AIR LEAKAGE CHARACTERISTICS OF DWELLINGS IN HIGH-RISE RESIDENTIAL BUILDINGS IN KOREA

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ABSTRACT

Reliable airtightness data is needed to calculate the estimate of air infiltration and the thermal loads for building energy efficiency and indoor comfort. While useful information on air leakage in low-rise dwellings does exist, there is little data available on dwellings in increasing high-rise residential buildings (particularly ones with central core plan). In this paper, we conducted airtightness measurement using fan pressurization method for about 350 dwellings in 4 high-rise residential buildings in Korea. The results were compared to airtightness requirements for high performance buildings or several airtightness ratings. The measured results show that average ACH50 was 2.3, and the ACH50 value was within the range of 2~5 which are level of 'quite tight' on the basis of ASHRAE airtightness ratings. The results of the building component test show that the most leak parts of dwelling are the internal walls between residential units.

KEYWORDS

Airtightness, Air leakage distributions, High-rise residential building, Fan pressurization method

INTRODUCTION

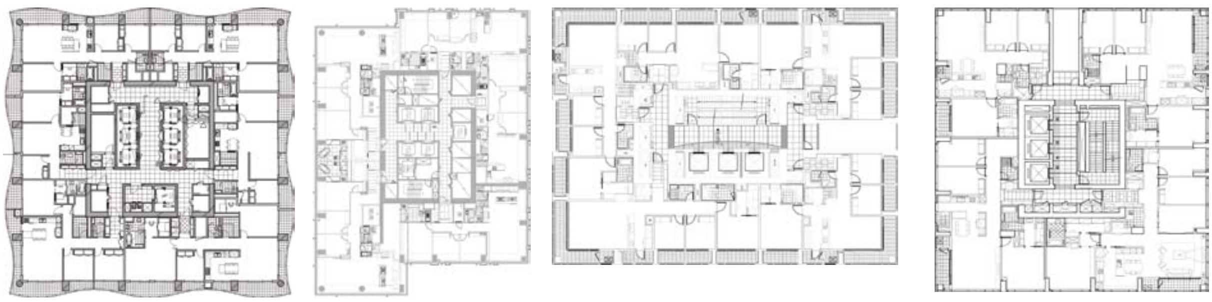
Most residential buildings located in the United States, Canada, and Europe are low-rise dwellings. Many studies have been conducted on the airtightness level of low-rise dwellings. Sherman and Chan(2004) reviewed various airtightness research and practices. This report reviews the most important publications relating to the building airtightness. Many studies in this report mainly presented the data on airtightness of single-family house. Measurement methods of the airtightness of single-family house and the airtightness standard for each nation were also suggested. On the other hand, most residential dwellings in Asia are constructed as a multi-family house and high-rise buildings where many units are adjacent to each other. Most Asian countries including South Korea lack airtightness standards and data.

In addition, the measurement data or standards for low-rise dwellings of the United States, Canada, and Europe are not applicable. Therefore, airtightness data of high-rise residential buildings should be investigated to provide an airtightness standard.

This study presented the airtightness data and air leakage distributions of dwellings in 4 high-rise residential buildings in South Korea. Fan pressurization method with blower door was used to measure the airtightness value of about 350 dwellings, and the measurement results were compared with the standards of each nation. The airtightness of building components that form units of residential buildings—such as envelope, internal walls between dwellings units, and floor—were investigated.

TEST BUILDING DESCRIPTIONS

The core was located at the center of all the tested buildings, and hallways and each unite were on the surrounding plane. In addition, the floor structure was a flat slab, and walls between units and hallways were dry walls. Thus, compared to concrete walls, it is difficult for joints to be airtightly constructed in dry walls, which degrades airtightness. The exterior wall was a curtain wall type for buildings A and B and a punched window type for buildings C and D. The construction outline of the targeted building are summarizes in Table 1.



