The Ventilation Improvement Assessment of Sky Gardens- A Case Study of Hysan Place

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Abstract. With the modernization and urbanization in recent decades, a mounting number of buildings has been built. Due to the limited land, these buildings were built higher and higher and side by side which created ‘Wall Effect’ blocking the wind and reducing air ventilation. It eventually led to bad thermal comfort of people. Therefore, sky gardens are increasingly important today, as they can significantly contribute to improving air ventilation by reducing ‘Wall Effect’. In order to know better about the influence generated by sky gardens to natural ventilation improvement, I selected the Hysan Place as a case study based on CFD simulation. I built two models --- the original model and the model without sky gardens for the simulation in different height. By comparison of different models, I found that the sky gardens of Hysan Place did slightly improve air ventilation of surrounding areas. Sky garden is an effective method to alleviate urban heat island effect, which is important to improve urban living quality, especially extreme high construction density.

1. Introduction

With the modernization and urbanization in recent decades, more and more people flooded into the cities leading to the dramatic increase of the population. And for the sake of meeting the demand of economic development of cities, mounting number of housing buildings, office buildings, commercial buildings were built. Due to the limited land, many buildings were built higher and higher. These concentrated high-rise buildings stand side by side, and created a ‘wall’ which can block the wind to go through, and this situation can be described as ‘Wall Effect’ in terms of architecture. Thus, the poor air ventilation caused by ‘Wall Effect’ aggravated the ‘Urban Heat Island Effect’ and eventually resulted in uncomfortable thermal comfort of people.

This kind of issue had already occurred in many high-developing cities in China. And the situation is much worse in Hong Kong. Hong Kong was located on the southern coast of China at the Pearl River
Estuary. This city is well known for its high density buildings landscape and population. Of course, Hong Kong’s Urban Heat Island Effect is very serious because of its large number of high-rise buildings, high proportion of imperious land in urban area and the massive amount of fossil fuels burning generated by vehicles.

Hong Kong is a city with humid subtropical climate. From the climate data below, we can see that the summer of Hong Kong is moist and hot, and for the winter, the weather is dry and cool. The average temperature of Hong Kong for a year is about 23.2°C. In general, the weather of Hong Kong is relatively humid and hot, especially in summer with the average temperature of 28.2°C. So during that time, the usage amount of air conditioners will reach the peak to make people more comfortable.

Table 1. Climate data of Hong Kong
Source: Hong Kong Observatory

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| **Record high °C (°F)** | 36.9 | 38.0 | 37.8 | 33.3 | 31.8 | 29.9 | 31.6 | 33.6 | 32.7 | 31.6 | 29.9 | 28.7 | 2017 |
| **Average high °C (°F)** | 26.9 | 28.1 | 23.6 | 23.3 | 23.0 | 21.7 | 21.3 | 20.1 | 20.0 | 20.4 | 21.0 | 21.2 | 2017 |
| **Daily mean °C (°F)** | 23.0 | 22.1 | 22.6 | 22.9 | 22.8 | 22.5 | 22.3 | 22.1 | 22.0 | 21.9 | 21.7 | 21.5 | 2017 |
| **Average low °C (°F)** | 14.3 | 15.0 | 15.2 | 15.2 | 15.3 | 15.5 | 15.6 | 15.7 | 15.6 | 15.5 | 15.3 | 15.0 | 2017 |
| **Wind speed range** | 0.0 - 2.5 | 2.6 - 4.0 | 4.1 - 6.0 | 6.1 - 8.0 | 8.1 - 10.0 | 10.1 - 12.0 | 12.1 - 14.0 | 14.1 - 16.0 | 16.1 - 18.0 | 18.1 - 20.0 | 20.1 - 22.0 | 22.1 - 24.0 | 24.1 - 26.0 | 2017 |

For the wind condition, we can use Climate Consultant to look at the figure of wind wheel and wind velocity range below. As a coastal city, Hong Kong has an average wind speed of approximate 3-3.2 m/s, this velocity is not low at all. It also shows that in the average level of a year, most winds are from east and northeast, while southwest and south winds just take up a little proportion of all wind direction frequency.

Although the wind is quite high, many citizens living in the urban area feel hot and use air conditioners instead of natural ventilation. Because in summer, the majority of the winds come from northeast and south, the temperature of these winds are 27 to 28°C. It is definitely too hot for the citizens. In addition, Hong Kong has very high density and high-rise buildings in its down town areas. These kinds of buildings create Wall Effect which leads to poor natural ventilation condition in the ground level.

