ASHRAE VIRTUAL WINTER CONFERENCE

February 9-11, 2021

Seminar 49 – Easier said than done: Controlling air movement in high-rise multi-family buildings

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Suite-based Air Leakage Characteristics of New and Old Multi-Unit Residential Buildings

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There is a lot of talk about air leakage compliance testing these days so I wanted to take today's presentation to share with you some of the specific and unique challenges we face with respect to air leakage testing in both new and existing multi unit residential buildings.

Learning Objectives

1. Discuss how to use building depressurization techniques, fan-compensated flow measurements, and differential tracer gas methods to assess component air leakage, ventilation system performance, and inter-suite pollutant transport.
2. Describe the effects of building configuration and mechanical system design intent as well as weather and occupant operational decisions on actual suite ventilation.
3. Discuss the consequences of uncontrolled air flow in apartment buildings.
4. Explain the opportunities to improve suite ventilation in existing buildings.

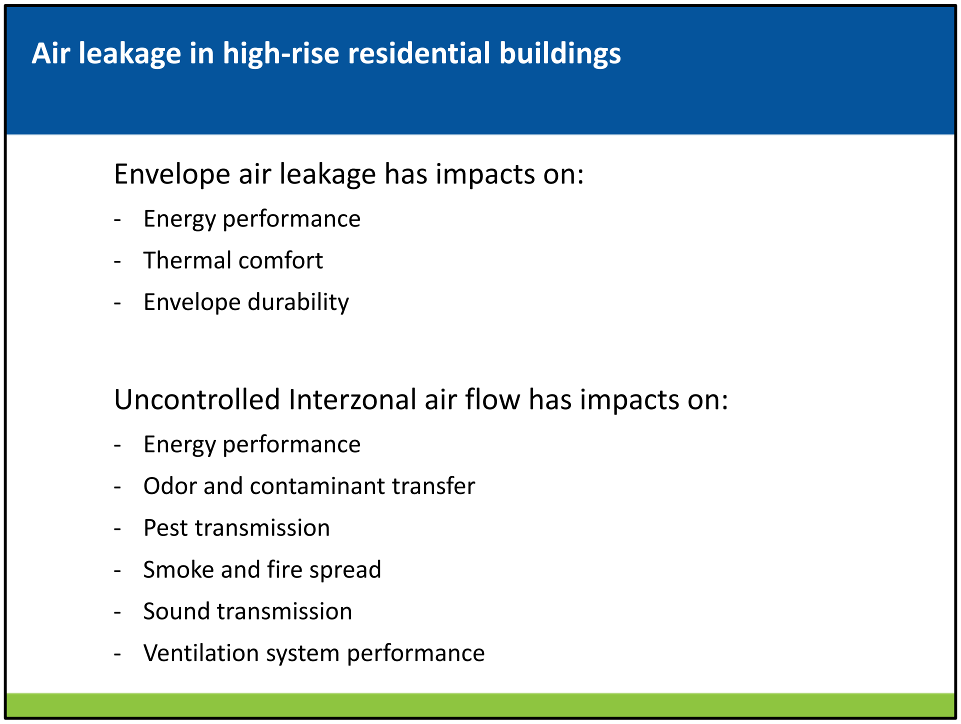
Acknowledgements

The presenter wishes to acknowledge the work of PhD Candidate Cara Lozinsky, post-doctoral fellow Jamie Fine, former MASc students Xinxiu Tian and Jason Gray and summer student Ivan Prijono from the University of Toronto. All of these individuals have contributed to the work presented here.

The presenter also wishes to acknowledge the funding provided by the ASHRAE New Investigator Award and from the Natural Science and Engineering Research Council of Canada (RGPIN-2016-06234)

