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Changes in air leakage levels of six Canadian office buildings

Old office buildings can be successfully retrofitted to improve their airtightness and reduce their energy consumption

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With a long severe winter, most Canadian buildings will likely experience some deterioration of their envelopes as they age. As air leakage is now suspected to be the major cause for such deterioration, it is common for airtightening to be included in the repairs of such buildings.

In addition, because of its direct relationship with energy usage, airtightening is also usually included in energy conservation retrofits of existing buildings. As a result, the airtightness of old buildings can be very much different from when they were new.

About 20 years ago, eight new office buildings in the Ottawa area were tested to measure their air leakage characteristics.[1,2] Because these and many other buildings of similar age are still in use, a follow-up fan pressurization test was conducted in 1991 on six of the eight buildings to determine the changes in the airtightness levels of such buildings.

The objectives of the 1991 test were:

- To determine the changes in the buildings' airtightness characteristics because of applied retrofit measures (if applicable); and
- To assess the potential for retrofitting old office buildings in Canada.

This article briefly describes the 1991 test procedures and the test results. As mentioned, six buildings in the Ottawa area were tested. These are identified as Buildings A, B, D, E, F and G.[2] These buildings, which are 10 to 26 stories high, were built between 1964 and 1974, and they were previously tested between 1970 and 1974. A detailed description of the buildings is given in *Table 1*.

Table 1. Description of Test Buildings

Building	A	B	D	E	F	G
Year built	1970	1964	1971	1968	1973	1974
No. of typical floors	9	17	20	21	16	25
Area, m² (ft²)	3264 (35,137)	1161 (12,498)	644 (6,932)	1200 (12,917)	1400 (15,070)	1628 (17,525)
Window area (% wall area)	38	33	26	35	52	26
Ratio of roof to total wall	31%	12%	8%	11%	15%	11%
Window type	Fixed sealed double glazing	Openable sealed double glazing	Fixed sealed double glazing	Fixed sealed double glazing	Fixed sealed double glazing	Fixed sealed double glazing
Wall construction	1	2	3	4	5	6

1. *Precast concrete; 203 mm (8 in.) tile; 51 mm (2 in.) insulation; air space; 152 mm (6 in.) tile; plaster*
2. *Precast concrete panel; 51 mm (2 in.) tile; insulation*
3. *Metal panel; air space; 51 mm (2 in.) insulation; 508 mm (20 in.) concrete*
4. *Metal panel; 51 mm (2 in.) insulation*
5. *Precast concrete panel; 25 mm (1 in.) insulation*
6. *Precast concrete panel; 25 mm (1 in.) insulation*

About the authors

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Measurement method

The test method for the 1991 test was the same as that developed for the original studies.[1,2] Briefly, it involves pressurizing the test building using the building's supply air systems with 100% outside air (*Figure 1*).

All the return and exhaust fans are turned off during the test. Supply airflow rates are varied and the corresponding pressure differences created across the building envelope at the ground and roof levels are measured and recorded.

The air leakage characteristics of the test buildings are then determined by plotting the airflow rates against the average value of the pressure differences measured at the ground and roof levels. The detailed test procedures are included in Shaw[1] and Tamura and Shaw.[2]

Results and discussion

Figure 2 and *Figure 3* show the previous and current measured overall airtightness values of the six buildings, respectively. Except for Building A, all data lie within a narrow band.

Building A is only half as high as the other buildings and its roof area is about twice that of the other buildings. Therefore, the leakage through the roof and basement may play a larger role in Building A's overall air leakage than in the other buildings.

For this reason, Building A may not be representative of the same category of tall buildings as the others that typically have a smaller roof-to-wall area ratio (see *Table 1*).

