Wind code and air quality standards for Hong Kong

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Abstract This report presents a summary of the guidelines currently in place in Hong Kong for the design against wind actions and urban air quality. The currently wind code and proposed revisions and standards governing indoor and outdoor air qualities are briefly outlined.

1. Hong Kong Wind Code

The Code of Practice on Wind Effects Hong Kong – 1983, currently governs the wind resistant design of all buildings and structures in Hong Kong. The wind code is published by the Building Department (previously the Building Authority), which is also the approving body for almost all buildings and structures. The format of the code, the calculation procedure and the various coefficients and constants are mostly adopted from the British Standard BS CP 3: Chapter V: Part 2: 1972. The Building Department also published a Practice Note for Authorized Persons and Registered Structural Engineers, PNAP 150 – 1994, to provide guidance to wind tunnel model testing of buildings, which have increasingly been employed for the design of tall buildings and structures in Hong Kong.

An ad hoc committee was formed in early 1990s by the Building Department to revise the Hong Kong wind code, in consultation with local practising engineering consultants and government departments. A Draft Revision was compiled in 1996, which incorporated many modifications based on advances in the past decades in the understanding of wind characteristics and dynamic effects of wind on structures, but this was never released publicly. The latest Draft Revision 2002 has undergone a lengthy public review process and is awaiting final approval for publication. More recent inputs were considered in producing the latest Draft Revision, particularly in the following areas:

- Wind velocity and turbulence profiles for typhoons.
- Design wind speed.
- Dynamic effects, both alongwind and crosswind, for wind sensitive structures.
- Topographical effects.
- Guidelines on wind tunnel model studies.

The most contentious specification of the Hong Kong wind code and PNAP 150 is a mean hourly design wind speed of 64 m/s at the gradient height, which is assumed to be at 250 m above ground for a general terrain and at 300 m for a built-up terrain. There have been considerable debates in the past twenty years over the validity of such a high design wind speed at these heights, with quite a number of publications devoted specifically to this topic, for examples Davenport et al. (1984), and Melbourne (1984). More recently a comprehensive study of the Hong Kong wind climate and the effects of topography have been undertaken based on a 1:400 scale model study of the flow field around Waglan Island and a 1:2000 scale topographic model of Hong Kong (Hitchcock et al., 2001, Kwok and Hitchcock, 2001.) Typhoon wind record collected at Waglan Island up to 1999 was also analysed using a peak over threshold approach (Holmes et al., 2001). The results of these recent studies reinforce the early findings of Davenport et al. (1984) and Melbourne (1984) that the 50-year return period mean wind speed is much less than the value suggested in PNAP 150 for heights of 200m~300m. Recent results of a typhoon wind study for Hong Kong based on computer simulation using the wind field model and the radius to maximum winds model proposed by Vickery et al. (2002a, b) also suggested significantly lower upper level (500m) design wind speeds. These predicted mean wind speeds are presented in Figure 1 and summarized in Table 1. The predicted mean wind speed at a height of 500 m over open sea for a return period of 50 year falls between 54 m/s and 57 m/s.

For codification purposes, Kwok and Hitchcock (2003) proposed the following power-law mean wind velocity profile for typhoons over an open sea terrain:

$$\frac{\overline{V}(z)}{\overline{V}(z_g)} = \left(\frac{z}{z_g}\right)^{\alpha}$$

in which

z_g = gradient height = 500 m
α = power-law exponent = 0.11

Furthermore, for design purposes, a 50 year return period mean wind speed of 57 m/s is recommended for a height of 500 m above an open sea terrain.

