FENG-SHUI AND COMPUTATIONAL FLUID DYNAMICS (CFD)

Analyzing Natural Ventilation and Human Comfort

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Abstract. The paper explores the analogies between Computational Fluid Dynamics (CFD) and Feng-Shui by undertaking an analysis of natural ventilation in Jiangmen city, Southern China. Feng-Shui has been used to inform the orientation, layout, and design of buildings in China for thousands of years. The research questions if these concepts are still valid for contemporary building design. Noting that computational simulation methods such as CFD allow architects to analyse the natural ventilation of buildings, this paper provides a novel study that examines if Feng-Shui principles can be reconciled against contemporary design processes. The research simulates ‘community’, ‘block’, and ‘single courtyard’ via CFD study to confirm the scientifically measurable concepts of Feng-Shui have concerning natural ventilation. We conclude that Feng-Shui concepts enhance natural ventilation and subsequently makes a positive contribution to sustainable building and design.

Keywords. Human comfort; Natural ventilation; CFD; Feng-Shui.

1. Introduction

Design principles guided by Feng-Shui have informed building design in China for thousands of years. These principles are reported to relate to the building environment at a range of scales (Mak & Thomas, 2005). The concept of Feng-Shui has expanded globally; thus, we believe a reexamination of these tools is of importance and also timely due to development in CFD (Feuchtwang, 1974). The design principles found in Feng-Shui can be applied to orientation, layout, and design for the entire cycle of buildings (Mak, 1995; Lee, 1986). Several researchers have focussed how Feng-Shui impacts the location and spatial arrangement in architectural design (Knapp, 1986; Knapp, 1992; Lawrence & Raffestin, 1994; Kalland, 1996); our research, however, explores how Feng-Shui concepts can be used for architecture design to supply human comfort concerning natural ventilation. CFD is grounded on modern fluid dynamics which combines

numerical mathematics with computer science (Guo & Liu & Yuan, 2015 (a); Guo & Liu & Yuan, 2015 (b)). It can simulate the wind loads of urban environments and offer data to understand the performance of buildings concerning natural ventilation. The simulated and optimised building design of natural ventilation is reported to supply a better living condition for human comfort (Du & Mak, 2017). This research seats the CFD case study computational analysis in Jiangmen city as a case study. The natural ventilation of the ‘community’, ‘block’, and ‘single courtyard’ were not only analysed based on human comfort but also confirmed the rationale of the Feng-Shui concept for building design.

2. Methods

2.1. CFD MODEL

The simulation employed three different scales of the geometrical models to analyse. These are the ‘community’, ‘block’, and ‘single courtyard’ (Fig. 1). They are generated in Sketchup software according to the real physical space in Jiangmen city (Fig. 2). Subsequently, three different Sketchup files were imported to the Phoenix software for analysing.

Figure 1. Three different scales of the geometrical models.

2.2. BOUNDARY CONDITIONS

The mean velocity profile for the inflow boundary was modelled as a power law, and the power-law exponent α was determined by the object terrain category (Liu et al., 2017). Because of the object located in the suburb of Jiangmen city, the α is 0.16. The average wind velocity is 2.3m/s in summer and 2.7m/s in winter. The wind direction is south southeast (SSE) in summer and north northeast (NNE) in winter, according to the Standard for Green Performance Calculation of Civil

Buildings (MOHURD, 2018).

Figure 2. Basic model.

2.3. COMPUTATIONAL DOMAIN SIZE AND MESH GENERATION

The computational domain for models considered the site and surroundings. For the height of the computational domain, the blockage ratio should be below 3% (Jorg & Alexander, 2007; Tominaga et al., 2008). The boundary in the four horizontal directions should be a distance of at least $5H_{max}$ (Jorg & Alexander, 2007; Scaperdas & Gilham, 2004). According to the Standard for Green Performance Calculation of Civil Buildings, the height to boundary above the object should be larger than $5H_{max}$, and the distance between object and wake region should be larger than $10H_{max}$ for a realistic flow (MOHURD, 2018; Bartzis & Vlachogiannis & Sfetsos, 2004). The distance of $5H_{max}$ for inflow, $10H_{max}$ for outflow, and the height of $5H_{max}$ beyond three objects were used. The model of summer simulation is shown in Figure 3. Moreover, the mesh generation was used object affects the grid and optimised by a hybrid grid scheme, which can adapt to the geometric structures very well.

