Airtightness Testing of Occupied, Multi-Unit Residential Buildings (MURBs) - Lessons Learned

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Presentation Outline

- Background – Airtightness Work at RRC
- Project Objectives
- Phase 1 and 2 Results
- Observations
- Conclusions

Introduction

Rob Spewak, M.Sc. - Building Envelope Technology Access Centre (BETAC) Centre Manager

- Senior Research Manager, AR&C, 2007 – 2015
  - Co-ordinate applied research projects between external industry partners and internal RRC staff, faculty and students
  - Primary focus on growing research enterprise for energy efficiency of large buildings
- Transition to BETAC Centre Manager – full time as of July 1, 2015

Building Research

Evolution of Airtightness Testing at RRC/BETAC

- NSERC-IE Grant: “Improving the Energy Performance of Buildings”
  - Focus on commercial/institutional buildings – reduce energy usage through expanded use of renewables, embodied energy, performance monitoring, etc.
  - Airtightness testing - Proskiw Engineering report - #1 ranked topic/project of interest
  - Acquisition of blower door equipment through NSERC – ARTI grant

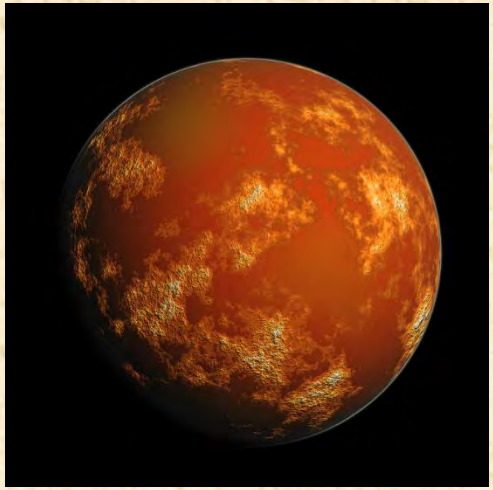
Building Research

Research Location

Climate/Location – Manitoba has extreme conditions - excellent "outdoor laboratory", and a diverse building stock that includes many heritage buildings

Dec.31, 2013 (daytime temps)

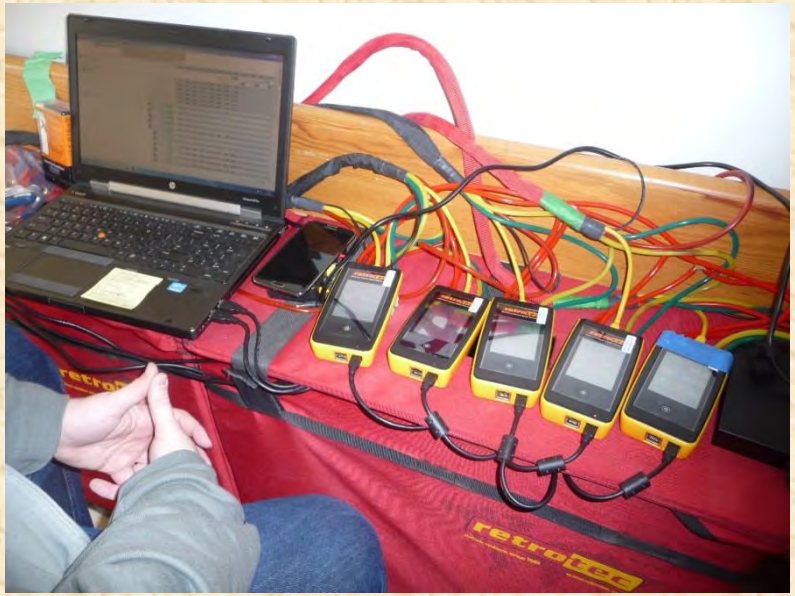
Mars: -29°C



Winnipeg: -37.9°C

Building Research

NSERC-IE Grant: Building Envelope Projects - Investigation of Air Leakage in Manitoba's Commercial Building Sector



Project funding – Manitoba Hydro ($66k)

Building Research

NSERC-IE Grant: Building Envelope Projects - Investigation of Air Leakage in Manitoba's Commercial Building Sector

