Available online at www.sciencedirect.com

SCIENCE DIRECT®

Building and Environment 40 (2005) 738–746

BUILDING AND ENVIRONMENT

www.elsevier.com/locate/buildenv

Investigating potential of natural driving forces for ventilation in four major cities in China

Lina Yang[a], Guoqiang Zhang[a,*], Yuguo Li[b], Youming Chen[a]

[a]College of Civil Engineering, Hunan University, Changsha, Hunan Province, Hunan 410082, China
[b]Department of Mechanical Engineering, The University of Hong Kong, Hong Kong SAR, China

Received 24 June 2004; received in revised form 23 August 2004; accepted 24 August 2004

Abstract

The potential of natural driving forces for ventilation in buildings is the possibility for providing sufficient outdoor air by only natural ventilation. Based on the early work of Fracastoro et al. (Fourth international conference on indoor air quality, ventilation and energy conservation in buildings—IAQVEC, vol. III, Hong Kong: The City University of Hong Kong; 2001. p. 1421–9.), we develop a simple prediction model for this natural ventilation potential applicable to Chinese residential buildings, using a simple analytical model of natural ventilation considering the combined effect of wind and thermal buoyancy forces. Comparing with the existing method developed by Fracastoro et al. (2001), the present prediction does not need sophisticated multi-zone modeling calculations and the constants in the model are no longer variables. Using the weather data from International Weather for Energy Calculations (IWEC) into our simple prediction model, the natural ventilation potentials for low-rise residential buildings in four representative cities of China including Beijing in the north, Shanghai in the east, Guangzhou in the south and Urumqi in the northwest were analyzed. We introduced the concept of the pressure difference Pascal hours (PDPH) for natural ventilation, and PDPH was calculated and compared for four cities. A high PDPH value means a great potential for application of natural ventilation. In addition, hourly effective pressure differences can be obtained and analyzed statistically. This information can help the designers to determine the building opening size, or to assess whether or when mechanical ventilation is necessary. The application of the model can be a simple design tool at preliminary design stage.

Keywords: Natural ventilation potential; Natural ventilation; China; Prediction method; Pressure difference Pascal hours

1. Introduction

Natural ventilation has the potential to reduce initial construction costs and operating costs for residential buildings while maintaining ventilation rates consistent with the requirement of acceptable indoor air quality. While a recent surge of interest in Europe and other developed/developing countries has advanced natural ventilation technology, much work is needed in China before this potential can be realized. China has a climate dominated by monsoon winds. It features a clear temperature difference in winter and summer in most part of the country. In winter, northerly winds coming from high latitude areas are cold and dry, and in summer southerly winds from sea areas at lower longitudes are warm and moist. In addition, climates differ from region to region because of the country's extensive territory and complex topography. Before we investigate applicability of various advanced natural ventilation technologies in China, it is necessary to analyze the potential of using natural ventilation in buildings located in different parts of China. In this paper, we focus on residential buildings. We will first adapt an existing natural ventilation potential model for the Chinese applications. Our improvement of the model involves in the application of vigorous analytical

*Corresponding author. Tel.: +86 731 8823900; fax: +86 731 8821005.
E-mail address: gqzhang@vip.sina.com (G. Zhang).

0360-1323/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.buildenv.2004.08.023

Nomenclature

A_s	south wall areas (m^2)
A_n	north wall areas (m^2)
A_f	floor areas (m^2)
A_{tot}	total opening areas (m^2)
C_d	discharge coefficient (dimensionless)
C_P	wind pressure coefficient (dimensionless)
g	gravity acceleration (m/s^2)
H	room height (m)
k, a	terrain coefficient
PDPH	pressure difference Pascal hours (Pa h)
N_P	number of people in building
q	volumetric flow rate (m^3/s)
q_R	required ventilation rate (m^3/s)
q_s	ventilation rate by stack effect (m^3/s)
q_w	ventilation rate by wind effect (m^3/s)
T_o	outdoor temperature (K)
T_1	indoor temperature (K)
v	local wind speed (m/s)
v_o	wind speed of weather station (m/s)
z	building height (m)

Greek letters

ρ_o	air density (kg/m^3)
ΔP_{eff}	effective pressure difference (Pa)
ΔP_R	required pressure difference (Pa)
ΔP_w	pressure difference by wind effect (Pa)
ΔT	temperature difference (K)
η	opening ratio or wall porosity

approach to a simple building model in China. We hope to discuss opportunities and issues specific to the application of natural ventilation to residential buildings in four cities in China, i.e. Beijing in the north, Shanghai in the east, Guangzhou in the south and Urumqi in the northwest (Fig. 1).

2. Natural ventilation potential model

The natural ventilation potential was defined as the possibility to ensure an acceptable indoor air quality by natural ventilation only [1]. We consider that the term of potential of natural driving forces is more suitable for this paper. The potential of natural driving forces for ventilation in buildings is the possibility for providing sufficient outdoor air by only natural ventilation. The potential of natural ventilation depends on many parameters, including the outdoor climate (outdoor air temperature and moisture, wind speed and direction, etc.), building site (outdoor air quality, outdoor noise, outdoor environment and urban structure, etc.) and the building itself (indoor pollutant sources, indoor heat sources and stored heat, indoor air quality requirements, position and size of ventilation openings, building type, orientation, height and structure, indoor temperature, orientation of building, etc.). The potential of natural driving forces is a much narrower concept than the potential of natural ventilation. It depends on the indoor and outdoor air temperature differences, the wind conditions as well as the building terrain and surrounding conditions.

Recently some relevant studies have been conducted in the literature to analyze the climate suitability for natural ventilation [2,3] or to analyze the building effective pressure difference for natural ventilation [4]. In [2,3], the outdoor temperature range for natural ventilation was calculated by energy conservation firstly, thus the climate suitability for natural ventilation can be evaluated based on the local weather data such as temperature. The climate suitability for natural ventilation is different from the potential for natural ventilation. The potential for natural ventilation also include the availability of natural driving forces and whether the buildings being considered, can take the advantage of available natural driving forces. The potential for natural driving forces is about the real ability of natural ventilation induced by stack effect or wind effect. In [4], though the effective pressure difference for natural ventilation was divided into two folds, i.e. the pressure difference introduced by thermal buoyancy and wind effect, the direct adding of the two pressure differences may be improper for complex residential buildings to represent the real natural ventilation ability. However, as demonstrated by this paper, the linear addition of two driving forces is a valid option when some assumptions are valid. The proposed effective pressure difference for natural ventilation proposed in [4] contains two variables, i.e. the non-dimensional effective distance from the neutral plane level and the effective wind pressure coefficient. The two variables can be determined if the building geometry and surrounding conditions are known. In our case, it is difficult to identify representative apartments in different Chinese cities due to the wide range of possible apartment design in China. We hope to identify the key features of the apartment buildings in China and develop a simple prediction tool for potential of natural driving forces.

Three basic steps for a typical prediction model for natural driving forces are as follows: (1) calculate effective pressure difference of a typical building based on the basic theories related to natural ventilation and hourly weather data; (2) calculate the required pressure difference for acceptable indoor air quality and thermal