Figure 3. The model of summer simulation.

3. Results

3.1. INITIAL RESULTS

The research explored conditions during summer and winter. Jiangmen city is in the Chinese ‘hot summer and warm winter’ climate zone. In summer, it is hot, and in winter, the building does not need heating (MOHURD, 2016). Therefore, natural ventilation is an essential measure for human comfort concerning indoor air quality and thermal comfort (Wang & Malkawi, 2019). In summer, strong natural ventilation will exhaust the excessive heat. In winter, reduced natural ventilation will provide a more comfortable living environment (He & Schnabel, 2016). According to the Assessment Standard for Green Building, the outdoor natural wind speed above 1.5m from the ground should be less than 5m/s in winter, and there should not exist calm wind zones in the main activity area in summer (MOHURD, 2019). The Standard of the Measurement and Evaluation for Efficiency of Building Ventilation shows indoor ventilation should flow from main rooms such as the living room and bedroom to functional rooms such as the bathroom (MOHURD, 2013).

The community simulation result showed the outdoor wind speed as being between 0.44m/s and 3.5m/s in winter. However, there are calm wind zones in summer, as highlighted in Figure 4. It is a problem since it is primarily caused due to the orientation of the community, which could be improved.

Figure 4. Outdoor wind simulation of community.

The block simulation result showed the wind speed as less than 5m/s in winter. Nevertheless, there are calm wind zones in the main rooms in summer, especially in the west of the block (Fig. 5 b). This problem is different from that in the community, which should focus on improving the layout of the block. As the other highlighted area shown in Figure 5 (a & d), there is also air pollution because of the bathroom in the upwind, which could be solved via a single courtyard layout.

The single courtyard simulation result showed that the indoor wind flows from bathroom to bedroom on the first floor, and the maximum wind speed in winter is 3.95m/s (Fig. 6). The winter wind speed meets the standard requirements. However, the wind flowing from bathroom to bedroom will cause air pollution. That is a problem with the design of a single courtyard layout.

Figure 5. Wind simulation of block.

3.2. OPTIMIZED RESULTS

The challenges, as mentioned above, are the calm wind zones in the community during summer. The Feng-Shui principles for the community orientation prescribed that it should 'Face South, with the Back to the North'. The building layout should be distributed. The building location should gradually raise with the site from south to north (Wang, 1998); because China is located in the northern hemisphere of the earth and eastern Eurasia. Most of the regions are affected by the southeast monsoon in summer and Siberian cold in winter. The community should face south with the back to the north orientation. Its location should also gradually raise with the site from south to north, which will achieve not only comfortable natural ventilation but also get better sunshine from the south. According to the

Feng-Shui philosophy regarding ‘community’, the optimised model of courtyards in this site is distributed. At the same time, the location of each building gradually rises from south to north. Then the optimised results showed that the outdoor wind speed is between 0.39m/s and 5.08m/s in summer, and between 0.36m/s and 3.28m/s in winter. The outdoor wind speed in summer is higher and in winter is lower than the initial results. The calm wind zones almost disappeared in summer, and the overall natural ventilation improved significantly (Fig. 7). The optimised community layout offers an improved comfortable wind environment.

Figure 6. Wind simulation of single courtyard.

Figure 7. Optimized outdoor wind simulation of community.

In terms of block simulation, every single courtyard is attached back to back,

which causes a rise in indoor calm wind zones, especially in the west of the block. The local block construction is according to Feng-Shui concept, which requires the typical layout style for blocks to be detached from each other, whether for traditional or modern block layout. This kind of block layout can form ventilation alleys between blocks. It not only optimises natural ventilation but also improves the thermal pressure ventilation because the ventilation alleys are affected by block shadows (Guo & Liu & Yuan, 2015 (b)). The optimised result of natural ventilation in summer is between 0m/s and 2.48m/s. It is higher than the initial result of between 0m/s and 2.22m/s. The overall natural ventilation has been optimised even though calm wind zones still exist in the main rooms. The result in winter also optimized as 0m/s and 2.87m/s was reduced to 0m/s and 2.57m/s. The overall wind speed was lower than 5m/s (Fig. 8). This natural ventilation will give people a more comfortable environment.

