# Ventilation Investigations in a densely built up Area of Hong Kong to describe Thermal Comfort

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ABSTRACT: For the tropical climate of Hong Kong better ventilation is needed urgently for the improvement of thermal comfort conditions. The investigation shows the influence of building structures, orientation of streets and the local sea breeze effect on the ventilation conditions inside the Urban Canopy Layer.

The government of Hong Kong has recently published an Air Ventilation Assessment System (AVAS) for guiding development and planning. Developments of a certain characteristics are required to undertake the assessment in order to ensure that they do not obstruct too much of the wind/air movement at ground level for pedestrian comfort. This is the first governmental legal system in the world dealing with weak wind conditions, design and planning. In this framework wind measurements were carried out. The case study side was within a densely built up area under reconstruction on Hong Kong Island. Topics were influence of sea breeze inside the urban fabric, thermal induced circulation systems and air temperature. On that base thermal comfort was calculated. Results were taken to study the conditions within the UCL in 2 m height.

The case study results were evaluated and to combined with an existing CFD calculation. As result a ventilation pattern is drawn and the effect on thermal comfort is discussed. Ventilation pattern shows clearly the different effects of sea breeze penetrating the city depending on the main wind speed and wind direction but also on the daily variation. Barrier effects of some buildings were studied in a scale of 1:2.000. In some parts wind direction was influenced and channelled by the buildings in a total opposite direction from sea breeze. Barrier effect of buildings could be mapped.

The wind and temperature analysis of this local circulation of Hong Kong Island was than used for a thermal comfort discussion for the conditions near the ground.

Keywords: thermal comfort, ventilation

## 1 INTRODUCTION

For Hong Kong ventilation is an important factor for any comfort discussions. The government of Hong Kong has recently published an Air Ventilation Assessment System (AVAS) for guiding development and planning. In the development of an older part of Hong Kong, on Hong Kong Island, the discussion was how dense and at what height future developments can go without destroying the thermal comfort completely.
The recent unfortunate events of Severe Acute Respiratory Syndrome (SARS) has brought the Government of Hong Kong Special Administration Region (HKSAR), Team Clean, and the inhabitants of Hong Kong to the realization that a quality built environment is the aim of Hong Kong to become a “world class city that we can proudly call home”. Gradation of development height profile, provision of breezeways, layout planning and disposition of building blocks to allow more open space, greater building setbacks to facilitate air movement, reduction of development intensity, increased open space provisions especially in older districts, and more greenery are all coined as measures to improve our built environment.

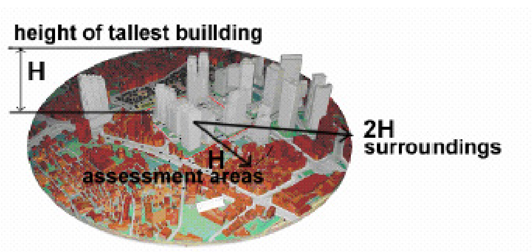


**Figure 1:** Existing investigation site

The Team Clean report also highlighted the need to establish methods for air ventilation to guide future planning actions [1].
With this case study one can show an approach how to promote a better layout of building blocks in the city, within one case study the ventilations was examining This study concentrates on seeing if it is

indeed possible, or feasible, based on current knowledge, such as the already existing investigations, and state of the art scientific know how, technology and facilities, for the Planning Department to establish an Air Ventilation Assessment System (AVAS) or Guidelines for better city design.

**Figure 2:** Typical skyline for blocking land sea breeze at Hong Kong Island

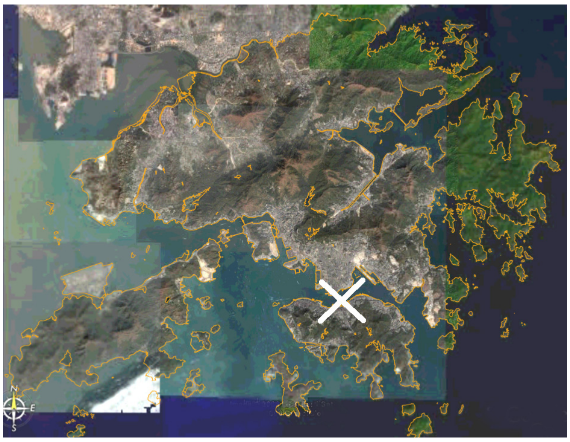

**Figure 3:** Land use and topographical situation of Hong Kong, red circle is investigation site from google earth [3]

From figure 3 one can see the shortage of land for buildings and the complicated topographical situation of Hong Kong, which makes it important to improve the ventilation in the densely built up areas.

