to the owner to plan their house design transformation, in order to avoid making any mistakes. As a preliminary step, an in-depth interview focusing on spatial assessment and post occupation evaluation is carried out. A misguided tendency for back yard development, which eventually leads to thermal comfort problems such as hot indoor temperature and mildewed walls, possibly caused by high humidity, has been identified (Sasongko et al., 2015).

The design transformation assistance initiative has recommended adding a courtyard into the space programming. This recommendation has been tested for its effectiveness, revealing that a courtyard has a positive effect by creating a lower indoor temperature, faster wind velocity and better air circulation (Aryani et al., 2016). However,

because of the limited available space for development and various spatial requirements that need to be added, it might be necessary to figure out the courtyard placement that produces the most effective thermal comfort improvement. This article explains the assessment of courtyard positioning to find the most effective courtyard placement in order to maintain natural ventilation in a transformed house.

2. Previous Research on Courtyards

The role of an internal courtyard in inducing a continuous internal air movement to achieve thermal comfort has been published by Dili, Naseer and Varghese (2010). The courtyard has been stated as a modifier for climate (Philokyprou and Michael, 2012) that improves natural ventilation and thermal comfort (Asfour, 2008; Sadafi et al., 2011; Zakaria and Ismail, nd) as well as for lighting purposed (Salama, 2006; Myneni, 2013). To support the courtyard's important role Ali (2007) has highlighted its importance regarding the land value factor, new building regulations of floor area ratios and, above all, indoor comfort. Emphasis was placed on the positive potential of courtyards in residential apartments for creating good thermal and luminous environments. Heidari (2010) noted the positive correlation of a courtyard with the passive cooling of a building, in terms of airflow and circulation pattern.

Hassan (nd) recommended that to ensure a good air-circulation performance of a courtyard, it is necessary to pay attention to certain parameters, such as the orientation and the geometry of the courtyard. Some researchers have examined factors relating to the courtyard’s proportional form (Heidari, 2010; Rizk and Henze, 2014; Shi, 2013; Tablada et al., 2005; Tablada et al., nd; Xie, Zhang and Xu, 2006; Yang, Li and Yang, 2012). Other articles have mentioned the characteristics and variables of courtyards that offer better performance regarding thermal comfort. These variables include wind orientation (Almhafdy et al., 2013; Yasa and Ik, 2014; Xie, Zhang and Xu, 2006; Zamani, Taleghani and Hoseini, 2012). Other researchers have considered the composition of the ‘opening on the envelope’ (Rajapaksa, Nagai and Okumiyam, 2002) and the existence of a second courtyard (Tablada et al., 2009) to enhance courtyard performance.

3. Methodology

The research is conducted by using an Ansys 14.5 simulation. Measurements are taken from a 2 m height above the floor, with the assumption of a 0.9 m/s wind velocity that blows from the west. The house model, made by Solidworks, is assumed with wall are on three sides. The model has the facade that facing the west, without wall as the main opening for air intake. The 81 m² simulated house is an open lay-out design without any interior partitioning; therefore, the wind circulation within the unit can be visualized. The 9 m² courtyard is tested in 9 different positions, in 3 different parts of the house. The observation is focused on the inside plan of the house. The result can be interpreted by matching the color parameter with wind velocity.

4. Result

The simulation result is presented via color gradation as there is no strict difference in the wind velocity at every observed spot. However, the gradation can be differentiated into 5 noticeable colors:

1. *Orange* that represents 3 – 3.3 m/s wind velocity
2. *Yellow* that represents 2.7 – 3 m/s wind velocity
3. *Green* that represents 1.5 – 2.7 m/s wind velocity
4. *Light blue* that represents 0.3 – 1.5 m/s wind velocity as the preferred range of air speed movement. The range itself can be divided into three parts: i) 0.25 – 0.5 m/s as the most comfortable, ii) 0.5 – 1 m/s as a comfortable wind movement that can still be felt and 1- 1.5 m/s as the maximum, but still comfortable, wind velocity (Frick, 2008)
5. *Dark blue* that represents 0 – 0.3 m/s wind velocity and means there is no wind movement that can be felt.