- 26 buildings across Manitoba
- From new construction to 100 years +
  - 5 New construction
  - 11 Warehouses/light industrial
  - 7 Office buildings
  - 4 Schools
  - 2 Churches
  - 2 Greenhouses
  - 3 Retrofits

Building Research

NSERC-IE Grant: Building Envelope Projects - Investigation of Air Leakage in Manitoba's Commercial Building Sector

Building Research

NSERC – IE GRANT → BETAC BUILDING ENVELOPE TECHNOLOGY ACCESS CENTRE

NSERC Technology Access Centre (TAC) Program

- Centre affiliated with Canadian college or cégep
- Securing of additional funds from Canada Mortgage and Housing Corporation (CMHC) to study airtightness testing in MURBS - 2014

MURB Airtightness Testing

Objective of testing MURBs

- Address three issues:
  - Is an accurate test possible with closed interior suite doors?
  - If windows are open in suites, can accurate results be obtained?
  - Is it possible to control access to building (tenants and others) during the time it takes to conduct the test?

MURB Testing

Project overview

- Phase 1
  - Field trials on unoccupied MURBs
  - Explore issues with open or closed doors and windows
  - Develop correction factor for MURB testing with closed doors
- Phase 2
  - Field trials on occupied MURBs
  - Evaluate practicality of testing with closed suite doors

Airtightness Metrics

Air Change Rate at 50 Pa

$$ACH_{50} = \frac{Total\ Air\ Leakage\ Rate\ per\ hour\ at\ 50\ Pa}{Building\ Volume}$$

$$= (Q_{50} \times 60) / V$$

where:

Q_{50} = Air leakage rate at 50 Pa (m^3/min)

V = Building volume (m^3)

Airtightness Metrics

Normalized leakage rate at 75 Pa

$$NLR_{75} = \frac{Total\ Air\ Leakage\ Rate\ at\ per\ hour\ at\ 75\ Pa}{Envelope\ Area}$$

$$= (Q_{75} \times 60) / A$$

where:

Q_{75} = Air leakage rate at 75 Pa (m^3/min)

V = Building envelope area (m^2)

Unoccupied MURB Testing

Phase 1 – Building #1

- Rural, unoccupied MURB
  - 39-year old, single-storey building with a large central common area and 15 individual suites (each with two doors - one to the common area and one to the outdoors)

Unoccupied MURB Testing

Phase 1 – Building #1 Test Results

Test	Interior Doors	Open Window	Depressurization			Pressurization		
			C (l/s•Pa^n)	n	r	C (l/s•Pa^n)	n	r
1-1	Open	No	189	0.6687	0.9972	97	0.8566	0.9919
1-2	Open	Yes	2282	0.0664	0.1315	5144	0.1380	0.2430
1-3	Open	Yes	1382	0.1957	0.3272	1,108,868	-1.5365	0.4298
1-4	Open	No	250	0.6043	0.9922	272	0.5960	0.9972
1-5	Closed	No	217	0.6223	0.9945	261	0.5924	0.9950

Unoccupied MURB Testing

Phase 1 – Building #2

- Winnipeg MURB, under renovations and occupied only by single tenant and small number of workers
  - 35-year old, six-storey structure with 124 suites and a common area.

Unoccupied MURB Testing

Phase 1 – Building #2 Test Results

Test	Interior Doors	Open Window	Depressurization			Pressurization		
			C (l/s•Pa^n)	n	r	C (l/s•Pa^n)	n	r
2-1	Open	No	587	0.6298	0.9984	435	0.7006	0.9980
2-2	Closed	No	633	0.5943	0.9985	386	0.7300	0.9952
2-3	Closed	Yes	737	0.6656	0.9968	744	0.6679	0.9989
2-4	Closed	Yes	533	0.6910	0.9969	336	0.7993	0.9919
2-5	Open	No	608	0.6411	0.9928	737	0.6542	0.9825
2-6	Closed	No	511	0.6729	0.9913	785	0.6273	0.9730
2-7	Closed	Yes	850	0.6263	0.9963	-	-	-
2.8	Closed	Yes	451	0.7486	0.9904	-	-	-
2-9	Closed	No	483	0.6815	0.9975	493	0.7132	0.9884