## 2 OUTDOOR THERMAL COMFORT IN HONG KONG

Outdoor thermal comfort could be achieved when the following factors are balanced: air temperature, wind speed, humidity, activity, clothing and solar radiation. For designers, it is possible to design our outdoor environment to maximize wind speed and minimize solar radiation to achieve comfort in the hot tropical summer months of Hong Kong. Typically, the desirable environment over the pedestrian is a balance between air temperature, solar radiation and wind speed. A higher wind speed might be needed if a pedestrian is only partly shaded, likewise, a lower wind speed might be desired if the air temperature is lower. Based on recent researches, refer to the figure below, when a pedestrian is under shade, a steady mean wind at pedestrian level of around 1.5 m/s will be beneficial for providing thermal relief and a comfortable outdoor urban environment in summer in Hong Kong. Factoring in the macro wind availability of Hong Kong, it might be quoted statistically that a good probability of achieving this 1.5 m/s mean wind speed (over 50% of the time) is desirable.

Referring to Hong Kong's general macro wind availability data (from Hong Kong Observatory), in order to capture this "mean 1.5 m/s wind over 50% of the time", it is desirable to have a city morphology that is optimized, and as much as possible, designed to capture the incoming macro wind availability. Properly laid out urban patterns and street widths, careful disposition of building bulks and heights, open spaces and their configurations, breezeways and air paths, and so on are all important design parameters.

Achieving a conducive outdoor thermal environment for Hong Kong is an important planning consideration. A well designed urban wind environment will also benefit the individual buildings and their probability of achieving indoor comfort, as well as contributing to other benefits, like the dispersion of anthropogenic wastes.

## 3 MESOSCALE CONDITIONS

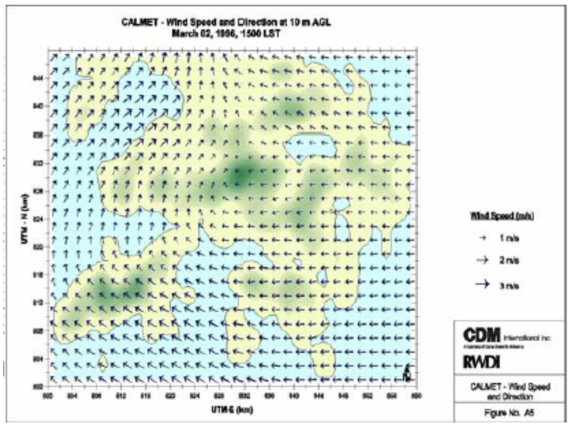


**Figure 4:** Results from a MM5 calculation Hong Kong [1]

Beside the reduction of wind speed also the wind directions are important for thermal comfort. Taking the results from figure 4, which demonstrated the wind situation during easterly wind flow, there are considerable deviations according to topography. As MM5 does not take land use into account at some parts a wind flow from sea to land is observed. In the case study at the investigation site described below this easterly wind flow occurs during the measurements as seen from figure 4. But in these mesoscale considerations the land sea breeze effects at the islands can not be seen. The same occurs with thermal conditions during July in figure 5. High PET values are within the city fabric but also with plain areas of high radiation income in the outer territories. Values more than 36 °C can be considered as heat stress. In the following chapter therefore the calculated mesoscale conditions were taken as frame for the microclimatic investigations.

