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C71

Mind the Gaps: Improving Elevator Shaft Airtightness in Multi-Unit Residential Buildings

John Hoang
Student Member ASHRAE

Marianne Touchie, PhD, PEng
Full Member ASHRAE

ABSTRACT

As cities expand vertically, high-rise multi-unit residential buildings (MURBs) are becoming more popular forms of urban housing. Elevators are an essential part of vertical living but are also detrimental to building performance when it comes to uncontrolled airflow. Unlike stairway doors, which can be weather-stripped using conventional solutions, the mechanical nature of elevator doors makes standard air-tightening methods impractical. However, ensuring airtight elevator shafts in MURBs is essential for energy efficiency, occupant comfort, and safety. The goal of this paper is to demonstrate the impact of elevator shaft airtightness on building performance and provide potential solutions. Elevator shaft airtightness impacts energy efficiency and comfort in MURBs as these shafts can act as vertical conduits for smoke, fire, and conditioned air. Typical values for elevator shaft airtightness are presented, then these are compared with existing airtightness requirements, focusing on smoke and fire safety regulations, to highlight the importance of compliance with established standards. Existing solutions to improve elevator doors include vestibules which are widely used in commercial buildings. However, these are less common in residential buildings and cannot be implemented easily on all floor plate configurations due to the space requirements. Adopting different solutions, particularly in a retrofit context, such as fire curtains, high-speed roll-ups, and bi-fold doors could offer improvements without encroaching on the current common area floor space. This paper emphasizes the need for improved elevator shaft airtightness in MURBs and illustrates how improving elevator shaft airtightness can enhance energy efficiency, occupant comfort, and safety. Further research efforts should focus on investigating the feasibility of applying some of these alternative solutions to improve elevator door airtightness.

INTRODUCTION

According to the 2021 Canadian census, approximately 65% of all dwellings in Toronto are multi-unit residential buildings (MURBs), such as apartments, and this number is continuing to rise (Statistics Canada 2021). MURBs are the most prevalent housing solution as urban areas grow increasingly vertical. Elevators are an essential part of vertical living but are also detrimental to building performance when it comes to uncontrolled airflow. With unrestricted vertical airflow, elevator shafts act as conduits for smoke, fire, and unconditioned outdoor air between floors. Unlike stairwell doors, which can be weather-stripped using conventional solutions, the mechanical nature of elevator doors makes standard air-tightening methods impractical. From a fire safety and health perspective, elevator doors are an important line of defence in separating corridors and dwelling units from these vertical shafts. However, because the seal on elevator doors is often inadequate, the gaps in the doors can allow smoke to spread through the elevator shaft, contributing to the overall movement of smoke within the building. Currently, most elevator door designs lack any additional air barrier beyond the mechanical doors themselves, which means

John Hoang is an undergraduate student in the Department of Civil & Mineral Engineering, University of Toronto, Toronto, Canada. **Marianne Touchie** is an Associate Professor jointly appointed in the Department of Civil & Mineral Engineering and the Department of Mechanical & Industrial Engineering, University of Toronto, Toronto, Canada.

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there is potential to decrease the air leakage rates of elevator doors through additional means. This could contribute to improved energy efficiency, occupant comfort, and fire safety in the building. The primary aim of this paper is to investigate potential solutions to reduce the air leakage of elevator doors and pave a path for future research into this topic.

BACKGROUND

This section describes the implications of interzonal air movement in MURBs, typical air leakage rates of elevator doors, and the relevant building code considerations.

Interzonal Airtightness in MURBs

Increasing interzonal airtightness in MURBs has four major benefits: reduced odour/pollutant transfer, reduced sound transmission, improved energy efficiency, and reduced risk of pest transmission (Black 2009; Lozinsky and Touchie 2024). Each of these aspects is important to improve, as MURBs have many residences living near each other. Recent sequential pressure neutralization air leakage testing in six Southern Ontario MURBs showed that suite-to-corridor walls were significantly leakier than the floor/ceiling, suite-to-suite walls, or the building envelope (Lozinsky and Touchie 2023). While this needs to be addressed, along with suite door airtightness, elevator shaft air leakage is far more significant than air leakage at the suite boundary. For example, in one Canadian study, the mean leakage rate of the suite-to-corridor walls was 2.46 L/s/m^2 at 50 Pa (0.48 cfm/ft^2 at 0.20 in. of water), compared to elevator doors with 154 L/s/m^2 at 50 Pa (30.3 cfm/ft^2 at 0.20 in. of water) (Lozinsky and Touchie 2023; Tamura and Shaw 1976).