Unoccupied MURB Testing

Open Windows – Effect on Tests

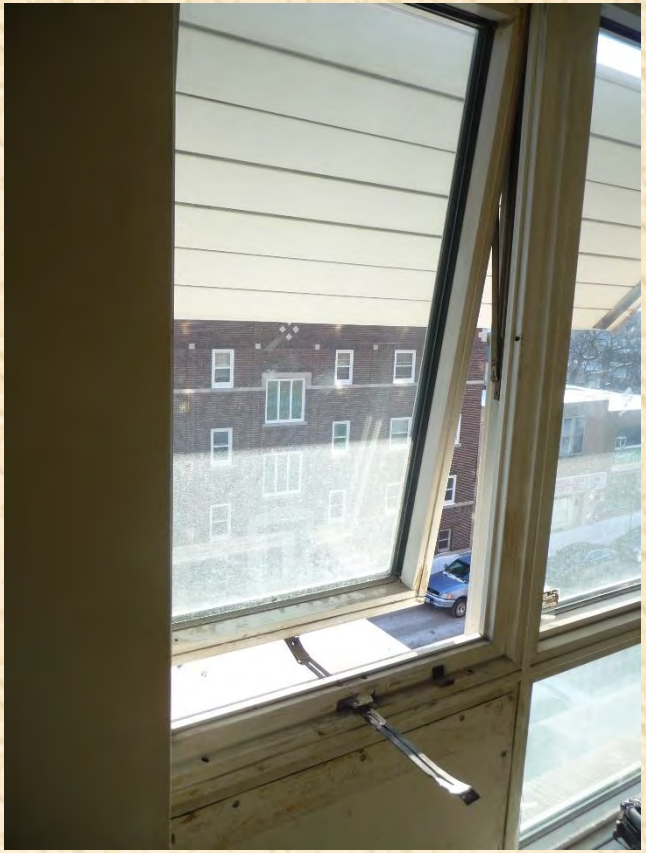
- Building #1
  - Flow coefficients (C) dramatically higher than anticipated
  - flow exponents (n) and correlation coefficients (r) far below acceptable minimums.

- Building #2
  - Number of open windows based on observations by Proskiw and Phillips (2006)
  - Significant change in NLR75 and ACH50 (more pronounced for envelope test vs. energy test)

Unoccupied MURB Testing

Open Windows – Effect on Tests

- Building #2 – pressurization only due to window operation



Unoccupied MURB Testing

Phase 1 – Air Leakage Data

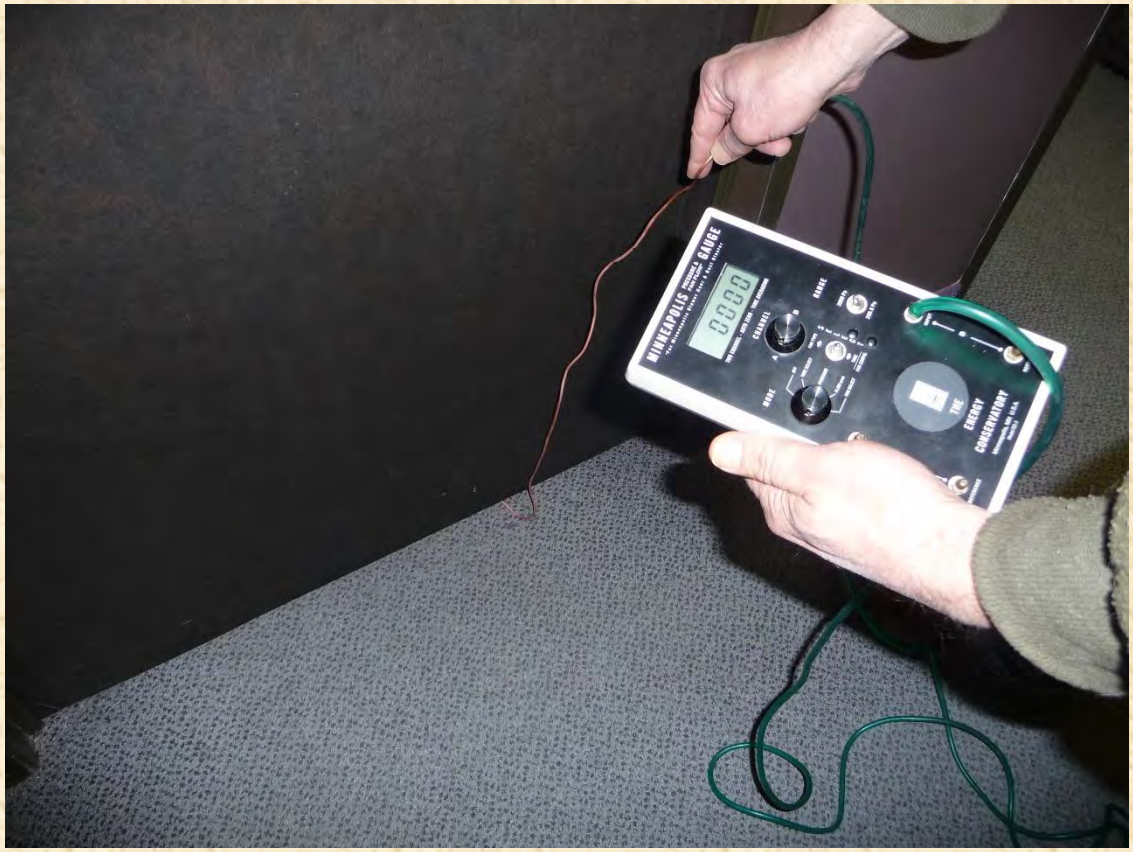
- Additional building – 55 unit rural Manitoba Housing MURB
- Not part of project, however leveraged opportunity to gather data for correction factor