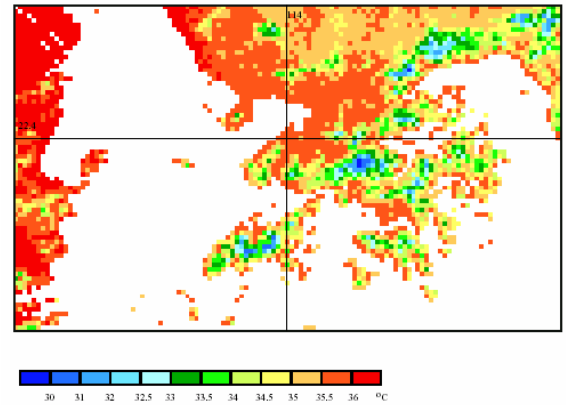


**Figure 5:** Thermal conditions (PET) in Hong Kong in July

## 4 CASE STUDY

The investigation site was located at Hong Kong Island see figure 6. The aim was to find the ventilation pattern during the normal easterly wind situation. Therefore mobile measurements were carried out. At all points the daily course was measured of wind direction and wind speed as well as the air temperatures. The distribution of measurement points follows from near harbour to the financial sites to a very densely built up area with narrow roads.

Field measurement were carried out on 26.11.2005 from 2pm to 4pm in Hong Kong Island to understand the urban climate of certain areas that would be influenced by urban planning or design so that we could establish or suggest appropriate and practical planning guidelines to improve our urban climate and to prevent worsening thermal comfort and air pollution. It is known that urban features such as urban textures, street pattern and orientation have implication on urban heat island effect. In Hong Kong, tall concrete residential buildings with sharp edges and low aspect ratio could trap both short and long wave radiation. This trapped radiation could contribute to UHI, which eventually could lead to air pollution [2].
The criteria of finding measuring spots is that the difference between structure of the city (e.g. near the sea, open space, wide street, narrow streets, slope situations and street direction) along a profile from sea to the site. Totally, six location were selected Instruments (Testo 400) was used to measure parameters that include wind speed, air temperature and relative humidity while wind direction was observed.

We select 6 points within the red circle of figure 6 with the following characteristics and city structures: point 1 near the sea, relatively open, low rise buildings nearby, point 2 wide street, major thoroughfare, surrounded by tall buildings, road runs east / west direction, point 3 Street with tram, bus lane and car lane, comparatively narrower than point 2, surrounded by buildings, street runs east / west and is bending at far ends, point 4 Narrow street, one way traffic, sloping and surrounded by buildings of varying and surrounded by buildings of varying height, at the function of cross road, point 5 & point 6 narrow lane, sloping downhill 4 and 5 storey buildings on both sides old neighbourhood, No vehicular traffic.

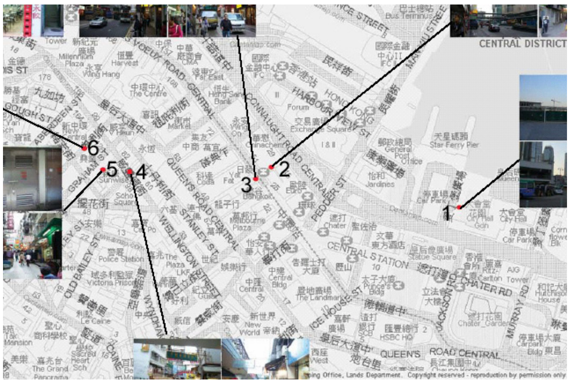


**Figure 6:** Case study site on Hong Kong Island, with measure points

Within each measure point again three different spots were chosen to get the average characteristic of the place. Morning and afternoon measurement was taken at 26th November 2005.

## 5 RESULTS

In respect to thermal comfort one has to judge air temperature for the radiation processes, humidity and wind speed. The humidity as well as the air temperatures differences were very small in space and time resolution. So the main important factor for thermal comfort is wind and sun/shadow situation. But even within the shadow parts air temperature does not decrease considerable so that main wind is dominant for thermal comfort. Results are shown in table 1.

Observations:
1. Easterly regional wind support the SE to NW orientated wider roads, but it does not serve the Des Voeux Road because it was inner, narrower road and bending.
2. At the water front or near the sea, the easterly winds are directed towards the city from North to South but it circles around the single tall buildings.
3. When the wind hit the high rise slab block buildings, it was blocked and started to reverse its flow.
4. At the site all streets are equally important to air movement. Small narrow sloping streets create downhill wind while the SE, NW orientated winds are effected by easterly regional winds. The 4 to 5 storey

buildings in this old neighbourhood provide good shading and thermal comfort zone.

