Effects of skyscrapers to air flow structures and heat dissipations

Abstract

Kuala Lumpur central business district (CBD) is certainly a vibrant hot spot in the years to come. The success should be managed well. Rapid developments within and around the CBD could cause smoke and heat to get trapped within the city in the same way smokes have plagued larger metropolitans such as Hong Kong and Beijing. Healthier and cool airs also are needed to supply dwindling oxygen and removing carbon dioxide content. Oxygen percentage in the CBD of Tokyo could go down to less than 10%. It proves that computational simulations, approving authorities have depended great deals upon, are failures.The objective of the research is to firstly design and fabricate a steel tower measuring 60m in height. 60m is chosen because the shear-layer is approximately 50-60m in the air. Secondly, to measure the shear-layer that exists between the grounds in two congested areas in the city centre. It also measures other data such as turbulence intensities, temperature profiles humidity and gas content using delicate equipment such as hotwire anemometry, pitot-tube – pressure transducer, temperature profiler humidity sensor and gas analyser. Two references will be performed, one in a hilly, remote areas and the other in open paddy fields. Since data cables will be long which could compromise the quality of data, there will be a traverse moving along the tower that contain all equipment in itself. The results and analysis from this experiment will be published and compared with the ones obtained from the meteorological models. The outcome will be shared with the mayor and the council and expected to greatly benefit the planning department. The more important issue is of making use of the recomendations so that our lovely Kuala Lumpur does not follow the failures of others.

Introduction

Highly hazardous air blanketing the airspaces in many of China's industrialized cities has been attributed to worrying numbers of deaths and sicknesses. These airs are polluted because of uncontrolled industrial activities and emission from vehicles. The infamous cities include metropolitans Beijing and Hong Kong. To a lesser extent, even in the CBD of megalopolis Tokyo, there is a worrying increase of Carbon Dioxide (CO_2). In the years 1990 – 2003 there is a 23% net increase of CO_2 in Tokyo despite everybody's effort in reducing CO_2 especially in their commitments to the Kyoto Protocol [1]. Recent reports shows that Oxygen (O_2) level is at as low as only 7% in certain times of the year. Other than the contribution of industrial activities and vehicles' emission, the rise of pollutions is due to the disappearance of open land and water surfaces. Street pavements and building materials absorb solar heat during the day and emit the heat at night causing the city's natural cooling capabilities to diminish. High-rise offices and housing blocks prevent the circulation of cool sea breezes to the inner city. Air conditioning and business machines in densely packed offices add massive doses of CO_2 to the surroundings [1].

Kuala Lumpur is already home to one of the highest buildings in the world (Petronas Twin Tower's antenna's height measures 452m) and there are more skyscrapers to come. There are other developments which supports the Economic Transformation Programme (ETP) such as the Greater Kuala Lumpur/Klang Valley. There are also plans to construct hotels and condominiums in the city centre totally funded by private investments. Certainly, without careful air flow managements, Kuala Lumpur city centre is in the 'making' of Beijing, Hong Kong and Tokyo. When Beijing was clogged with smoke in winter 2012-2013, the authorities instructed many factories to shut down, however this instruction and other remedial activities are far too late. What the city (Kuala Lumpur) needs is natural cooling capabilities which allow outside air to flow in from outside. The cooler airs are especially from Banjaran Titiwangsa; where some of their highest peaks are located only within 50 – 100km from the city.

The proposed research measures the ‘shear-flow’ that exist between the surface of the earth (where the velocity is zero) and the bulk velocity very far away from the earth (Prandlt’s law of the wall). This layer is called the boundary layer. However, the shear layer in this type of wall (city centre) is highly affected by the presence of structures namely the skyscrapers, they may not be called boundary layers at all. However the shear layers do exists because of the Prandlt’s law. An existing facility, measuring the statistics of the atmospheric shear-flow have been built in the flat Salt Lake, Utah. Because of its flatness, most of its statistics are similar to laboratory data, however certainly at much higher Reynolds number (Re in order of 10^6) [2,3,4]. The boundary layer in the Salt Lake facility thickness measures 60m. The location and topological data is shown in Figure 1. The tower structure is shown in Figure 2.

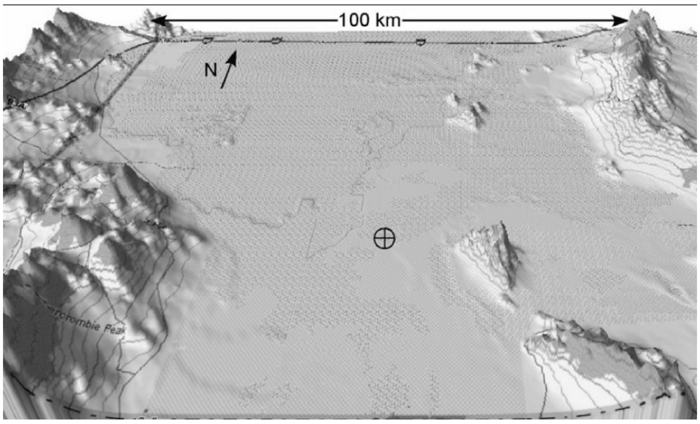

Figure 1: Atmospheric boundary layer facility location map in the West Desert Utah. Picture from [5].