Building	NLR75		NLR75 Reduction		ac/hr50		ac/hr50 Reduction		ΔPdoors/ ΔPtotal
	Doors Open	Doors Closed	Absolute	Percent	Doors Open	Doors Closed	Absolute	Percent	
Building #1	1.37	1.28	0.09	6.6%	3.83	3.60	0.23	6.0%	20.5%
Building #2	1.67	1.62	0.05	3.0%	1.40	1.35	0.05	3.6%	8.8%
55 unit MURB	1.32	1.30	0.02	1.5%	1.40	1.32	0.08	5.7%	12.8%

Unoccupied MURB Testing

Development of Correction factor

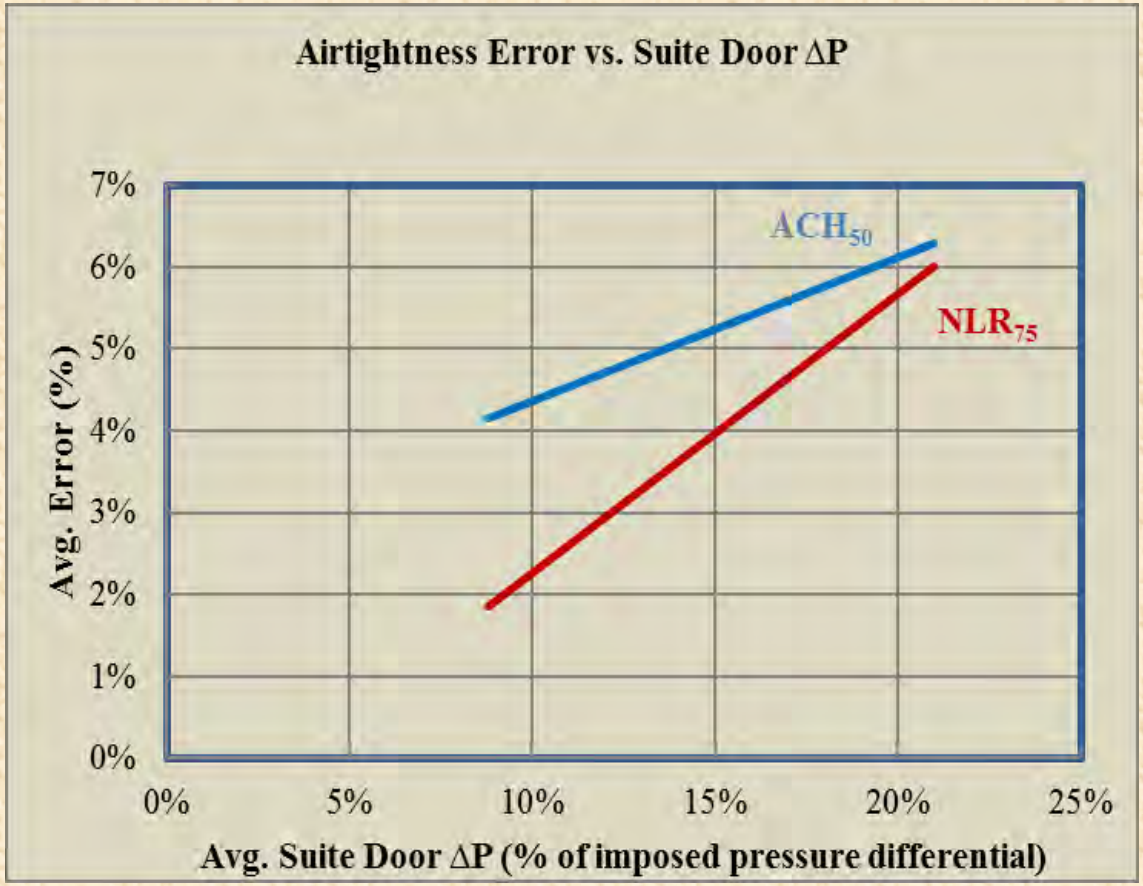
- Measurement of pressure drop across closed suite doors