Table 1 A summary of predicted 50 year return period mean wind speed for open sea terrain

	50 year return period mean wind speed $\overline{V}(z)$ (m/s)	Height z (m)	Typhoon record used	Comments
Chen (1975)	44.3	75	1953-1974	Extreme value analysis for multiple sites
Davenport et al. (1984)	48	Notional 500	1953-1982	Wind tunnel model studies Extreme value analysis for multiple sites Computer simulation
Melbourne (1984)	37.5	50	1884-1980	Wind tunnel model studies Extreme value analysis for multiple sites Deaves and Harris wind model for a suburban/treed terrain
PNAP 150 (1994)	64	200	-	Code specification
Holmes et al. (2001)	47.3	200	1953-1999	Wind tunnel model studies Waglan Island records Peaks over threshold approach
ARA (2002)	52~55 34~36	500 10	-	Computer simulation

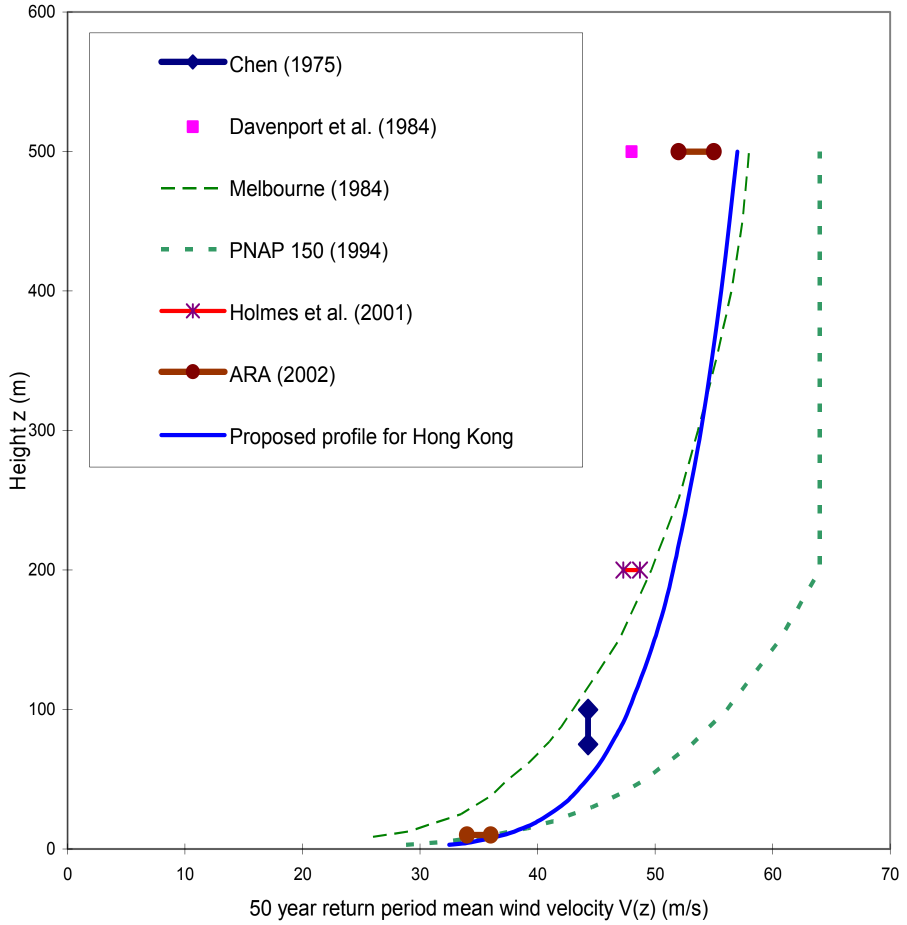

Figure 1 Predicted 50 year return period mean wind speeds for open sea terrain

2. Hong Kong Air Quality Standards

2.1 Outdoor Air Quality

In Hong Kong the Environmental Protection Department is the major governmental agency in charge of air quality matters. The outdoor air quality is monitored by a dense array of eleven general stations and three roadside stations. The general stations are usually on top of three or four storey government buildings. Due to the mountainous terrain of Hong Kong the territory is divided into different air control zones which are actually air sheds. Each air control zone has at least one monitoring station to monitor the air quality of that zone. Three roadside stations are located in the busy road junctions within the urban center to monitor street level air quality. The most effective air pollution control measure is direct administrative orders such as legislations on fuel changes to ultra low diesel and LPG. To control the emissions from major stationary polluters and infrastructure projects, environmental impact assessment method is used. The intention is to keep the air quality of each air control zone within the air quality objectives. Table 1 is the air quality objective of criteria pollutants in Hong Kong.