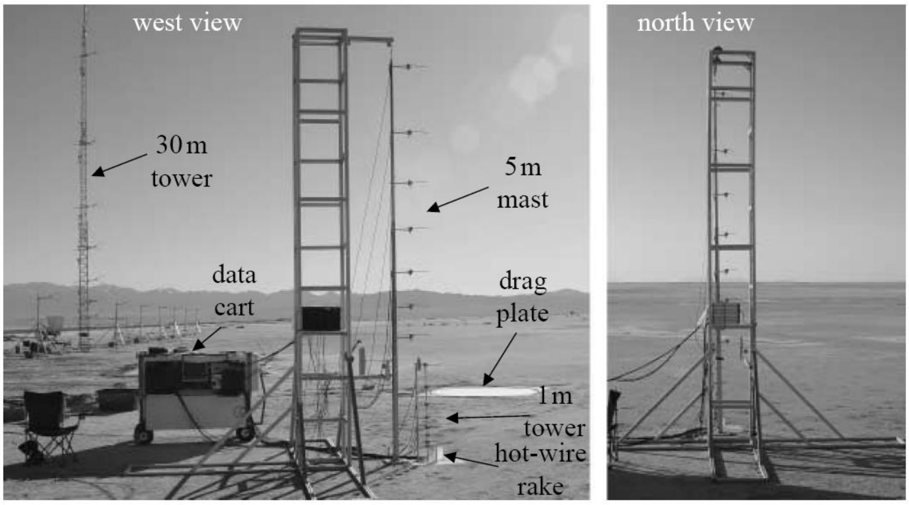

Figure 2: Atmospheric boundary layer facility, main structures. Picture from [6].

Present studies for urbanized area have only been performed using computational simulations, one for Tokyo using the Large Eddy Simulation (LES) and the meso-scale meteorological model (MM5) [7] and one for Osaka using meteorological model WF2 [8]. Because of the complexity of the study, no large-scale experiments measuring velocity and temperature profiles have been conducted in city centres. This is because the shape of the buildings and the topological landscapes cause simulations to be too complicated, let alone experiments. The structures caused by the skyscapers and topology of the landscapes cause flows to converge and diverge and these features are important in most engineering applications [9]. In this study, experiments to be conducted measures the velocity, turbulence intensities and temperature profiles from the ground to the edge of the shear-flow in order to study the actual flow structures in highly urbanized areas. The settings proposed here will sufficiently produce high quality data needed to obtain information about flow and temperature profiles, in order for the reseachers to conclude the guidelines for building planning.

Objectives

1) To design, fabricate and install a 50m - 60m high makeshift traverse-tower for velocity, tubulence and temperature measurement. The tower is capable to be installed temporarily

2) To investigate the effects of high rise in the city centre to (air) flow structures and temperature dissipations, in comparison with natural environments (where there are only trees or plain grass-field).

3) To propose guidelines to the mayor of Kuala Lumpur of the spaces required within buildings to ensure sufficient air flows to remove heated and potentially hazardous airs due to pollutions by vehicles and other sources near buildings.

Methodology

A state of the art traverse-tower will have to be designed, fabricated and installed at the four different locations. A metal base on top of a reinforced concrete (RC) structure is required so that the weight of the tower could be spread. The tower is to be fabricated from 'L' or 'I' beams with bolts and nuts used to tighten them. Supporting metallic cables in four directions are used to keep the tower from collapsing. These activities will accomplish the first objective.

The quantities to be measured are the mean velocity, turbulence intensity, temperature, humidity and air content therefore the equipment required for these measurement are a pitot tube (and a pressure tranducer), a hotwire anemometer, a temperature sensor, a humidity sensor and a gas analyser respectively. A data acquisition apparatus with cable & accesories and a laptop are required to make the acquisition automated. The motor drives sensors in vertical direction at pre-selected locations either in a logarithmic or a linear sequence. Since the vertical distance is quite large i.e. approximately 60m and the weight of this equipment (sensors and holders) is quite significant, a large stepper motor is required. Since the distance to travel is large, the acquisition system including the acquisition equipment and a laptop will have to move together with the sensors, to avoid lengthy cables for the approximately 5 sensors required. To erect the tower, the tower is first assembled on the ground, crane is used to erect the tower with four supporting strings used to stabilise the tower. Necessary approvals will be obtained first thus these steps complete the second objective.

Since close contacts have been established with the staff of DBKL before and while erecting the tower, it is presumed and hoped that sharing the findings is not too difficult. The guidelines will have to be based on published journal and comparison with meteorological model to ensure all aspects are addressed. These will help accomplish the last objective.

Expected Results/Benefit

The effects of skyscrapers in the city are known to affect its natural cooling capabilities. There have been no experiments conducted to determine the extent of shear-layer and temperature gradient between the surface of the earth and the edge of the shear-layer.These findings are beneficial to the planning department of the town hall (DBKL) for its future planning. Reference data obtained from flat and semi-flat areas (paddy fields and hilly areas) could contribute to the understanding of shear flows in highly congested place in city centre. This could contribute for long term plan to resolve smokes' and heats' release in Kuala Lumpur CBD.

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