Ventilation Strategy for Civil Buildings in Response to Stricter Standards of Energy Conservation and Indoor-Air-Quality Issue in China

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ABSTRACT

China has been undergoing fast urbanization during the last three decades. Air tightness design equipped with air-conditioning units are currently popular in commercial rather than residential buildings to meet the policy needs of energy conservation. Meanwhile, indoor chemical contamination mainly derived from excessive interior decorating activities causes broad attentions to indoor heath concerns. This paper reviews the development of building ventilation and energy-conservation as well as indoor-air-quality (IAQ) related standards in China. Comparative analysis to related international standards and those in developed countries indicated that both academic research and practice for building ventilation is still relative weakness in Chinese HVAC field. China promulgated a series of IAQ-related standards since 2001, in which physical indices related to building ventilation and energy such as fresh air supply rate, temperature and relative humidity are also included. In summary, ventilation strategies in civil buildings should be renovated to meet those stricter standards. This review also indicated that demand controlled ventilation basing on IAQ, integrated with indoor air pollution warning system using carbon dioxide and total volatile organic compounds as dual indicators, supplies a new option to enhance building energy efficiency and to guarantee good IAQ.

KEYWORDS

Ventilation, Building Energy Conservation (BEC), IAQ, Civil Buildings, China

I. INTRODUCTION

China has been undergoing fast industrialization and urbanization during the last three decades. Currently, buildings energy consumption bulks more than a quarter in Chinese total consumption of primary energy, becoming one of the top three energy consumers, together with energy consumption for industry and transportation. The promulgation of the primary “Energy Conservation Law of PRC” in 1998 underpins the gradual buildup of an integrated technical standards system of building energy conservation (BEC).

Proper ventilation strategy acts as an important role in BEC, as well as a guarantee of acceptable indoor climate. So far, natural ventilation is adopted by the majority of residential buildings with restrained usage of mechanical ventilation in kitchens and bathrooms. By comparison, it did not occur until the mid-1990s when the number of airtight buildings equipped with air-conditioning systems has increased rapidly, especially in public buildings such as offices and commercial buildings, to satisfy the policy needs of energy conservation. At the same stage, indoor refurbishment/

decoration/ remodeling activities are prevalent among both residences and public buildings, resulting in broad heath concerns of indoor air pollution mainly derived from building and interior decorating materials as well as lack of indoor ventilation. China has paid great attentions to control IAQ issues and a series of IAQ related standards are revised or newly promulgated at the normative management stage since 2001.

This paper reviews the development of BEC- and IAQ-related standards in China, in relation to building ventilation. Limitations of the present ventilation strategies in civil buildings are discussed to find out advanced options to ensure a comfortable indoor climate while meet the BEC requirements.

2. BUIDLING ENERGY CONSERVATION AND VENTILATION IN CHINA

2.1 Development of BEC-Related Standards

Studies on energy conservation in buildings started in China since the adoption of the policy of reform and opening-up in the early 1980s. The Ministry of Construction (MC) took the responsibility for nationwide investigations on buildings energy saving performances, afterwards promulgated the first "Design standard for energy efficiency of civil building (Heating residential buildings) "(JGJ26) in 1986. Energy utilization for heating in residential buildings took up a large proportion of the total building energy consumption. A limited number of other BCE-related standards/norms were promulgated during this primary stage of development (1980~1994), such as "Design standard on building envelope and air conditioning for tourist hotels" (GB50189-93), and "Thermal design norm of civil buildings" (GB50176-93) which is still effective.

In response to the strategy of sustainable development, an appointed BEC office led by MC came into existence in 1994 to better organize national frameworks of BEC cause. JGJ26 are then revised in 1995 to achieve an objective of reduction of heating energy consumption by 50%, compared with corresponding level in 1980, according to the 10th five-year plan (1996~2000) for energy conservation in buildings. A series of standards/norms concerning of BEC were newly promulgated or revised from their 1980s' versions by MC during the normative and organizational management stage (1994~present). Today China has established its BEC standards system including design standards, testing standards, management standards, and building energy consumption standards, in which HAVC aspects are regarded as a main component.