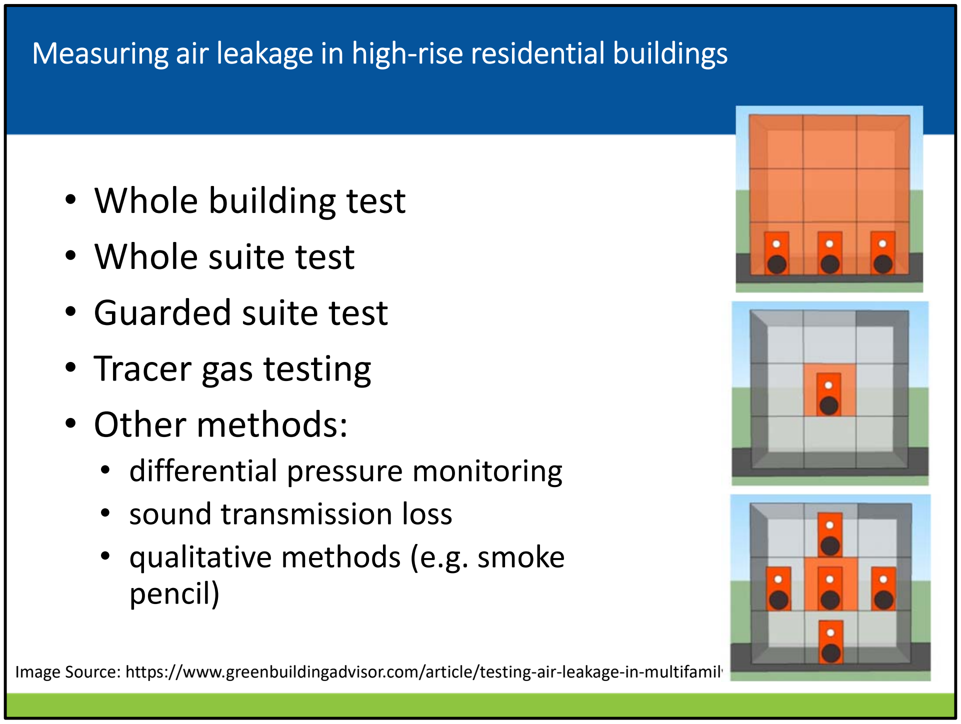
Outline/Agenda

- Importance of quantifying air leakage in high-rise residential buildings
- Measuring air leakage in high-rise residential buildings
- Existing air leakage standards
- Results of Field testing in Toronto, Canada
- Future Research



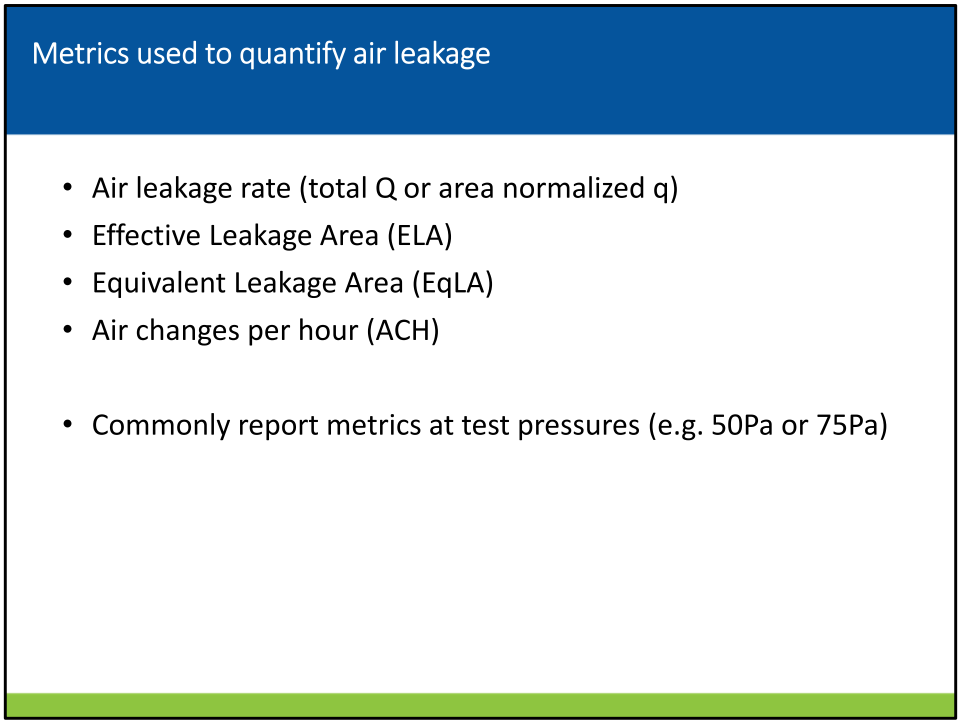
- We know that air leakage can impact building energy performance and the durability of our building envelope and we also know that the effects of wind and stack increase with building height so that our taller buildings are often subjected to more significant uncontrolled air leakage than low rise buildings.
- However, our focus on air leakage is often only on the building envelope
- The reality is that, interzonal air leakage can have a significant impact on many aspects of building

performance. These performance impacts are particularly important in a multi-family context where occupants have a great deal of control over things like window and fan operation, cooking, showering etc.