Table 2 Hong Kong Air Quality Objectives (AQO) (ug/m^3)

Pollutant	1 hour	8 hours	24 hours	3 months	1 year
Sulphur Dioxide	800		350		80
TSP-Total suspended Particulates			260		80
RSP-Respirable Suspended Part.			180		55
Nitrogen Dioxide	300		150		80
Carbon Monoxide	30,000	10,000			
Photochemical Oxidant (as Ozone)	240				
Lead				1.5	

Unfortunately due to the rapidly increasing economic activities of the Pearl River Delta, the number of days per year when air quality objectives are breached have increased over the past few years. The roadside stations monitoring results are very site specific as expected. During normal conditions the pollutant concentrations are higher than the rooftop stations. It was observed during one street canyon wind measurement project, the air quality improved immediately when the wind direction shifted to along the road. To raise the awareness of the general public on air pollution problems, hourly and daily Air Pollution Indices (API) are published. API value of 100 is the AQO value for that particular criteria pollutant. Other API values are simply proportional to pollutant concentrations. The worst sub-API of all the criteria pollutants except TSP is the reported API.

2.2 Indoor Air Quality (IAQ)

There will be no indoor air quality problem if air-conditioning is not used. Unfortunately for subtropical Hong Kong nearly every office building and some high class residential building have central air-conditioning. To save energy the fresh-air intake rate is reduced. The carbon dioxide from occupants, VOCs from office machines and furniture, tobacco smoke, bacteria, fungi and radon are the main indoor air pollutants. Several studies have been carried out by government appointed consultants. The IAQ of the buildings studied are comparable to value in other cities. Up till now no legislations on IAQ have been established. Many government bureaux and departments are involved in this issue. Only guidelines on IAQ classification are published by EPD.

Table 3 IAQ Objectives for Office Buildings & Public Places

Parameter	Unit	8 hour average	
		Level 1	Level 2
Carbon Dioxide	ppm	<800	<1000
Carbon Monoxide	ug/m^3	<2000	<10000
RSP	ug/m^3	<20	<180
Nitrogen Dioxide	ug/m^3	<40	<150
Ozone	ug/m^3	<50	<120
Formaldehyde	ug/m^3	<30	<100
Total VOC	ug/m^3	<200	<600
Radon	Bq/m3	<150	<200
Airborne Bacteria	Cfu/m^3	<500	<1000
Room Temperature	^oC	20-25.5	<25.5
Relative Humidity	%	40-70	<70
Air Movement	m/s	<0.2	<0.3

Due to the multiple sources of pollutants and the involvement of many government departments (such as Labour Department, EPD, Health Department etc), the government has set up an inter-departmental IAQ Management Group to co-ordinate the development of a control strategy. They adopted the following four principles, (a) the precautionary principle, (b) the polluter-pays principle, (c) voluntary mechanisms and (d) the right-to-know principle (Lam 2001). The main idea is for building owners to improve IAQ voluntarily. By having an IAQ Level 1 classification, it improves the prestige of the building. Subsequently a higher rent can be charged that can compensate the expenses of improving the IAQ.

2.3 Outdoor-indoor interface

Compare to indoor air quality even less work has been done in the street canyon air quality problem and dispersion /ventilation among building groups. A few field studies have been carried out to verify ASHRAE type of formulas to prevent exhaust from rooftop vents being re-circulated into the air-conditioning fresh air intake.

There is a general consensus among architects, urban planners and general public that Hong Kong urban building density is too high for good natural ventilation. The tragic event of SARS outbreak at the Amoy Garden Estate in 2003 accentuated this problem. One important circumstantial evidence of the cause of spreading of SARS virus to upper floors is the stack effect of narrow re-entrant (light-well) of the complex. The width of the re-entrants is only 1.5 meters and lined with bathrooms on both sides.