4.1. Front Part of the House Simulation

Below are the results of the courtyard placement at the front part of the house, named as the 1st, 2nd and 3rd courtyard positions.

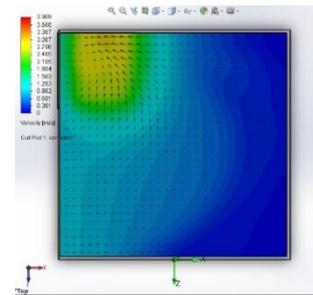


Figure 1. The result of the 1st courtyard position.

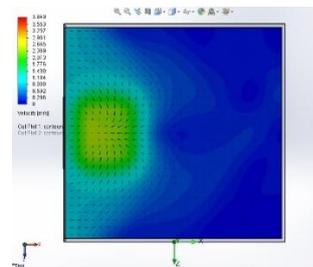


Figure 2. The result of the 2nd courtyard position.

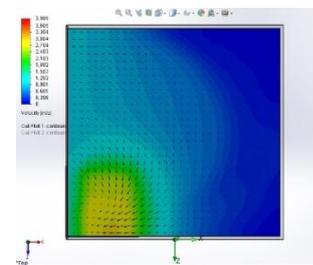


Figure 3. The result of the 3rd courtyard position.

It can be clearly seen that the 1st and 3rd courtyard positions have greater proportions of light blue color (60-61%) than the 2nd position (18.9%) and have even

shown traces of orange as the fourth color (0,3%). The worst courtyard performance is indicated in the 2nd courtyard position, where the 71.3% of dark blue color represents a low level of wind velocity.

In spite of its unsatisfactory natural ventilation performance, this type of courtyard placement is found in the majority of self-help transformation initiatives, where the house has been developed by using all of the backyard of the property. As a result only the front yard is left as an open space.

Table 1. Percentage of area as wind velocity presentation on the front part of the house

Courtyard Position	Orange	Yellow	Green	Light Blue	Dark Blue
1	0.32%	7,36%	7,2%	60%	25,12%
2	0%	5,32%	2,95%	18,9%	71,3%
3	0,29%	6,80%	5,92%	61%	25,88%

4.2. Middle Part of the House Simulation

Below are the results when the courtyard placement is in the middle part of the house. The data are presented as the 4th, 5th and 6th courtyard positions.

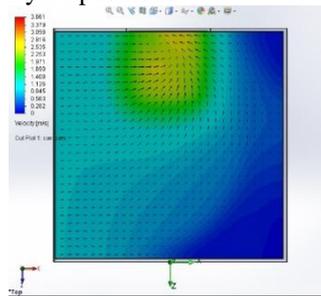


Figure 4. The result of the 4th courtyard position .

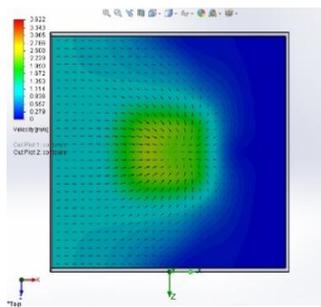


Figure 5. The result of the 5th courtyard position.

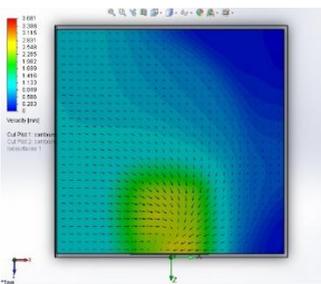


Figure 6. The result of the 6th courtyard position.

From the simulation results it can be seen that the 4th and 6th courtyard positions show similar proportions, with 75% light blue color indicating good air movement. The worst courtyard performance is presented in the 5th courtyard position that has 29% dark blue color, indicating

minimal wind velocity. However, compared to the front part simulations, these courtyard positions offer better performance as they present smaller amounts of dark blue color than the courtyard from the front part courtyard placement

Table 2. Percentage of area as wind velocity presentation in the middle part of the house

Courtyard Position	Orange	Yellow	Green	Light Blue	Dark Blue
4	0%	7.52%	8%	75.3%	9.2%
5	0%	2.4%	10.6%	58%	29%
6	0%	8.13%	7.84%	74.9%	9%

4.3. Back Part of the House Simulation

The courtyards located on the back part of the house are the 7th, 8th and 9th courtyard positions. The simulation results can be seen below.