Elevator Door Airtightness

To understand the importance of elevator airtightness within MURBs, understanding the principles of air movement within a building is vital. Stack effect is a key driver of air movement in MURBs due to their height and vertical connectivity between floors. Equation (1) shows how the magnitude of stack-generated pressures is calculated based on building conditions including interior and exterior air densities, distance from the neutral pressure plane and the thermal draft coefficient.

$$\Delta P = 0.0342 \gamma H \rho_{air} \frac{\Delta T}{(T_i T_o)} \quad (1)$$

In this equation, the constant 0.0342 is a unit conversion to ensure that the resulting pressure difference is in Pascals when height is in meters, temperature in Kelvin, and air density in kg/m^3. The key variable that represents vertical connectivity and thus the impact of elevator door airtightness, is the thermal draft coefficient, γ. This dimensionless coefficient ranges from 0 to 1 and, as it decreases, it represents a greater level of vertical compartmentalization in a building or resistance to vertical air movement resulting in smaller stack effects. This variable is a way to characterize the effects of floor slabs and separation between floors and vertical chases. An elevator shaft represents a completely unobstructed vertical shaft which would contribute to a higher thermal draft coefficient, relative to a building that did not have an elevator shaft. Table 1 below summaries various elevator door air leakage rates at 75 Pa (0.30 in. of water) from three different studies ranging from 307-1156 L/s (650-2449cfm).

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Table 1 Elevator Door Air Leakage Rates at 75 Pa (0.30 in. of Water)

Source	Doors tested	Building type	Door dimensions m x m (ft x ft)	Comments	Air Leakage Rate L/s (cfm)
(Tamura and Shaw 1976)	7	Unspecified	1.07 x 2.13 (3.5' x 7')	Maximum	448 (949)
		Unspecified	1.07 x 2.13 (3.5' x 7')	Minimum	307 (650)
		Unspecified		Average	360 (763)
(Ricketts 2014)	3	Residential	Not specified	Average	612 (1297)
(Fang and Persily 1994)		Office	1.07 x 2.13 (3.5' x 7')	Door crack width of 6.8 mm	1006 (2132)
		Office	1.07 x 2.13 (3.5' x 7')	Door crack width of 5.8 mm	838 (1776)
		Office	1.07 x 2.13 (3.5' x 7')	Door crack width of 5.3 mm	357 (756)
		Office		Average of three above	734 (1555)
	1	Residential	Not specified		867 (1837)
	2	Office	Not specified		1156 (2449)

In this paper, when analyzing the air leakage rates, Equation 2 is used with a differential pressure of 75 Pa (0.30 in. of water) to compare the results to these elevator door air leakage rates (Tamura and Shaw 1976). The resulting volumetric flow rate, Q, is expressed in cubic meters per second, The effective air leakage area, A, is given in square meters, and the differential pressure is in Pascals. The flow coefficient, C, is assumed to be 0.6 and the flow exponent is assumed to be 0.5 to represent the dynamic pressure loss that is dominant through a sharp-edged orifice.

