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ON MANAGING INDOOR AIR QUALITY IN HONG KONG

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ABSTRACT

The local government of Hong Kong is going to implement new codes for controlling indoor air quality with the aim to provide a better environment. Different views were collected from the public on what should be done to give a good built environment. A wide area of application was proposed for the building management team to follow. However, the part on spaces with mechanical ventilation and air-conditioning (MVAC) system is not adequate. In this article, key aspects of indoor air quality for spaces with MVAC systems are discussed. Items that should be included in the new code are also outlined.

INTRODUCTION

Buildings should be designed with adequate ventilation for comfort, health, and satisfaction of building occupants. When natural ventilation cannot be provided satisfactorily, as in most non-residential buildings in Hong Kong, Mechanical Ventilation and Air-Conditioning (MVAC) systems are installed [1]. The primary objective of installing an MVAC system is to provide occupants with a healthy and comfortable indoor environment for carrying out their activities [2]; or to provide the required indoor environmental control for manufacturing (e.g., textile mills, electronic factories), product storage, or other development processes. However, surveyed results on local MVAC systems [3, 4] illustrated that the MVAC system is installed essentially to satisfy the thermal comfort requirement. This is typical for those office buildings with high rental price, however, it is only one of the purposes of providing those systems. A "gap" was found between the design and the preference on MVAC systems. Macroscopic numbers such as the number of air changes per hour, N_{ACH}, were specified in designing those systems.

The intention of the new government of the Hong Kong Special Administrative Region (HKSAR) to provide better indoor air quality [5, 6] is a good move, bearing in mind that there are many recent complaints of unsatisfactory indoor environmental quality [7]. Local professionals were consulted as such practice is now common before the HKSAR government implements new codes. For this code [5, 6], there are at least three points to consider:

- Operation of MVAC system
- Local air speed
- Turbulence intensity

Both local air speed limits and turbulence intensity would affect the mixing of pollutants with fresh air. However, these two parameters were not discussed in the proposed code of practice for the management of indoor air quality [5, 6].

OPERATION OF MVAC SYSTEM

There should be two *modes* of operation for the MVAC systems at any indoor spaces without natural ventilation:

- Normal Mode (for normal operations)
- Refurbishment Mode (for operations during periods of refurbishment)

No major technical problems regarding the MVAC systems with good management under "Normal Mode" of operation were found in earlier studies [e.g., 8-10]. The operation and maintenance of MVAC systems provided by most responsible building management teams were shown to be satisfactory. Cleaning schedules of the filters and air diffusers are normally acceptable, using well-trained technicians and workers.

However, the "Refurbishment Mode" of operation was not considered seriously. The indoor environment was very unsatisfactory as reflected in earlier studies. It is usual that the contractors did not care about the indoor environment and the impact on the occupants inside. For example, some construction workers failed to seal off return air grilles before starting the construction work. As a result, volatile organic compounds (VOCs) and dust particulates liberated in the room under refurbishment were driven back to the MVAC system and recirculated elsewhere.

In the last two years, many complaints were reported to management offices of big organizations concerning poor indoor environments, particularly during major renovation periods. Some offices had to be closed several times because rooms were suddenly full of dust and irritating VOC smells.

It is understood that construction schedules are very tight. However, better supervision of refurbishment operations is needed, and indoor environmental protection measures should be worked out. A new scheme of the Housing Authority to issue licenses to workers seems to be helping matters. Further, the

MVAC system itself will be contaminated if the "Refurbishment Mode" is not operated properly. When all desks in offices are observed to be covered with dust, care should be taken.

Accordingly, regular inspection should be made of MVAC systems in structures undergoing renovation. After several refurbishments, the building management team should consider conducting in-depth field measurements to survey the indoor environment.

LOCAL AIR SPEED

In the consultation paper, nothing was mentioned about the local air speed, i.e., air speed in the occupied zone. Air speed is a significant factor in evaluating thermal comfort, but it is not considered in current building codes for natural ventilation [e.g., 11-13].

The preference for thermal comfort of building occupants is closely related to the local conditions in the occupied zone [e.g., 14, 15]. Physical parameters affecting thermal comfort include air speed, air temperature, humidity, and radiant temperature. The MVAC systems installed should have the first three parameters well controlled. For example, temperature and humidity in the occupied zone would be dramatically controlled by placing sensors in representative locations in the occupied zone. Usually, there are no sensors designed for the MVAC systems to measure the local air speed, so the local air speed is not controlled by the system automatically. Apart from changing the fan speed, air speed is seldom taken as a control parameter in operating the MVAC.

Specifying the local comfort conditions in the occupied zone of buildings at the design stage is difficult, though it is one of the solutions to the above problem. Relating the macroscopic numbers to the local human comfort conditions is an alternative.

The upper and lower limits of air speed at occupied zones are specified in different ventilation standards. The values should not be so high as to give the draft effect nor so low as to produce air stillness. These results came mainly from cold countries where the required air speed V(t) (in ms^{-1}) at time t (in s) is low.