As there is no worldwide accepted standards for reference, guidelines and codes for the design of buildings with good ventilation or pollutant dispersion are still under discussion among Hong Kong government departments and experts. Meanwhile new residential buildings are encouraged to have so called 'environmental' balconies to aid natural ventilation and shading of the sun. Relaxation on the allowable floor areas is used as an incentive. On a larger scale, computational fluid dynamics models have been used in the design of next generation of public housing estate by the Housing Department. The main streets will be oriented in the direction of prevailing wind while most of the estate will be sheltered from northerly wind in winter. The re-entrant spaces and the separation between buildings will be widened.

References

- Code of Practice on Wind Effects Hong Kong-1983, Building Authority, Hong Kong.
- British Standard BS CP 3: Chapter V: Part 2: 1972.
- Environment Hong Kong 2003, Environmental Protection Department, HKSAR, 2004.
- Practice Note for Authorised Persons and Registered Structural Engineers PNAP 150 – 1994, Building Authority, Hong Kong.
- SARS in Hong Kong: from Experience to Action, Report of the SARS Expert Committee, p40-42, 2003.

Davenport, A.G., Georgiou, P.N., Mikitiuk, M., Surry, D. and Kythe, G., "The wind climate of Hong Kong", *Proceedings of 3rd International Conference on Tall Buildings*, Hong Kong and Guangzhou, 1984, pp. 454-460.

Hitchcock, P.A., Chim, K-S, Kwok, K.C.S. and Yu, C.W., "Non-typhoon wind conditions at Hong Kong Waglan Island", Proceedings of Australasian Wind Engineering Society 9th Workshop on Wind Engineering, 2001, Townsville, Australia.

Holmes, J.D., Hitchcock, P., Kwok, K.C.S. and Chim, J., "Re-analysis of Hong Kong typhoon wind speeds using the 'peaks over threshold' approach", *Proceedings of 5th*

Asia-Pacific Conference on Wind Engineering, Kyoto, Journal of Wind Engineering, No. 89, October, 2001, pp. 165-168.
Kwok, K.C.S. and Hitchcock, P.A., “Designing for typhoons in Hong Kong”, *Proceedings of 5th Asia Pacific Conference in Wind Engineering*, Kyoto, Journal of Wind Engineering, No. 89, October, 2001, pp. 689-692.
Kwok, K.C.S. and Hitchcock, P.A., “Design wind speeds for Hong Kong – A modified approach”, Technical Report WWTF001-2003, CLP Power Wind/Wave Tunnel Facility, Hong Kong University of Science and Technology, July, 2003.
Lam, A.K.L., “Improving Indoor Air Quality-A Shared Responsibility”, in ‘The Air We Breathe: Air Pollution in Hong Kong’, edited by A.T. Chan et al., HKU Press, 2001.
Lam, K.S., Kot, S.C., Fung, K.W. and Ma, R.Y.P., A field validation of roof-top dispersion formula in an Urban Centre, J. of Wind Eng. and Ind. Aero., vol. 21, 1985, pp 295-305.
Lam, K.S. and Kot, S.C., Probability of concentration of gas effluent from exhaust vents on the roof-top, Atm. Env., Vol. 19, 1985, pp1040-1044.
Melbourne, W.H., “Design wind data for Hong Kong and surrounding coastline, *Proceedings of 3rd International Conference on Tall Buildings*, Hong Kong and Guangzhou, 1984, pp. 461-467.
Qin, Y. and Kot, S.C., Dispersion of vehicular emission in street canyons, Guangzhou City, PRC, Atm. Env., Vol. 27B, No. 3, 1993, pp283-291.
Vickery, P.J, Skerlj, P.F., Steckley, A.C. and Twisdale, L.A., “Hurricane wind field model for use in hurricane simulation”, *ASCE Journal of Structural Engineering*, 126(10), 2000, pp. 1203-1221.
Vickery, P.J, Skerlj, P.F. and Twisdale, L.A., “Simulation of hurricane risk in the U.S. using Empirical track model”, *ASCE Journal of Structural Engineering*, 126(10), 2000, pp. 1222-1237.