Building and Environment 61 (2013) 133–139

Contents lists available at SciVerse ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

Improvement in the applicability of the air tightness measurement using a sudden expansion of compressed air☆

Sungryong Bae, Hyojun Moon, Min Jung Lee, Nam Il Kim*, Hong Sun Ryou

School of Mechanical Engineering, Chung-Ang University, 221 Heukseok, Dongjak, Seoul 156-756, Republic of Korea

ARTICLE INFO

Article history:
Received 19 October 2012
Received in revised form
13 December 2012
Accepted 28 December 2012

Keywords:
Air tightness
Effective leakage area
Smoke suppression
Fire safety
Sudden expansion

ABSTRACT

Air tightness is an important parameter for both smoke suppression in a fire and for the energy efficiency of buildings. A transient method using a sudden expansion of compressed air (SECA) was recently introduced to measure the air tightness, or effective leakage area, with the least amount of labor or preparation. Although the feasibility of SECA has been reported, relevant experimental data has been limited to small leakage areas of up to 20 cm^2, which has not been sufficient to cover the leakage of rooms in buildings. In this study, a test room and the test module for SECA were modified and the basic equation of the transient method was improved. As a result, the application limit of the leakage area can be extended up to 700 cm^2, and further extension would be possible simply by increasing the chamber volume or its initial pressure. The experimental results of SECA can be related theoretically to the results of a steady method, and they were not affected by the volume of the room. The results of this study will help prove the most convenient measurements for air tightness and for the effective leakage areas in rooms and ventilation systems.

1. Introduction

Air tightness is an important parameter not only for smoke suppression in the event of a fire [1,2], but also for the construction of energy-efficient buildings [3,4]. The spread of smoke in a building fire is a major cause of mass casualties. To secure safe refuge shelters and escape routes, various smoke suppression systems have been employed, and the air tightness of the refuge spaces should be guaranteed for successful performance. With the recent increase in the number of high-rise buildings, the role of smoke suppression systems is becoming more important. This is because the evacuation time increases in high-rise buildings, and the stack effects within stair-wells and elevator shafts will significantly hinder the successful performance of the systems [5]. If one of the refuge spaces has poor air tightness, all the other refuge spaces would suffer a deficiency in air supply due to their interconnected structures. Thus, a much greater air supply system is necessary to guarantee the overall performance of the smoke suppression systems. If the air tightness is inspected for all refuge spaces, the necessary air supply system can be optimized by regulating the air tightness of each space. However, such a comprehensive inspection is a formidable task without a convenient measurement method.

There are several schemes commonly used for air tightness measurement, including methods that employ fan pressurization [6–8], blower doors [3,9], piston-cylinders [10,11], and tracer gas dilution [12]. The first two schemes are steady methods, while the latter two are transient methods. The steady fan pressurization scheme has been adopted as a standard method to measure the effective leakage area (ELA) in a laboratory. This method would be the most reliable if we can apply the same method in real building spaces. However, it was a difficult method in practice. Thus, some modified schemes using blower doors or piston-cylinders have been used for the purpose of field applications. Nevertheless, since these schemes employ an external air supply from the outside into the test room, they will require preparation processes for tests in practical building rooms. Another problem is that a change in the configuration of the test room is unavoidable. For example, in the blower door scheme, an actual door is replaced by a blower door module. Thus the air leakage through the gap of the actual door cannot be measured, despite being one of the major routes for air leakage in practice [13]. As an alternative, the tracer gas scheme

☆ This manuscript contains original research results, and it will be not submitted to elsewhere during the review process of the Building and Environment.

* Corresponding author. Tel.: +82 2 820 5753; fax: +82 2 825 5753.
E-mail address: nikim@cau.ac.kr (N.I. Kim).

0360-1323/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.buildenv.2012.12.017

Nomenclatures

A_{eff}	effective leakage area (ELA)
A_{open}	actual open area
m	air mass
n	polytropic exponential constant
P	absolute pressure
ΔP	gauge pressure
Q_{leak}	leakage flow rate
T	temperature
t	time
Δt	period of the room pressure variation
V	volume
ρ	air density
Subscript	
atm	atmosphere
C	chamber
R	room
SV	solenoid valve
0	initial state

may have merit, as it does not require any change in the room configuration. However, the spatial inhomogeneity of the tracer gas within the test room makes the measurement difficult.