$$\boldsymbol{Q = CA\,[\frac{2}{\rho_{air}}(\Delta P)]^{0.5}} \tag{2}$$

Current Requirements and Building Codes

Elevators must adhere to various specifications and requirements to ensure safe operation, including four building code requirements related to elevator air sealing techniques and their interaction with existing systems. First, in CSA B44:22, which is the safety code for elevators and escalators in Canada, section 2.11.6.3 outlines that any additional doors or devices that are not part of and do not function with the elevator but that are provided in lieu of an enclosed elevator lobby to guard against the migration of smoke in or out of the hoistway shall comply with the building code and shall not interfere with the function and operation of the elevator (CSA Group 2022). Second, elevator designs should comply with CSA B651, the building code for accessible design for the built environment (CSA Group 2020). This means that any additional air barriers added to the elevator door must be accessible for everyone. Third, elevators should comply with building standards for air leakage rate and fire safety. In this case, UL 1784 mentions that the air leakage rate of the door assembly is not allowed to exceed 15 L/s/m^2 at 25 Pa (3 cfm/ft^2 at 0.10 in. of water) for both an ambient temperature test and an elevated temperature exposure test at 204 °C (400 °F) (UL 2025). For the purpose of this paper, the smoke control of the elevator doors must not be compromised by any additions to the elevator doors. Additionally, UL 10C, Standard for Positive Pressure Fire Tests of Door Assemblies, should be taken into consideration, particularly the fire ratings of elevator doors and related products. This ensures that any additions to elevator doors are fire-safe and free from flammable materials (UL 2021). Finally, like UL 10C, UL 10D for Fire Tests of Fire-Protective Curtain Assemblies should be considered if the products meet fire curtain-related standards (UL 2022). Any elevator airtightness improvements must adhere to these elevator specifications and building code sections.

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METHODOLOGY

This study evaluates the effectiveness of various recommendations using theoretical data from established standards rather than empirical or physical modeling. The primary goal is to provide a conceptual framework for understanding how elevator door airtightness can be improved with various potential solutions. To achieve this, the paper utilizes ASHRAE Standards 90.1, the 1997 ASHRAE Fundamentals Handbook which includes component-based air leakage data not available in the current version, and product data sheets to estimate potential air leakage rates. These standards and data sheets were used to determine the airtightness values based on previous studies and industry practices for proposed additions to elevator doors. While a physical or experimental data validation is beyond the scope of this study, the proposed methodology gives a sense of the potential impacts of the various recommendations for elevator door air tightness. For the purpose of this paper, a standard elevator door size of 1.07m wide by 2.13m tall (3.5’ wide by 7’ tall) will be used for all potential improvements to find their respective air leakage rates (Ozelift 2024).

The analysis follows a comparative approach, where proposed improvements are assessed against baseline values derived from the literature and presented in section Elevator Door Airtightness. Any recommendation that results in a lower air leakage rate than these typical values is considered an enhancement over current conditions. This evaluation assumes that the air leakage rates measured during product testing and under testing conditions accurately reflect the actual air leakage rates in real world scenarios, which of course, is not always the case. Additionally, this study acknowledges that airtightness levels may differ significantly across regions due to variations in building codes and construction habits. Future work is planned to incorporate regional data and real-world case studies to validate the theoretical findings presented here.

POTENTIAL IMPROVEMENTS

To address the challenges with elevator door air leakage, four potential improvements are presented. First, elevator vestibules are already a well-recognized solution but one inherent issue, particularly in a retrofit context, is the space requirement outside of the elevator doors. Second, smoke curtains can provide a low-profile solution. Additionally, taking inspiration from high-speed roll-up garage doors, employing a similar solution may also be an effective low-profile solution. Finally, utilizing conventional weatherstripping techniques on an additional set of bi-fold doors may offer another potential solution.

Vestibules

Elevator vestibules are small, enclosed rooms around the entrance to the elevator shaft. The main purpose is to act as a buffer zone between the elevator shaft and the rest of the building floor. Utilizing a double-door system, vestibules help to control airflow through the elevator door. This potential improvement recommends adding vestibules to every floor within a MURB. This will reduce the amount of shaft to corridor air leakage and overall improve the air tightness between each floor.

According to the 1997 ASHRAE Fundamentals Handbook, the best, minimum, and maximum effective air leakage areas (for low-rise residential applications) estimate for weather-stripped single doors is 12 cm^2 each, 4 cm^2 each, and 27 cm^2 each (1.86 in^2, 0.62 in^2, and 4.19 in^2), respectively (ASHRAE 1997). Adjusting the values to a typical elevator door size, the best potential air leakage rate is approximately 8 L/s at 75 Pa (17 cfm at 0.30 in. of water).