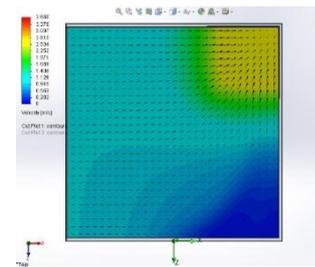


Figure 7. The result of the 7th courtyard position.

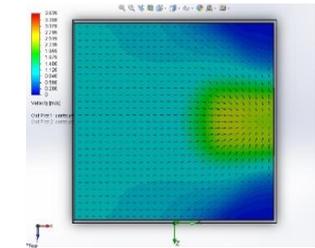


Figure 8. The result of the 8th courtyard position.

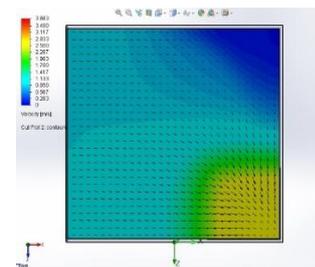


Figure 9. The result of the 9th courtyard position.

The 7th and 9th courtyard positions show similar results. The best courtyard performance comes from the 8th courtyard position, which has the smallest proportion of dark blue color (2.9%) that represents a lower wind velocity than the other back-of-house courtyard positions.

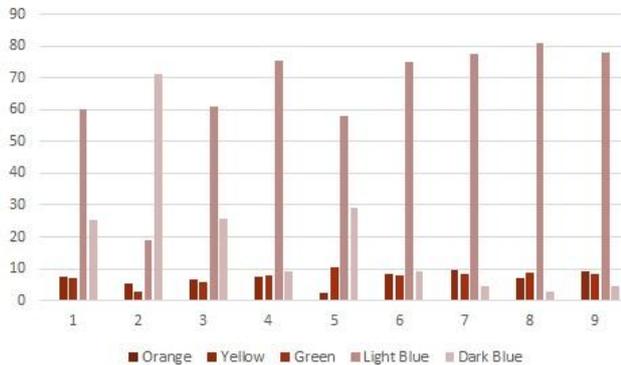
Table 3. Percentage of area as wind velocity presentation in the back part of the house

Courtyard Position	Orange	Yellow	Green	Light Blue	Dark Blue
7	0%	9.47%	8.43%	77.6%	4.44%
8	0%	7.1%	8.87%	81%	2.95%
9	0%	9.31%	8.43%	77.8%	4.44%

Compared to the previous results, these courtyard positions have the best performance, with the greatest proportion of the light blue color.

5. Discussion

Below is a summary of the simulated 9 courtyard positions, presenting the wind velocity data in graphic form.



It can be seen that a courtyard that is placed at the back part of the house has a smaller area of low wind velocity, together with a larger light blue area representing the preferred range of wind velocity, than courtyards in the other six areas / positions. The 4th and 5th area in the middle part of the house also produced a high percentage of the comfortable, light blue range of wind movement. The 2nd courtyard position presents the worst performance for wind / air movement.

6. Conclusion

Based on the research results, it can be concluded that the 2nd area should be avoided as a courtyard placement. However, the 4th, 5th, 7th, 8th and 9th courtyard positions can all be proposed as acceptable courtyard locations, as they provide comfortable levels of air / wind movement. This conclusion is supported by the smaller areas of dark blue color that represents low / poor air circulation and the much bigger light blue areas representing preferred levels of wind velocity and associated comfort. Therefore, the research data suggest areas 4, 5, 7, 8 and 9 can be recommended as courtyard placements. However, further research may be required to finally choose the best back-of-the-house courtyard position, as there is another variable that should be considered; that of indoor temperature. Other variables that might be considered include sun direction and wind orientation.

This conclusion leads to a further research question relating to the in-house temperature performances created by the 9 different courtyard positions; an issue to be discussed in another publication.

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