Ignoring Building A, the data were fitted to the standard air leakage equation with a flow exponent of 0.65:[2]

$$Q = CA\,(\Delta P)^{0.65}$$

where,

Q = overall airtightness value, L/s (cfm)

C = flow coefficient, $L/s \cdot m^2 \cdot (Pa)^{0.65}$ [$cfm/ft^2 \cdot (in.\ water)^{0.65}$]

A = area of exterior wall, m^2 (ft^2)

ΔP = pressure difference across envelope, Pa (in. water)

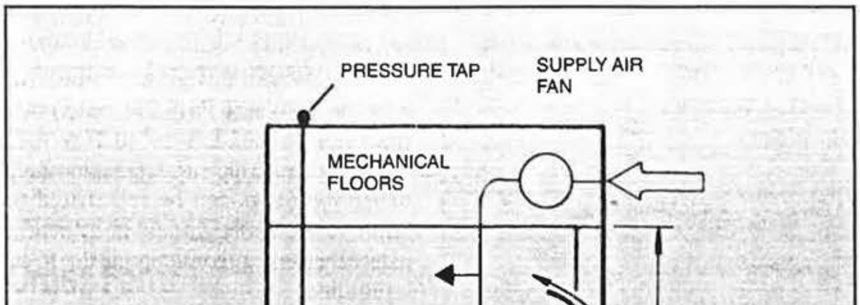

Figure 1. Text building set-up

Three curves were obtained, representing the lower and upper limits and the average value. The values of the flow coefficient for the lower limit, average value and the upper limit were 0.106, 0.147 and 0.205 $L/s \cdot m^2 \cdot (Pa)^{0.65}$, respectively. In English units of measurement, the values were 0.753, 1.045 and 1.457 $cfm/ft^2 \cdot (in.\ water)^{0.65}$, respectively.

For comparison, the corresponding flow coefficients for the previous study were 0.137, 0.185 and 0.249 $L/s \cdot m^2 \cdot (Pa)^{0.65}$ respectively. In English units of measurement, the values were 0.974, 1.315 and 1.770 $cfm/ft^2 \cdot (in.\ water)^{0.65}$ respectively.

The upper limits shown in *Figure 2* and *Figure 3*, which appear to be too high, are the result of fitting the data to the air leakage equation with a constant exponent, 0.65.

The above coefficients can be used by designers to estimate air infiltration rates for heating load, cooling load or energy consumption calculations. They also provide a realistic basis for establishing an achievable airtightness criterion for office buildings.

To determine the changes in airtightness, the previous and current measured overall airtightness values of each building at 50 Pa (0.2 in. water) and the differences between the two tests are compared in *Table 2*.

The results indicate that, except for Building F, the building envelopes are more airtight now than 20 years ago. The improvement in the overall airtightness value at 50 Pa (0.2 in. water) ranges from 0% to 43.3% of the original value.

Discussions with the property managers and building engineers indicate that, except for Building F, Buildings B and D have been extensively retrofitted to improve airtightness. The other three buildings have also been partially retrofitted. The following summarizes the retrofit measures applied to improve the buildings' airtightness.

- Building A: A new vapor barrier with 100 mm (4 in.) thick rigid insulation was installed for the 10th floor and part of the 9th floor.

Changes in air leakage levels

• Building B: All windows were recaulked and resealed. All vertical columns were sealed from the inside.

• Building D: The metal panel was replaced with a new curtainwall cladding system.

• Building E: All joints in the curtainwall were recaulked.

• Building F: No retrofit measures were applied.

• Building G: A new roof was installed.

The degree of improvement appears to depend on the extent of the retrofit and how airtight the building was prior to the retrofit. The results also indicate that Building F is now 23% leakier than 20 years ago.

The airtightness of Building E has not changed, even though it was recently retrofitted. Therefore, it is expected that this building would have been much leakier than before if it had not been retrofitted.

