CIBSE Hong Kong Branch Research Project Report

Estimating city ventilation rates in Hong Kong

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Building services engineers use the concept of ventilation rate in a building or a room. To achieve an acceptable indoor air quality environment, a minimum ventilation rate often needs to be provided in a building. Currently, depending on the standard or regulation used, we provide outdoor air into a building at about 10 L/s per person. Ventilation rates in a building may also be measured, e.g. using a tracer gas decay method or direct measurement in the ventilation duct or at ventilation supply.

Similar to a building, we also need to maintain a reasonable thermal and air environment in our city, though a greater variation of the urban climate is allowed. The rising trend of urban heat island and urban air pollution in cities like Hong Kong calls for better understanding of our urban environment.

What happens if we treat a high-rise compact city such as Hong Kong as a building? What new understanding can we gain by treating a city like a building? An example is the city ventilation rate. It is easy to understand that a large ventilation rate in a city will enhance the removal of airborne pollutants and heat by wind flows. The question is how can we measure or estimate the ventilation rate in such a large space? For example, if we have a good knowledge of ventilation rates in different cities in the world, we may be able to identify the best urban planning strategy for the maximum removal abilities of airborne pollutant and heat in a building.

Obviously, we may first try to understand the driving forces of city ventilation. It is known that natural ventilation of buildings can be driven by winds and/or buoyancy forces. The same can also be shown to be true for natural ventilation of cities; see Figure 1.

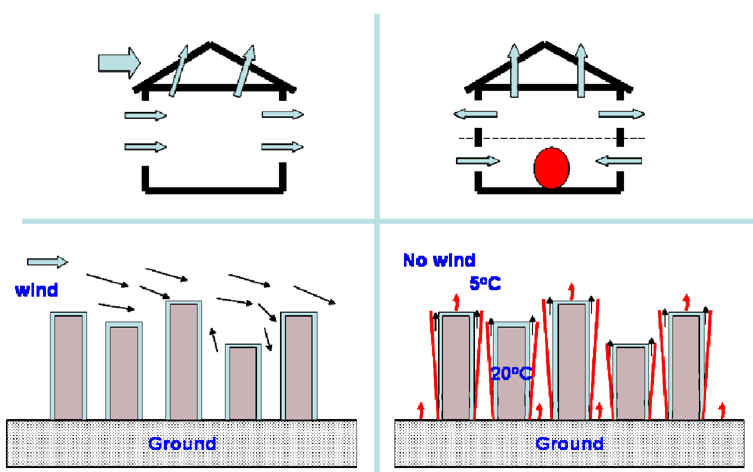

Figure 1. The analogy of natural ventilation of buildings (above) and a city (below).

In a large city, we often do not have the luxury of cross ventilation, but rely on turbulence exchange across the urban canopy (roughly at the building roof level). One interesting question is what happens to city ventilation when there is no wind. Our hypothesis is that the natural convection flows at building wall surfaces and mountain slopes help to provide the so-called buoyancy driven city ventilation, analog to the stack ventilation in buildings.

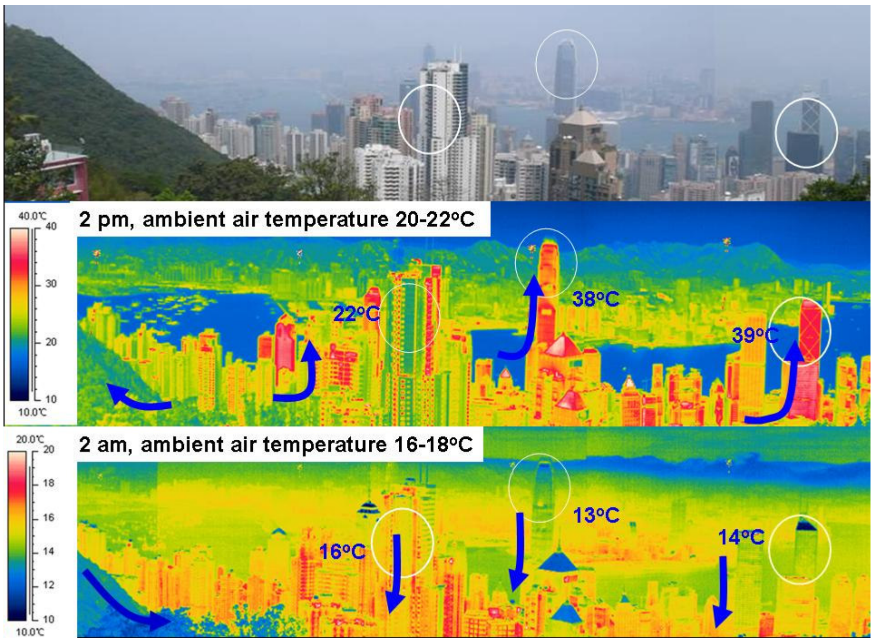

Figure 2. Two infrared photos of the surface temperature profiles of Hong Kong on 15 March 2008 at 2 PM (middle) and 2AM (bottom) respectively. The warmer building and mountain surfaces create upward buoyancy flows to drive the natural ventilation of the city in the daytime, and the downward slope flows and wall flows for city ventilation during the nighttime, as illustrated.

The latter hypothesis encourages us to carry out a field study of urban surface temperatures using an infrared camera. Sample infrared photos of surface temperature profiles of Hong Kong are shown in Figure 2 on 15 March 2008. The data allows us to estimate the city ventilation rate of Hong Kong at no wind conditions. The city ventilation rate due to building wall flows is estimated to be around 2-4 ACH, while that due to slope flows around 1 ACH, see Yang and Li (2009). We also estimated the city ventilation rate in Hong Kong using the airborne pollutant CO as a tracer gas. The annual average ventilation rate is estimated to be 2 ACH, or 1200 L/s per person in Hong Kong (Luo et al., not published). As a comparison, the city ventilation rate in Helsinki is estimated to be 7700 L/s per person.

Further work is being carried out to study the urban thermal environment using 2IFC as a temperature indicator. The results will be reported in a future article at this website.

It may be interesting to discuss the relevance of this project to the building services engineers. Climate change and the urban heat island phenomenon also present significant challenges to the building design and urban planning in future. Once these buildings including their building services facilities are built, they will be very difficult and costly, if not impossible, to be adjusted for the expected future climate change. For example, the loading for building ventilation and air conditioning systems depends on the ambient air temperature. It is an issue for both energy efficiency, and possible system failures in the extreme climate.

The CIBSE sponsored project helped us to provide essential additional measurement on urban surface temperature profile, as well as providing basic understanding of the driving forces for city ventilation in Hong Kong.

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References

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