Lee et al. [14] recently introduced a new transient method of SECA, in which the experimental system was located within a room without any configuration change. The preparation process could be minimized, and the measuring time could also be markedly shortened. The air was first compressed into a chamber and then ejected through a solenoid valve. Pressure variations both in the chamber and the room were monitored simultaneously. The ELA was estimated using two applicable transient methods: a differential method and an integral method. Both methods had good reliability, and their results could be compared with those of the steady methods. In the differential method, however, a larger number of data with a higher sampling rate were necessary, and an additional post-process of data smoothing was also necessary. Thus, the integral method was more convenient than the differential method, and it was recommended as a practical test method. However, the maximum range of the measured ELA was limited to 20 cm^2. This was not sufficient for measuring the leakage areas of the refuge spaces of practical buildings, since there are larger leakage areas including the gaps of doors. The experimental limitation was mainly due to the insufficient performance of the previous test room. To extend the experimental limits, a larger blower fan was necessary to obtain the reference data using the steady method. At the same time, a more rigid test room was necessary to suppress the deformation at the higher steady pressure. In addition, the correlation between the integral method and the steady method could not be sufficiently explained.

In this study, a modified test room was re-constructed to extend the measurement range. An additional air blower fan with higher flow rate was used for a steady pressurizing method to obtain extended reference ELA data for comparison with the SECA results. In addition, the test module of SECA was also improved for better performance. This will be explained further in the next section. Using this experimental setup, the following issues are investigated.

1) Improvement in the basic equation of the integral method
2) Feasibility of the SECA method for much larger ELAs
3) Effect of the test-room volume on ELAs.

2. Experimental apparatus

A modified test room was used for gathering reference data with the steady pressurizing method, and this is shown in Fig. 1. It was made of sandwich panels (thickness 50 mm) and its joining parts were sealed with silicone rubber and cellophane tape. The structure of the test room is shown in Fig. 1(a) and a photo is provided in Fig. 1(b). The test room consists of three rooms of the same height (2.3 m). The scale of the main test room (2 × 2 × 2.3 m) was designed according to the Korean National Fire Safety Codes [15], and two supplementary rooms (1 × 1 × 2.3 m) were also prepared. Most of the experiments were conducted within the main test room. The supplementary rooms were used to examine the effect of the test-room volume. Four gate doors were installed, with two doors for each room. The doors were 0.8 m in width and 2.1 m in height, and each door had a plastic window (0.6 × 0.6 m, 10 mm thickness). In addition, one window was equipped in each supplementary room, and three windows were equipped in the main test room; one on the side of the main test room was equipped for a connection with external blower fans, while the other two were for installing hole-plates with many circular holes. Each hole had a diameter of 8 cm, and the open area was about 50 cm^2. The total open area was proportional to the number of holes.

The improved test module of this study is schematically shown in Fig. 2, and it was installed within the test room. Although the overall configuration was similar to the previous module [14], there are three differences. The first difference is that the temperature within the chamber was measured using three thermocouples of different diameters (stainless steel sheath K-type; 0.5, 1.0, and 1.5 mm). The effect of temperature variation within the chamber will be discussed later. The second difference is that two air chambers (10 L/each) and two solenoid valves (VPW2165, SMC, Korea) were prepared, and

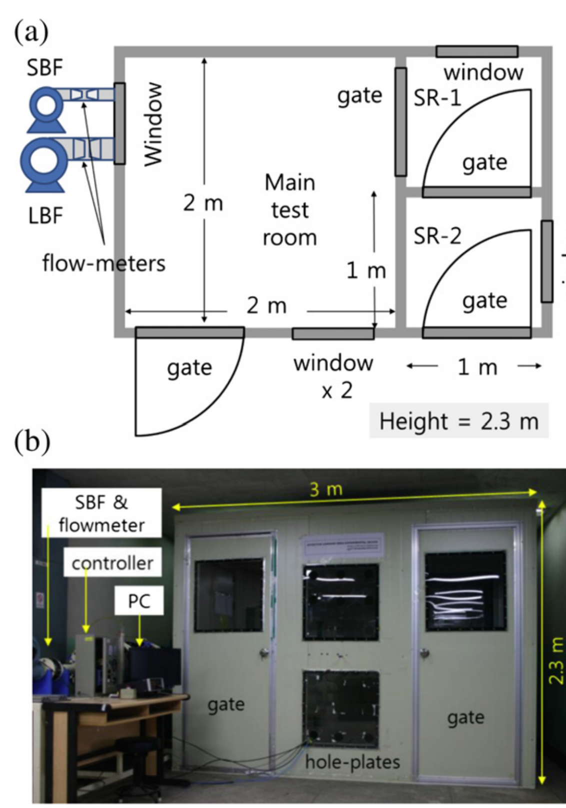

Fig. 1. An improved air tightness test room for the steady pressurizing method; (a) a schematic of the experimental test room (SR: supplementary room, SBF: small blower fan, LBF: large blower fan), (b) a photo of the experimental test room.