Unoccupied MURB Testing

Development of Correction factor

- Regression (k) graph



Unoccupied MURB Testing

Development of Correction factor

$$\boldsymbol{corrected\ NLR_{75} = (measured\ NLR_{75}) \times K1}$$

Where $\boldsymbol{K1 = 1 + [0.341\ (\Delta P/75) - 0.0115]}$

$$\boldsymbol{corrected\ ACH_{50} = (measured\ ACH_{50}) \times K2}$$

Where $\boldsymbol{K2 = 1 + [0.1752\ (\Delta P/75) + 0.0261]}$

and $\boldsymbol{\Delta P}$ **= average pressure differential across the suite doors (in Pascals)**

Occupied MURB Testing

Phase 2 – Four Occupied Buildings

Occupied MURB Testing

Phase 2 Observations – Planning and Coordination

- Efficient, disciplined procedure needed to minimize tenant inconvenience
- Cooperation of property manager – communication to tenants
- Building visitors – essential services (home care staff, cleaning, post delivery, repair/maintenance staff)
- Mechanical system – if need to be disabled, can become health concern

Occupied MURB Testing

Phase 2 Observations – Field Experiences

- Windows
  - hardware issues for locking in closed position
  - Windows opening during pressurization test
  - Some tenants not physically capable of closing
- Tripped circuit breakers for powering fans
- Tenants
  - Mostly cooperative
  - Some repeatedly disruptive (opening windows, exiting to smoking area)
    - Communication – English not spoken or written
    - Short-term memory loss in some tenants

Occupied MURB Testing

Phase 2 Observations – Other Issues

- Some tenants and less experienced testing personnel did not inform when entering/exiting building
- On-site communication
  - Large buildings, many team members
  - Cell phones work, but…
    - Signal issues
    - Battery life
    - Sharing of phone numbers, time to connect and relay info
  - Two-way radios may be a solution

Occupied MURB Testing

Conclusions

- Error introduced by closed interior doors can be corrected by applying correction factor
- Windows must be kept closed during tests
  - Modest amount of open windows can invalidate results
- Owner cooperation/participation is essential
  - Must be established long before test takes place
- Communication is KEY – not only between building owners and tenants, but also among testing personnel

Occupied MURB Testing

Future Recommendations

- Increase sample size of buildings tested in open and closed door configurations
- Increased training for large building airtightness testing
  - Air Barrier Association of America standard – now an ASTM work item

Occupied MURB Testing

Acknowledgments

- Natural Sciences and Engineering Research Council (NSERC)
- Canada Housing and Mortgage Corporation (CMHC)
- Manitoba Hydro
- Manitoba Housing
- Tenants and maintenance staff for all buildings
- Airtightness testing personnel

THANK YOU!

www.rrc.ca/betac

http://tech-access.ca/

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