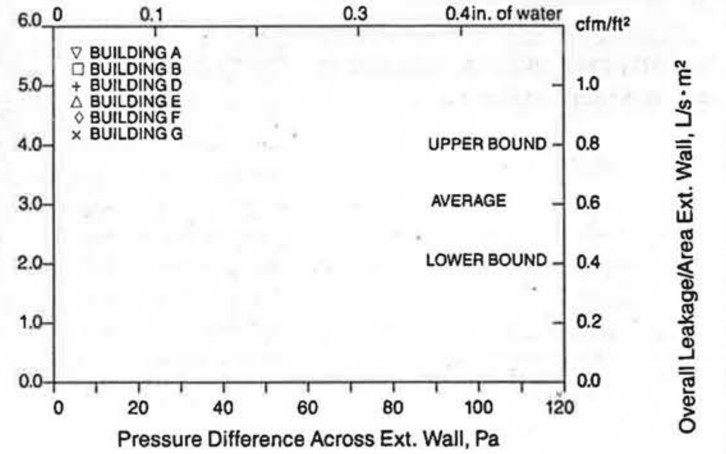

Figure 2. Previous airtightness values for all buildings.

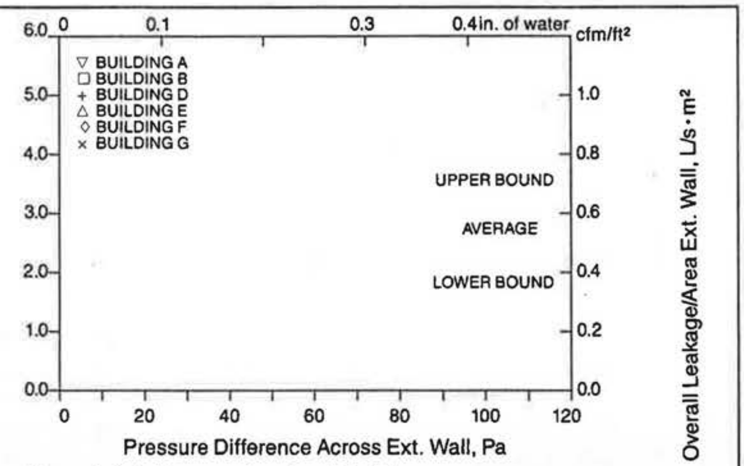

Figure 3. Present airtightness values for all buildings.

Table 2. Overall Airtightness Values per Unit Area of Exterior Wall at 50 Pa

Building	Previous Result q_o L/s·m²	[cfm/ft²]	Present Result q_n L/s·m²	[cfm/ft²]	Changes $(q_n - q_o)/q_o$
F	1.73	[0.34]	2.13	[0.42]	23.1%
E	1.81	[0.36]	1.81	[0.36]	0
A	4.85	[0.95]	3.65	[0.72]	−24.7%
G	2.49	[0.49]	1.80	[0.35]	−27.7%
B	2.17	[0.43]	1.36	[0.27]	−37.3%
D	2.54	[0.50]	1.44	[0.28]	−43.3%

Summary

Six Canadian office buildings that were tested 20 years ago were retested to determine the changes in their airtightness levels. Of the six buildings, five had been retrofitted to improve airtightness.

Building F was the only one of the six that has not been retrofitted. It is now 23% leakier than it was 20 years ago.

The other five buildings have all been retrofitted in different ways and, consequently, they are more airtight now than 20 years ago. The exception is Building E, whose airtightness has not changed even though all joints in its curtainwall were recaulked.

Thus, the improvements in overall airtightness values at 50 Pa (0.2 in. water) range from 0% to 43.3% of the original value, depending on the extent of the retrofit and how airtight the building was originally.

The overall airtightness values of these buildings at 50 Pa (0.2 in. water) vary from 1.36 to 3.65 L/s·m² (0.27 to 0.72 cfm/ft²). The results suggest that most old office buildings can be retrofitted to improve their airtightness and, hence, reduce their energy consumption due to air infiltration.

The results can be used by designers to estimate air infiltration rates for heating and cooling load or energy consumption calculations. They also provide a realistic basis for establishing an achievable airtightness criterion for office buildings in cold climates, particularly for those buildings that are to be retrofitted.

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