The conclusions are that see a wind breeze penetrate into the site only in the office houses in a plain shore situation. This circulation system is stopped at the denser built up areas. Sometimes a counter wind flow was observed, which lead at the wider street to opposite wind directions and to high turbulences around the corner. The second important observation was a downhill wind flow, which is a thermal induced circulation coming from cool vegetation type slopes. This again is stopped by the opposite sea breeze. This situation is shown in figure 7.

**Table 1:** Results from the one day experiment with windspeed and direction, air temperatures and himudity measurements at 6 spots (figure 7) in moring and afternoon

| Location | | Group 1 Direction, Velocity ($ms^{-1}$) | Group 2 Direction, Velocity ($ms^{-1}$) | Group 3 Direction, Velocity ($ms^{-1}$) | Mean air temperature (°C) | Relative humidity (%) |
|---|---|---|---|---|---|---|
| 1 | 1st data | NE, 0.98 | N, 1.14 | E, 1.1 | 28 | 45 |
| | 2nd data | NE, 1.48 | N, 0.93 | N, 2.0 | 25.3 | 62 |
| | average | NE, 1.25 | N, 1.04 | NE, 1.55 | 26.7 | 54 |
| 2 | 1st data | E, 2.0 | N, 1.15 | SE, 1.8 | 26.6 | 49 |
| | 2nd data | E, 1.41 | N, 1.27 | SE, 1.1 | 26 | 55 |
| | average | E, 1.7 | N, 1.21 | SE, 1.45 | 26.3 | 52 |
| 3 | 1st data | NW 1.2 | NE, 0.95 | NW, 0.8 | 26.6 | 50 |
| | 2nd data | NW 0.94 | NW, 0.80 | NW, 0.8 | 26.2 | 55 |
| | average | NW 1.07 | N/A, 0.88 | NW, 0.8 | 26.4 | 53 |
| 4 | 1st data | SW, 1.29 | SW, 0.61 | SE, 0.9 | 25.5 | 54 |
| | 2nd data | SW, 1.11 | SW, 0.87 | SE, 1.3 | 25.7 | 54 |
| | average | SW, 1.2 | SW, 0.74 | SE, 1.1 | 25.6 | 54 |
| 5 | 1st data | SW, 0.49 | SE, 0.45 | SE, 0.5 | 26.2 | 52 |
| | 2nd data | SW, 0.74 | SE, 0.52 | SE, 0.6 | 25.9 | 55 |
| | average | SW, 0.62 | SE, 0.49 | SE, 0.55 | 26.1 | 54 |
| 6 | 1st data | SW, 0.59 | N/A, 0.44 | SE, 0.4 | 26.4 | 53 |
| | 2nd data | SW, 0.79 | N/A, 0.41 | SE, 0.6 | 26.1 | 53 |
| | average | SW,0.69 | SW, 0.43 | SE, 0.5 | 26.3 | 53 |

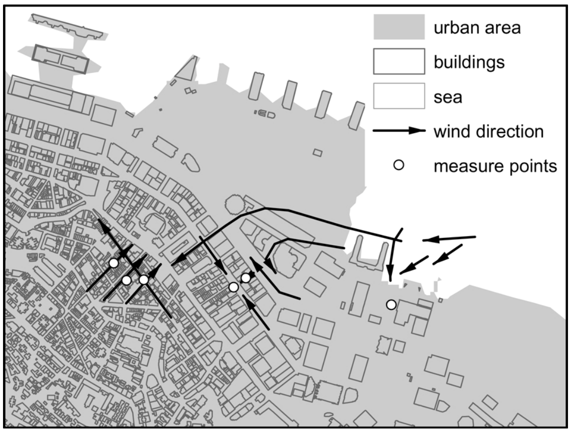


**Figure 7:** Wind distribution near the ground from a one day experiment with easterly wind flow

## 7 CONCLUSION FOR THERMAL ASPECTS

Based on our observation and findings:
1. If we can layout these small streets grid in the direction of regional wind;
2. Not to allow tall and wide building blocking the wind before the wind reaches the site;
3. Limit the height of buildings flanking these small streets;
4. Make use of the sloping streets because these help to generate downhill air movement.

Then we can create a thermal comfort outdoor space for the neighbourhood.

## REFERENCES

[1] Team Clean, 2003, Report on Measures to Improve Environmental Hygiene in Hong Kong, HKSAR, p. 87.
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[3] Google earth 2006; google-digital