AIR TURBULENCE

For places in hot climates, MVAC systems are designed to provide lower indoor air temperature and higher mean air speed at the occupied zones; higher installation and operation costs of the mechanical systems are required to cool the incoming air at a large flow rate. Air turbulence was proposed as another factor to be considered [16, 17]. To qualify this factor, turbulence intensity (Tu) (in percent) was defined in terms of the mean air speed u and the mean velocity fluctuation u', from time t_0 to $t_0 + t_1$ as:

$$Tu = \frac{u'}{u} \tag{1}$$

where

$$u = \frac{1}{t_1} \int_{t_0}^{t_0 + t_1} V(t)dt \tag{2}$$

and

$$(u')^2 = \frac{1}{t_1} \int_{t_0}^{t_0 + t_1} (V(t) - u)^2 \, dt \tag{3}$$

Maintaining suitable values of turbulence intensity (Tu) in the occupied zones will give the same comfort level even at higher temperatures and lower air speeds. This phenomenon must be studied in detail before determining the comfort range of turbulence intensity. Field measurement and thermal comfort surveys in different indoor spaces should be carried out. Macroscopic parameters for design purposes are to be developed using theories of turbulence.

THERMAL COMFORT DUE TO DRAFT OR ELEVATED AIR SPEED

A parameter known as Percentage of Dissatisfied (PD) (in percent) [16, 17] was proposed for assessing the thermal comfort by quantifying the air draft effect. This is given in terms of u, Tu, and the air temperature, T_a:

$$PD = (3.143 + 0.3696\ u\ Tu)\ (34 - T_a)\ (u - 0.05)^{0.6223} \tag{4}$$

In the above equation, u is taken as 0.05 ms^{-1} if it is less than this value, and PD is taken as 100 percent if it is greater than 100 percent. Note that many effects such as those due to adaptation, cultural differences, climate and seasons, age and sex differences are not considered.

Recent studies by Chow and Fung suggested an opposite view in sub-tropical countries [18]. Local Chinese prefer to have higher air speed, or at most, feeling less comfortable only instead of feeling dissatisfied with the imposed elevated air speed, during hot and humid seasons. Studies by de Dear and Fountain confirmed that office workers in warm and humid climates prefer more indoor movement [19].

A new parameter known as Percentage of Feeling Less Comfort (PLC) due to elevated air speed was proposed by Chow and Fung using a climate chamber [18]. This parameter is taken to be either a positive value of PD or a negative value of PD, or somewhere between the two, depending on two critical air temperatures (θ_1 and θ_2) which were determined empirically. The equation for PLC is given by:

$$\mathrm{PLC}=\begin{cases}-\mathrm{PD} & \text{for } T_a > \theta_1 \\ f(T_a)\cdot \mathrm{PD} & \theta_2 \le T_a \le \theta_1 \\ +\mathrm{PD} & T_a < \theta_2 \end{cases} \tag{5}$$

The function $f(T_a)$ is given by:

$$f(T_a)=\frac{2(T_a-\theta_1)}{(\theta_2-\theta_1)}-1 \tag{6}$$

This parameter should be investigated more thoroughly in actual sites for coverage of the wide range of buildings.

MACROSCOPIC PARAMETERS

Macroscopic parameters are useful in quantifying the requirement. A good example is the modified jet momentum number (J*) for air diffusion devices. Experimental studies in big spaces with MVAC were carried out extensively with correlation relations among macroscopic parameters calculated and thermal comfort indices and key concentrations of pollutants derived. For example, in railway stations [19, 20], the median value u_{50} (in ms^{-1}) of mean air speed measured at different positions is related to N_{ACH} and J* as:

$$u_{50} = 0.0483\ N_{ACH} \tag{7}$$

$$u_{50} = 288 \times 10^{-6}\ J^* \tag{8}$$

The mean age of air (A_{50}) (in s), a concept reviewed in the literature [21], and the mean carbon dioxide concentration C_{50} (in ppm), are related to J* as:

$$A_{50} = -2.75 \times 10^{-4}\ J^* + 74.2 \tag{9}$$

$$C_{50} = -5.19 \times 10^{-2}\ J^* + 570 \tag{10}$$

CONCLUSION

Indoor spaces cover residential buildings, commercial buildings, halls, theaters, car parks, tunnels, and railway stations. Likewise, vehicles such as trains, buses, and car compartments are also regarded as indoor spaces and should be covered by current regulations. Works related to indoor aerodynamics should be specifically studied at the first stage for understanding the ventilation requirement. Reference should be made to the local works [e.g., 18] noted earlier.

Another move by the HKSAR government is to revise all building codes related to the provision of ventilation [22]. Demonstration works to be done [23] are to be integrated with the proposed codes [6].

Finally, on the problems encountered due to poor management of renovation works, it is recommended that the client and the contractor work out "partnership" programs that give incentives to the contractors to watch the indoor environment, instead of punishing them.

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