The poor air ventilation condition of the streets near the buildings had aroused the notice of Hong Kong Government long time ago. In order to enhance the wind and ventilation condition, the Planning Department of Hong Kong adopted the regulation of air ventilation assessment as one of the considerations for future urban development planning in August 2003. And then in 2005, the Feasibility Study for Establishment of Air Ventilation Assessment System (the AVA Study) was conducted and finished. Basing on the AVA study, some qualitative guidelines and a framework had worked out for implementing the air ventilation assessment. In the guidelines, there are many strategies and recommendations for air ventilation improvement in urban design. (Planning Department, 2005) But it has no relative design guidelines for the sky gardens, despite of its air ventilation improvement function. This fact shows that the design and function of sky gardens had not been regarded as high importance since that time. In the building permeability section, it mentioned creating gaps between building blocks and podium to enhance air permeability. This principle is similar to the function of sky garden. The definition of sky gardens differ from different scholars. A most adapted definition was raised by Osmundson - any planted open spaces that may be below or above the ground level, intended to provide human enjoyment or environmental enhancement that is separated from the earth by a building or other structure [1]. It can be sorted as two types of sky gardens --- podium gardens and roof gardens by the
position in the high-rise buildings of the sky gardens. The podium gardens are in the intermediate floors while the roof gardens in the rooftop [2].

Sky gardens was first introduced into Hong Kong in 1970s which was built in the Mei Fo Sin Chuen. Then in 2000, some departments of Hong Kong Government issued some guidelines and recommendations for ‘green and innovative buildings’. The communal sky gardens and communal podium gardens were included in the green feature lists (Building Department Report, 2000).

In this paper, my research objective is the podium type gardens which is in the intermediate level of a buildings. This type of sky gardens are likely to improve the natural ventilation by reducing the Wall Effect.

2. Study Area
Hysan Place is a large and modern shopping mall and office building locating at Causeway Bay, Hong Kong. It is the only significant new mixed-use commercial building that can provide AAA grade office space and a brand new shopping mall to open on Hong Kong Island this year.

Hysan Place covers a total gross floor area of about 66,000 square meters consisting of 15 levels of office space and 17 floors of retail shops. Hysan Place is regarded as the milestone of green buildings in Hong Kong. It is also the first Hong Kong building that has achieved pre-certification of the highest Platinum level under Leadership in Energy and Environmental Design (LEED) of the U.S. Green Building Council (USGBC).

![Figure 1. Location of Hysan Place](source)

It is said that Hysan Place has performed very well in ventilation and cooling aspect. Hysan Place features its numerous and large opening spaces, such as sky gardens and urban windows. This opening features help to reduce the ‘Wall Effect’ by enhancing natural ventilation circulation. They can also further improve the micro-climate in the neighborhood area in Causeway Bay, especially in Hennessy Road which ‘Canyon effect’ is serious and the pollutants can’t be removed, and, eventually mitigate the ‘Urban Heat Island Effect’.

According to the research theories and technical guideline from Ng, three different scales of areas should be defined; the project area, the assessment area and the surrounding area. The radius of assessment area should be as long as the height of tallest building on the study site, and the radius of surrounding areas should be double of its height [3-4].

But after on-site survey, I finally set up the boundary of study area based on the real situation instead of the research theories. These real situation included the arrangement pattern and height of buildings in surrounding area. The boundary of my study area is displayed below (red lines) in Figure 2.
3. Materials and Methods

3.1. On-site survey

With the purpose of recording the actual wind speed of the study area, I firstly set 10 test points which are in 2m height level in my study area. These test points are located at Hennessy Road, Kai Chiu Road, Russell Road, Lee Garden Road, Yun Ping Road and Jardine’s Crescent respectively. More details of test points are showed in the Figure 3 below.

I collected the wind data at noon of 15, June, 2015 from 10am to 1pm. The weather of that day was very sunny and hot. This kind of weather is typical in Hong Kong’s summer. So the measurement results are also representative for wind tendency in Causeway Bay in some extent. Table 2 shows the specific measurement results of test points.

| Test Points Number | 1    | 2    | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   |
|--------------------|------|------|------|------|------|------|------|------|------|------|
| Site               | Hennessy Rd | Hennessy Rd | Kai Chiu Rd | Kai Chiu Rd | Russell Rd | Lee Garden Rd | Yun Ping Rd | Jardine Rd | Yun Ping Rd | Lee Garden Rd |
| Wind Speed (m/s)   | 2.8  | 2.4  | 1.8  | 1.3  | 1.8  | 0.9  | 1.2  | 2.5  | 2.1  | 1.4  |
According to the results, the average wind speeds in Lee Garden Road, north part of Yun Ping Road and middle part of Kai Chiu Road are relatively low (0.9m/s, 1.4m/s, 1.2m/s and 1.3m/s respectively). It indicates the air ventilation condition in these areas are poor.