Building A | Building B | Building C | Building D

Figure 1. Building Plan

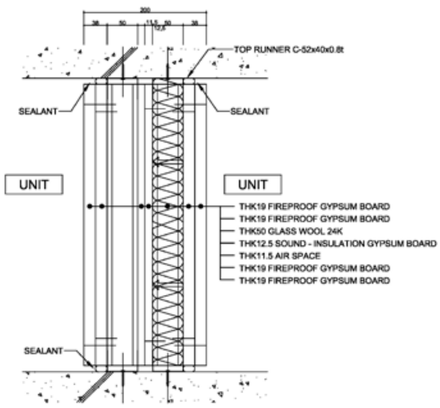


Figure 2. Structure of Dry Wall

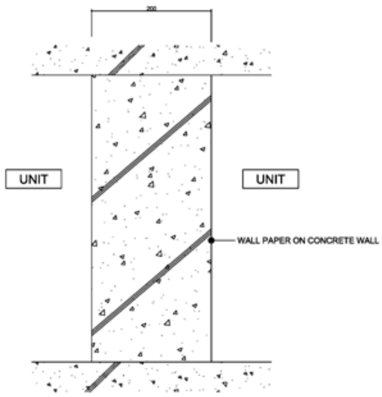


Figure 3. Structure of Conctre Wall

Classification	A	B	C	D
Building site	Incheon, SOUTH KOREA			
Construction	Flat Slab			
Number of stories	2 basements, 47 stories	2 basements, 42~49 stories	2 basements, 12~28 stories	2 basements, 11~33 stories
High	161.1	174.6	-	108.8
Building use	Multi-unit dwelling, commercial facility, neighbourhood living facility	Multi-unit dwelling, commercial facility, neighbourhood living facility	Multi-unit dwelling	Multi-unit dwelling
Exterior wall	Curtain wall type	Curtain wall type	Punched window type	Punched window type

Table 1. Test building summaries.

MEASUREMENT METHOD

The test conditions presented by the ATSM standard were followed to measure the airtightness of the unit and building components such as envelope, internal walls between dwelling units, floors, and ventilating equipment.

In order to measure the airtightness of a dwelling unit, a blower door was installed in the entrance door at each dwelling unit, and the pressure difference was controlled at 5–10-Pa intervals for measurement. In order to prevent the influence of the airtightness of adjacent units on the building, large openings (windows and doors) of units located above and below were left open so that the situation can be set based on ambient conditions. Building components were distinguished as envelope, internal walls between dwelling units, floors, and ventilating equipment for their air leakage distributions. In order to measure the airtightness of envelope, the airtightness data of envelope was measured two times (built condition and no air leakage condition). When the difference in the amount of air leakages is calculated before and after airtight processing, the airtightness of envelope could be identified. Airtightness of the ventilation equipment was measured with same.

To measure the internal walls between dwelling units and floors, two blower door sets were placed on either side of the measurement target. Then, pressurization and de-pressurization methods were conducted on the measured unit and adjacent units. If the pressure difference between the two dwelling units stayed at ±0 Pa, then air leakage did not occur from the measurement target. The amount of air leakage without air leakage through internal walls was measured. Finally, airtightness data of the internal walls were determined by the differences between in whole airtightness value of the dwelling unit and measured value without air leakage through internal walls.

MEASUREMENT RESULT

Analysis on airtightness of unit dwelling of each building

Measured ACH50 results for 350 dwellings of high-rise residential buildings are displayed in Figure 4, and the mean values for each building are marked. ACH50 range was about 1.9–3.8 for building A, 2.6–5.2 for building B, 1.4–3.8 for building C, and 1.4–3.7 for building D. Each the mean value was calculated as 3.1, 3.9, 2.5, and 2.3 ACH50 respectively. Thus, building D was the most airtight followed by buildings C, A, and B in order. Since the ground structure, internal walls between dwelling units, and ventilation types of the buildings were similar, the exterior wall was considered to be the factor with the greatest influence.

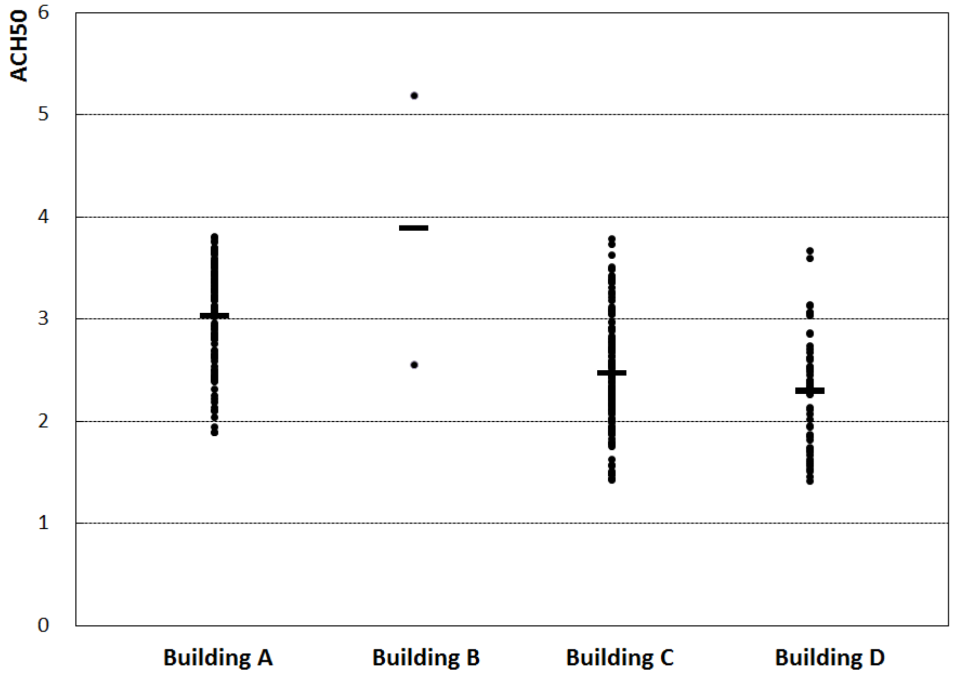


Figure 4. Results of airtightness for each building (ACH50)