Elevator lobbies are often found in parking garages or on the main floor of a building but are less common on residential floors. According to ASHRAE 90.1, section 5.4.3.4.2, “Interior and exterior doors shall have a minimum distance between them of not less than 2.1m when in closed position. The floor area of each vestibule shall not exceed the greater of 5m^2 or 2% of the gross conditioned floor area for that level of the building” (ASHRAE 2022). Due to the minimum distance

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required between the elevator and outer doors, vestibules are extremely uncommon on residential floors. Within MURBs, space is a commodity, and this is especially true on the residential floors where developers want to maximize saleable floor space. From a design standpoint, this solution will add extra doors, potentially require more space based on the elevator layout, and potentially decrease accessibility to one's home from the elevator.

Ultimately, vestibules are a commonly used solution to improve elevator door airtightness and prevent elevator shaft-to-corridor airflow. However, they come with the inherent drawbacks of the space requirement and potentially being inconvenient to residents.

Figure 1 Exterior view of an elevator vestibule in the Myhal Centre's underground parking at the University of Toronto. The exterior self-closing door separates the building's environment from the parking garage (Trillium Group 2025).

Smoke Curtains

Smoke curtains may offer an elegant solution to the air tightness problem. Given the space constraints in MURBs, smoke curtains can be installed requiring virtually no additional space, unlike vestibules. There are a variety of products that offer this solution for elevator doors with retractable smoke curtains in the case of a fire outbreak. The design usually uses reinforced translucent material connected to flexible magnets strips. Attached to a rail system, the curtain quickly deploys along the rails at a closing speed of 0.15 m/s (6 in/sec) to create a tight seal. Some products require the user to push a button to automatically retract the engaged system. The entire system is fully automated but requires electricity to be connected to the emergency generator. Figure 2 shows how these devices can be deployed as an attachment to elevator doors.

According to product design specifications, smoke curtain products for elevators meets UL 1784 test standard of having an air leakage rate less than 15 L/s/m^2 at 25 Pa (3 cfm/ft^2 at 0.10 in. of water). Using the standard elevator door size as discussed in the Methodology section, the air leakage rate is 67 L/s at a pressure difference of 75 Pa (142 cfm at 0.30 in. of water). This product also meets UL 864, Standard for Control Units and Accessories for Fire Alarm Systems which means that product has sufficient fire resistance ratings and will not inhibit on the current elevator fire rating.

Given efficiency and effectiveness of smoke curtains, the adoption of smoke curtains may be an advantageous solution. Not only do smoke curtains require little to no extra space to install the additions, but they also improve air leakage and smoke control.

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Figure 2 Smoke curtains half deployed on an elevator door. This design uses a roll-up system with flexible magnetic strips attached to a translucent material (Smoke Guard 2025).

High-Speed Roll-ups

Another potential solution from inspired from parking garages is the high-speed roll-up door. Figure 3 shows a steel high-speed roll-up garage door installed in a MURB parking garage entrance. High-speed roll-up doors are often used in MURB parking garages to quickly open and close entrances for cars. This minimizes the amount of time a door is opened to reduce the amount conditioned air lost. From a design standpoint, this solution uses a similar approach as with the smoke curtains discussed before. The material, typically steel or fabric, is coiled up and can be rapidly deployed using rails aligned on both sides of the door.

As these doors are adapted from parking garage doors, the air leakage rate of 6.6 L/s/m^2 at 75 Pa (1.3 cfm/ft^2 at 0.30 in. of water) for non-swinging doors intended for vehicular access and material transportation with a minimum opening rate of 0.8 m/s from ASHRAE Standards 90.1, section 5.8.3.2 Maximum Air Leakage for Fenestration and Doors is used (ASHRAE 2022). Adjusting the values to the standard elevator door dimensions, the estimated air leakage rate is approximately 15 L/s at 75 Pa (32 cfm at 0.30 in. of water). Pre-existing high speed roll-up doors products meet both UL 1784 and UL 10B which means that the addition of these doors should not inhibit current systems for fire and smoke rating of the elevator doors (Bravura Architectural Products 2025).

With some modifications for indoor residential use, the inspiration of high-speed roll-up door from parking garages can be a potential solution for decreasing air leakage rates of elevator doors.

Figure 3 High-speed steel roll-up door, installed at parking garage (Rytec Doors 2025). The door mechanism rapidly opens and closes to allow for cars to enter and exit the parking garage.