In addition, I had also measured the wind data in the sky garden of Hysan Place. The average wind speed is quite high with 3.3m/s. I really could feel strong wind passing through the sky garden when standing in there.

3.2. Models Building

This model of Hysan Place done by Gary was downloaded from 3D Warehouse in the internet. We can see that this model was built quite well as it contain some details, especially the sky gardens and urban windows of Hysan Place. Then I adjust the coordinate and the direction of the model.

![Figure 4. The Sketchup model of study area (refined from Sketch 3D Warehouse)](image)

If I want to observe the influence of the sky garden, a single original model is not enough. So I made another model which with the assumption that Hysan Place had no sky garden. As the Figure 5 displays below, I just filled in the sky gardens and urban windows (areas inside red circles) of the Hysan Place in the original model. This new model is called the model with no sky gardens, which can be used for comparison.

![Figure 5. The Sketchup model without sky garden](image)

3.3. CFD Simulation

Before putting the sketchup models into CFD calculation, their format must be transferred at first. The meshes were created based on the sketchup models by using software Harpoon. After the transformation, each model consists of about 2.3 million cubes. After the models were imported to ANSYS Fluent 14.0,
some parameters must be set before calculation. And each model was simulated under the wind direction profile - 67.5° (ENE).

4. Results
The ventilation environment in 2m height can represent the pedestrian level which affects passengers most. In general, the ventilation conditions of the streets which are on the south side of Hysan Place, are relatively bad, which corresponds with the real measurement results mentioned before. And it seems have no obvious difference between the Model (a) and Model (b) in air ventilation performance. Only in some areas which are in very poor ventilation conditions, the Model (a) has done a little better.
From the comparison chart, we can find that in most test points (point 2, 3, 5, 7, 8, 9, 10), the wind speed in Model (a) is slightly higher than Model (b). It proved that when under annual prevailing wind (ENE), the sky garden can improve the natural ventilation of the street on its south side in pedestrian level (2m). But this improvement effect is not obvious.

The ventilation environment in 25m height can represent the low-high level which affects the residents who live in this height on surrounding buildings. And 25m also is the height from ground of the sky garden in Hysan Place. From the contours figures, the most distinct difference is that, there are wind passing through the sky garden in Model (a). And the air ventilation condition of Model (a) is much better than Model (b) in the near back side of Hysan Place.

![Figure 9. The Velocity Contours of (a) (b) (ENE, 25m)](image)

![Figure 10. The Comparison of Test Points Results (ENE, 25m)](image)

From the comparison, the result of Point 4 is noticeable. The wind speed of Point 4 in Model A is much better than Model B because that place is the wind outlet of sky garden in Hysan Place. But other test points seem have no significant differences except Point 9.

5. Conclusion
Hong Kong, which is a typical case for high compact city, will surely has fewer lands and denser buildings in the future. So it is significant to utilize the land source efficiently. Sky garden is an excellent design for solving this problem. Also, many intensive high-rise buildings lead to bad air ventilation condition of whole district. Sky garden can be a good idea for high-rise buildings to improve ventilation by reducing the Wall Effect. Thus, the optimal design of sky garden should be considered more and more in coming future.
Actually, according to other scholars’ research, there are various causes accounting for improvement ability of sky garden. Such as the orientation, size, height and shape of the sky garden. In addition, the width of the surrounding streets and the density of buildings also can be the impact factors.

For the study area in Causeway Bay, the buildings behind Hysan Place are too dense. In addition, there are many tall buildings in front of the Hysan Place which block the wind. These factors can potentially have the influence toward the wind environment.

In this study, I made comparison analysis of simulation results between Model (a) (original) and Model (b) (without sky gardens) under 2 condition: ENE wind in 2m height and in 25m. And the conclusions can be drew below:

1) The sky garden did have the improvement function for air ventilation, and the nearer, the influence is stronger.
2) The improvement function is more powerful in 25m height level than in 2m. Because the height of the sky garden is quite high with an altitude of 24.6m.
3) In general, the improvement function of existing sky garden is not quite distinct.

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