When the four test buildings were evaluated according to the ASHRAE ventilation standard for residential buildings, they showed “airtight” or “quite airtight” level, which was sufficient airtight according to the standards of European nations such as Norway, the Netherlands, and Switzerland. However, the airtightness results were evaluated as insufficient airtight that is based on the standards for energy-conservative buildings such as the passive house of Germany and R-2000 of Canada. Figure 5 shows a comparison of airtightness of each nation’s standard and the test buildings in this measurement study.

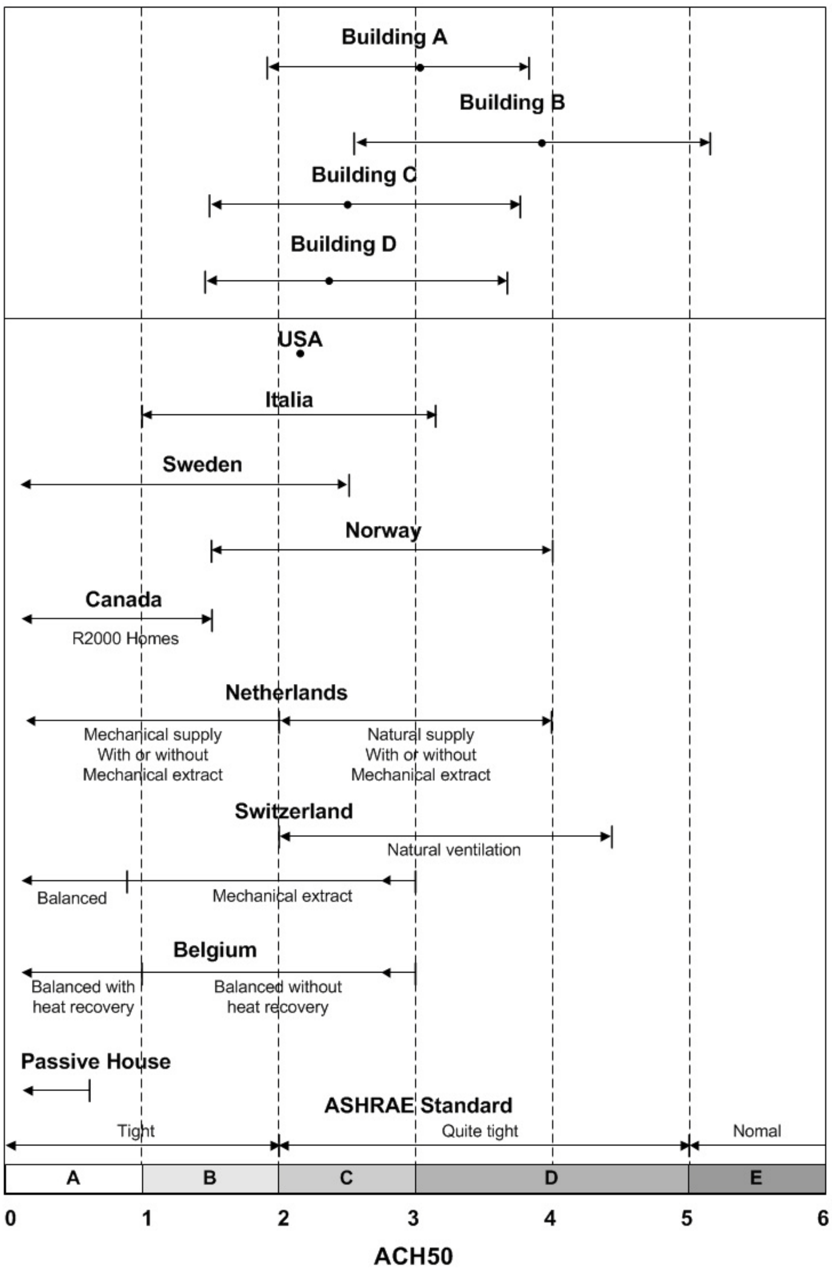


Figure 5. Comparison between measurement data and standard of each nation

Airtightness distributions of building components

The airtightness distribution of building components was measured for building A. Nine dwellings were targets for measurement in building A. Two dwelling types with general plans and one side facing the ambient were selected. Table 2 presents detailed information on the measured dwellings.