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Bi-fold Doors

Although it may be challenging to directly weather-strip the elevator directly due to the mechanical nature of the elevator doors, adding a weather-stripped additional set of compact doors may make it possible. For example, having an automated set of bi-fold doors that run on a simple track system may allow for the integration of weather-stripping while taking up minimal space around the elevator entrance, as seen in Figure 4 below. Compared to a vestibule, which requires additional space to form the room, the bi-fold doors can be placed directly outboard of and in line with the elevator doors. Using a bi-fold design prevents the doors from significant outward swing out into the hallway which can be a hazard for residents in a narrow space.

According to the 1997 ASHRAE Fundamentals Handbook, the best, minimum, and maximum effective air leakage areas (for low-rise residential applications) estimate for weather-stripped double doors is 8 cm^2 each, 3 cm^2 each, and 23 cm^2 each (1.24 in^2, 0.47 in^2, and 3.57 in^2), respectively (ASHRAE 1997). Adjusting the values to a typical elevator door size, the best potential air leakage rate is approximately 12 L/s at 75 Pa (25 cfm at 0.30 in. of water). There is commercially available silicone rubber weather-stripping that meets UL 10B, UL 10C, and UL 1784 that can be used on fire-rated doors (McMaster-Carr 2025). With these fire-rated weather-stripping, the fire rating of the elevator door system should not be impeded on.

The additional set of weather-stripped doors can provide a substantial improvement to the air leakage rates of elevator doors while meeting necessary fire-ratings to not inhibit the integrity of the system.

Figure 4 Example of an automated glazed bi-fold door that has weather stripping along the sides of the doors (Label Spa 2025).

DISCUSSION

After investigating each of the potential recommendations for elevator door additions, they have promising results. Table 2 compares the elevator door airtightness data, where the door dimensions were specified (1.07m x 2.13 m [3.5’ x 7’]), with the potential improvements, calculated based on the same door size.

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Table 2. Summary of Potential Air Tightness Improvement Measures on Standard Elevator Door at Standard Pressure Difference of 75Pa (0.30 in. of water)

Potential Improvements	Air Leakage Rate L/s (cfm)
No Change	307-1006 (650-2132)
Vestibule	8 (17)
Smoke Curtain	67 (142)
High-Speed Roll-ups	15 (32)
Bi-fold Doors	12 (25)

Comparing each of these air leakage rates to the air leakage data from previous elevator door testing which ranged between 307-1006 L/s at 75 Pa (650-2132 cfm at 0.30 in. of water), it is clear that any implementation of the proposed solutions has the potential to significantly decrease the airflow rate at the elevator door. Even the least effective solution, the smoke curtain, reduces the air leakage rate by about 93% compared to the tested elevator door air leakage rates however, these solutions should be further investigated and tested to evaluate operation time, reliability and feasibility of installation.

CONCLUSION

This paper investigated possible recommendations to reduce elevator door air leakage through four alternative door additions. To achieve the full benefits of reduced elevator door airtightness, these solutions would need to be installed on every elevator door and floor. The recommendations range from vestibule spaces which are common in parking garages to smoke curtains with magnetic strips, high-speed roll-up doors inspired by parking garages, and a weather-stripped bi-fold double door, any of which have the potential to reduce elevator door airflow rates by over 90%.

Although these recommendations seem promising, further research is required to see if they are practical in the field. The operational constraints of each of these recommendations should be further investigated including whether all materials meet fire rating requirements, whether the doors can operate quickly and reliably and how each solution can be installed.

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NOMENCLATURE

$\boldsymbol{A}$ = *Effective air leakage area (m^2)*
$\boldsymbol{C}$ = *Flow coefficient (dimensionless)*
$\boldsymbol{H}$ = *Height (m)*
$\boldsymbol{Q}$ = *Volumetric flow rate (m^3/s)*
$\boldsymbol{T_i}$ = *Indoor air temperature (K)*
$\boldsymbol{T_o}$ = *Outdoor air temperature (K)*
$\Delta\boldsymbol{P}$ = *Differential pressure (Pa)*
$\boldsymbol{\Delta T}$ = *Differential temperature from indoor and outdoor (K)*
$\boldsymbol{\gamma}$ = *Thermal draft coefficient (dimensionless)*
$\boldsymbol{\rho_{air}}$ = *Density of air, 1.225 kg/m^3*

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