2.2 Climatic Regionalization for Residential BEC Managements

With a vast territory, China stipulated the "Standard of climatic regionalization for architecture" (GB50178) early in 1993. Basic requirements for constructions in seven primary climatic regions are specified. Subsequently, a compulsory thermal design norm aiming at civil buildings (GB50176) was put in force, which classified the climatic regions into five major types (see Fig. 1). Different indicators were regulated to evaluate energy saving performances of residential buildings in main climatic region. This norm promotes the subsequent promulgations of revised JGJ26 in 1995, JGJ134 in 2000 and JGJ75 in 2001, focusing on energy efficiency design for heating residences in severely cold and cold zone, those in hot summer/cold winter zone and in hot summer/warm winter zone, respectively. In addition to indoor temperature, air change rate should be designed to be 1.0 $h^{-1}$for residences. However, JGJ26

contains no parameters in relation to residential ventilation in severely cold/cold zone.

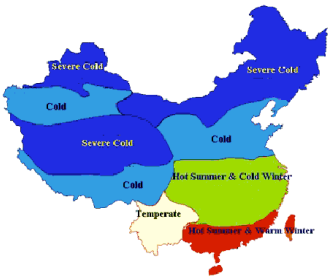

Figure 1: Regionalization for thermal design in China

The "Design code for residential buildings" (GB50096) emphasized that bedrooms, living rooms and bathrooms be well ventilated, and ventilation inlet area in kitchen should not be smaller than 0.60m^2. Kitchens and bathrooms are both required for installation of exhaust outlet. The "Code for design of HVAC" (GB50019-2003) also stipulates natural ventilation should be chosen with priority to eliminate surplus indoor thermal energy and humidity in bedrooms and living rooms. Further more, area ratio of natural ventilation inlet to floor in bedrooms, living rooms and kitchens should not be less than 1/7, with a gross ratio not less than 5% within entire residence, according to the compulsory "Residential building code" (GB50386-2005). Residential indoor air pollutants such as benzene and VOC are limited to comply with IAQ requirements for class-1 civil buildings regulated in GB50325.

2.3 BEC Management and Ventilation in Public Places

One fifth of floor spaces of annual newly completed buildings are for public places, that is nearly 400 million m^2. To further accomplish the 50% target of energy conservation, China extends its attention to energy conservation in public buildings except for residential buildings in recent years. Derived from thermal design norm for tourism hotel, the "Design standard for energy efficiency of public buildings (GB50189-2005)" is newly issued to improve thermal conditions and energy efficiency of HVAC system in various public buildings. In accordance with the ASHRAE method, acceptable air change flow are calculated and regulated for various public places, partly listed in Table 2. It also regulates that demand controlled ventilation based on indoor concentration of carbon dioxide ought to be adopted in rooms with occupier in relatively high density and fluctuation, to keep CO_2 concentration in line with hygienic norms. In addition, three parameters (i.e. indoor temperature, air flow velocity and humidity) are set for air conditioning design, separately in summer and in winter.

3. CHINESE RESPONSES TO IAQ ISSUE

3.1 Main Sources of Indoor Air Pollution

3.1.1 Cooking Activities

Currently, China holds more than 350 million residential kitchens with an increasing rate of 13 million annually, with the exception of large numbers of restaurants and eateries. Air pollution generates during cooking time from domestic fuel combustion and Chinese special cuisine. However, hygiene conditions in residential kitchens have been meliorated substantially nowadays, especially in urban areas. Above all,

domestic energy consumption structure has changed. Rising utilization of relatively clean energy resources such as LPG, nature gas and solar energy, have gradually minify the usage of solid fuel since 1990s, and therefore lower heath risk associated with solid fuel combustion. Appliances like microwave oven are taken in homes and hence alter the traditional way of cooking to be more energy-saving and timesaving. For another, kitchen units in newly constructed buildings are commonly designed to be separate spaces combining with range hoods, in line with related design requirements for kitchen ventilation.

3.1.2 Indoor Environmental Tobacco Smoke

In China, approximately 350 million people smoke and over 540 million are exposed to the secondhand smoke, 180 million of which under the age of 18. Exposure to ETS mostly happened in families, offices and various public places. China has applies plenty of energy to control smoking since 1990s, and became one of the 168 member states to the WHO “Framework Convention on Tobacco Control—FCTC” in 2006. Legislation against smoking in public places are successfully implemented in some large cities of China, like Beijing, and are proved to be an effective measure to control indoor ETS using experiences by developed countries as references.