	Floor area (㎡)	**Floor height (m)**	**Unite envelope area (㎡)**	**Volume (㎥)**
Type 1	103.85	3.1	342.71	321.94
Type 2	132.53	3.1	418.17	410.84

Table 2.Test dwelling information

The airtightness measurement results were calculated as the air leakage distribution ratio for each building component and are summarized in Figure 6. The test residential units took up the highest amount of air leakage with 30%–58% of the overall amount of air leakage. Because of the trend of lighting structures of high-rise residential buildings, they were mainly constructed with dry walls. Thus, a great deal of air leakage occurred between wall joints or joints where columns and slabs came in contact with walls. The envelope took up 5%–30% of the overall air leakage of residential units. In addition, 3%–32% of air leakage occurred because of floors. Smoke inspection results showed that air leakage occurring from continuing curtain wall frames to adjacent dwellings. As a heat exchanger ventilation system was installed in the dwellings, the amount of air leakage coming through the ventilation equipment was 3%–19% of the overall air leakage of dwellings. The remaining 7%–30% of air leakage was considered to come from the entrance door of the each dwelling unit, equipment penetration, and electrical pipes. Further studies are needed to identify of specific air leakage areas as well as the air leakage distribution ratio.

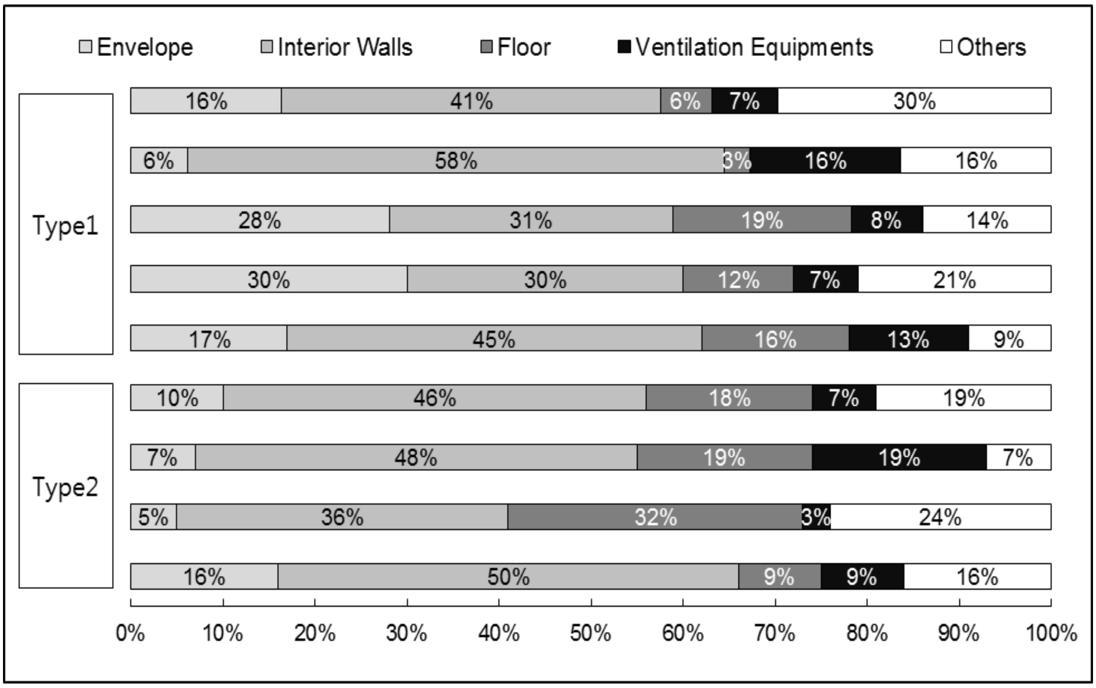


Figure 6. Infiltration (air leakage) distribution ratio for each building component

CONCLUSION

The airtightness data of 350 dwellings in 4 high-rise buildings in Korea was about 1.4–5.2 ACH50. Building A had an average ACH50 of 3.1, building B had an average ACH50 of 3.9, building C had an average ACH50 of 2.5, and building D had an average ACH50 of 2.3. The airtightness of the four test buildings was at the level of “quite airtight” and satisfied the standards of European nations such as Norway, the Netherlands, and Switzerland. By measuring the airtightness of building components of each dwelling and by calculating the air leakage distribution ratio to identify leaking parts where airtight-constructions are needed, the air leakage distribution ratio was determined to be the highest (31%–58%) for the internal walls between dwelling units. This is considered to be properties of high-rise residential buildings constructed with dry walls, and airtight construction is needed at internal walls between dwelling units.

ACKNOWLEDGEMENTS

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