Figure 8. Optimized wind simulation of block.

The initial result of the single courtyard showed that the bathroom would pollute the air quality of the other rooms because the wind is blowing from the east, whether in summer or winter. According to Feng-Shui, the design of a house

should put the bathroom to the corner and in the downwind position (Yan, 2016). Therefore the design of the single courtyard should be optimised. The indoor wind should flow from main rooms to functional rooms, as shown in Figure 9.

Figure 9. Single courtyard design diagram.

4. Discussion

The three challenges to natural ventilation were described and analysed. These were 'community', 'block', and 'single courtyard'. The results showed that natural ventilation could be optimised according to Feng-Shui. In the community, the lighting surface orientation of facing south, and the foundation gradually raising with the site from south to the north offered higher wind speed in summer and lower wind speed in winter - resulting in improved human comfort. In the block, the layout of blocks is detached from each other. This way, more ventilation alleys are formed. Furthermore, the overall natural ventilation is optimised, whether in summer or winter. In the single courtyard, functional rooms such as bathrooms were designed to be put downwind of the building, subsequently solving the air pollution problem. All of our certified Feng-Shui principles have an architectural and building science value that can be applied in future architecture design. They also offer advantages for human comfort and provides support for other scholars' research (So & L, 2001; Jeffreys, 2000).

The research of CFD analysis only proved the value of natural ventilation based on Feng-Shui, which is only one part of the overall Feng-Shui philosophy relating to architecture design. The optimised community layout by raising the foundation with the site has only be simulated virtually, while the optimised result of block indoor natural ventilation in summer results in calm wind zones even though it is better than before. The computational simulation analysis for the optimised single courtyard was not designed to be a specific design. These issues need to be explored in future research.

5. Conclusions

In this paper, the results of the 'community', 'block', and 'single courtyard' in Jiangmen city were simulated by the CFD method. The community's outdoor wind speed between 0.44m/s and 3.5m/s in winter, and there are calm wind zones in summer. The block simulation showed wind speed less than 5m/s in winter. There are calm wind zones in the main rooms in summer, especially in the west of the block. The indoor wind flowed from the bathroom to the other main rooms. The single courtyard simulation result showed that the indoor wind flows from bathroom to bedroom on the first floor, and the maximum wind speed in winter is

3.95m/s.

The 'community', 'block', and 'single courtyard' have been optimised according to the Feng-Shui concept. Community optimised result showed the outdoor wind speed between 0.39m/s and 5.08m/s in summer, and between 0.36m/s and 3.28m/s in winter. The wind speed in summer is higher and in winter is lower than the initial results. The calm wind zones almost disappeared in summer. Overall natural ventilation improved significantly. Block optimised result of natural ventilation in summer between 0m/s and 2.48m/s, and it is higher than the initial result between 0m/s and 2.22m/s. The overall natural ventilation has been optimised even though there are still exist calm wind zones in the main rooms. The result in winter also optimized from 0m/s and 2.87m/s reduced to 0m/s and 2.57m/s. The overall wind speed lower than 5m/s. The single courtyard optimised result showed that the bathroom layout in the house to the downwind position could solve air pollution according to Feng-Shui philosophy.

This research used CFD computational simulation method to analyse the natural ventilation of 'community', 'block', and 'single courtyard' in Jiangmen city, according to the human comfort required by relevant standards. The problems of initial results were found out. According to Feng-Shui philosophy, the optimised plans were built. Then the optimised results were analysed to show that the Feng-Shui wisdom has value for the fields of architecture and building science. We conclude that in the context of natural ventilation, CFD confirms that principles of Feng-Shui and its philosophy can contribute to natural ventilation and human comfort, ultimately improving architectural design and livability.

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