3.1.3 Interior Decorating Activities

Indoor refurbishment, decoration and remodeling activities have been popular to create aesthetic and comfortable indoor environments since 1990s. So far, chemical contamination mainly derived from building and interior redecorating materials appears widely among civil buildings and hence causes broad attention to “Sick Building Syndrome” and other indoor heath concerns, especially in airtight microenvironments with low air exchange rate. In 2001, compulsory national standards for limits of harmful compounds in ten types of interior decorative materials (LHSCIDM) were promulgated to be significant components of the IAQ-related standards systems, placing strong emphasis on indoor source control.

3.2 IAQ-Related Standards System and Ventilation Requirements

China began its IAQ researches in the late 1970s and subsequently promulgated the primary “Hygienic standards for industrial enterprises designing” focusing on occupational indoor environments. Since the late 1990s, the Ministry of Heath has paid great attentions to IAQ issues in civil buildings. After nearly 20 years of effort, China has finally established its standards system for IAP controlling and evaluating. As a whole, the development of IAQ related standards in China may be divided into three stages, summarized in Table 1. The hygienic norm of IAQ is considered as a preparation for the promulgation of recommendatory “Standards for IAQ”, which stipulates that “indoor air should be innoxious, uninjurious and without abnormal odor”.

TABLE 1: Summary of IAQ-related standards in China

Starting Stage (1970s-1993)	Developing Stage (1994-2000)	Normative Management Stage (since 2001)
Hygienic standards for 12 public places (1988)	All Revised in 1996 (GB9663~GB9673, GB16153)	
Recommendatory hygienic standards for 7 types of indoor air pollutants (1995-1999)		Hygienic Norm of IAQ (2001.9)
GB50325-2001 Code for Indoor Environmental Pollution Control of Civil Building Engineering (issued by MC and SQSIQA)		
GB/T 18883-2002 Standards for Indoor Air Quality (issued by SQSIQA, SEPA and MH)		
Air conditioner ventilating system hygiene norm of public place (2006)		

The promulgation of GB 50325-2001 (partly revised in 2006) ended the time when IAQ standards for civil buildings were absent in China. However, it does not contain any ventilation requirements which actually influence IAQ to a great extent. Extra items regarding ventilation are currently being discussed to add to the present version. Ventilation requirements for civil buildings in IAQ-related standards are summarized in Table 2.

TABLE 2 Ventilation requirements for civil buildings in IAQ-related standards

Style of Architectures	Rooms	Air change flow [$m^3/(h \cdot p)$]
Residence/Office	bedroom, living room, office	≥30, Air flow velocity ≤0.3m/s in summer, ≤0.2 in winter
Tourism servings	hotel room	≥20 (≥30 for 3-star and above)
	dining room, banqueting hall	≥15 (2-star), ≥20 (3-star), ≥25 (4-star), ≥30 (5-star)
	Restaurant	≥20, Air change flow ≤0.5m/s
Culture/Entertainment	movie theater, concert hall, etc.	≥20 (≥30 in ballrooms, ≥10 in taprooms)
	gymnasiums□emporium, etc.	≥20, Air change flow ≤0.5m/s
School	classroom	≥11 (Elementary), ≥14 (Junior high), ≥17 (Senior high school and above)

3. CONCLUSION

(1) Indoor air pollution results from both indoor and outdoor sources, probably worsened by improper ventilation conditions. HVAC parameters such as temperature, humidity, air flow velocity and air change flow are involved both in BEC- and IAQ-related standards.
(2) The development of BEC techniques has resulted in improved capacity for energy conservation and insulation of civil buildings, contributing to the degradation of IAQ. Moreover, in addition to economic growth, traditional indoor fuel-combustion air pollution is becoming secondary to that resulting from building and interior decorating materials especially in urban and more developed rural areas.
(3) Indices such as air change flow, air flow velocity, area ratio of ventilation inlet to floor, etc., are quoted as indicators of ventilation conditions in civil buildings. However, ventilation techniques for civil buildings are relatively weak in Chinese HVAC field. Ventilation strategies should be further improved to satisfy needs of both personal health and energy conservation. Demand controlled ventilation using carbon dioxide and total volatile organic compounds as dual indicators, probably supplies a new innovative approach to enhance building energy efficiency as well as to guarantee an acceptable indoor environment.

4. OUTLOOK

When enacting BEC- and IAQ-related standards, China used related international standards and those of other countries for references. Hence, China needs to go further in amending and perfecting those standards and norms. New ventilation techniques and strategies would help present contradictory aspects between energy conservation and IAQ guarantee in civil buildings. More collaboration between MC, MH and other departments are expected to better manage ventilation strategies in various civil buildings to meet those stricter standards.

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