- Whole building test: difficult, time-consuming, requires multiple operators, only gets us exterior envelope air leakage
- Whole suite test:
  - o most common in MURBs, easy, quick and inexpensive
  - o just as you would conduct this test in a single family home but with the blower door in the suite door.
  - o There are a number of standards that describe this method (*ASTM E779*; *CAN/CGSB 149.10-M86*; *ISO 9972* (aka, *EN 13829*); *ANSI/RESNET/ ICC 380*; and the *United States Army Corps of Engineers Air Leakage Test Protocol for Building Envelopes*.)
  - o Drawback: can't separate interzonal from envelope
- Guarded test:
  - o can be used to separate interzonal air leakage from envelope air leakage, if each side of the suite is neutralized sequentially, can determine how leaky each partition is
  - o no standard test method so researchers typically adapt their methodology from
  - o prone to large errors due to the small air flow rates through individual partitions
  - o incredibly time-consuming, disruptive, expensive, and difficult to execute properly.

- Tracer gas techniques:
  - uses inert or non reactive gases to tag the air in different zones.
  - Described more fully in ASTM E741.
  - Useful for determining inter-suite air exchange but cannot characterize air leakage paths the way the other methods do.
  - based on our own MURB experience, this is must be conducted under relatively steady state conditions so very difficult to do in occupied buildings



- air leakage testing is typically conducted at differential air pressures much higher than ambient operating conditions
- Many of the metrics are also reported as such (e.g. at standard test pressures of 50 or 75Pa), this is usually denoted as a subscript on the relevant metric
  - Air leakage rate: Either presented as total air leakage Q or area-normalized for easier comparison between buildings or suites
  - ELA: an effective leakage area that would yield the same flow rate as the actual building assuming that the collection of leakage paths were represented by a single sharp-edged orifice (n=0.5, discharge coefficient = 1), presented at a reference pressure of 4Pa
  - EqLA: same as above but with a discharge coefficient of 0.611 and presented at a reference pressure of 10Pa
  - ACH: time required to completely replace the air in the zone, often presented at test pressure of 50Pa,
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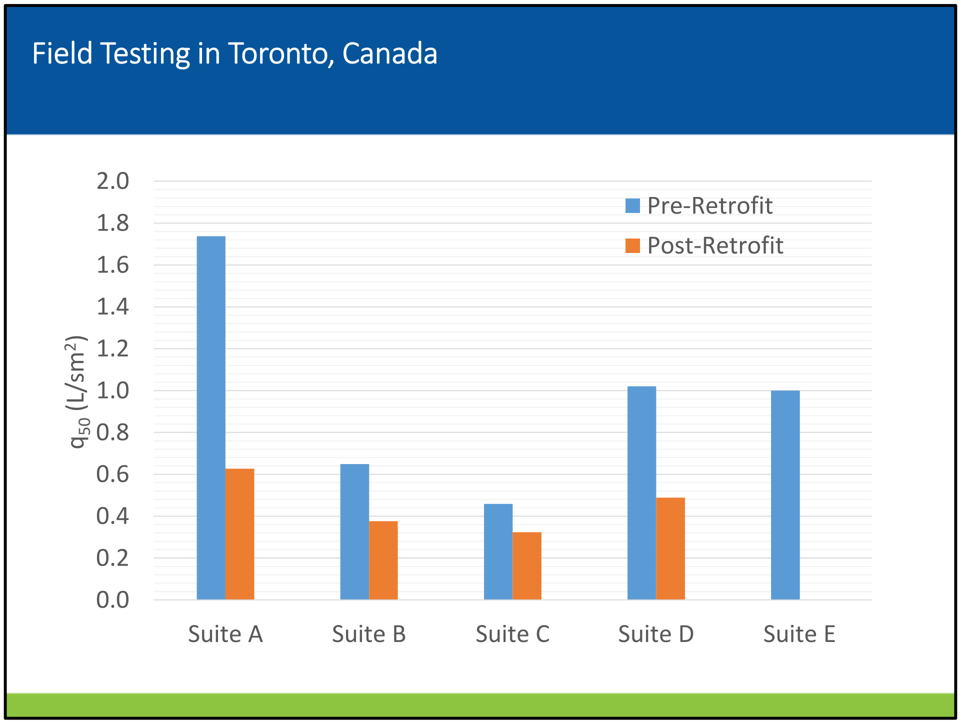
- even though there has been a great deal of research and air leakage testing conducted industry, it’s still hard to find representative data in the MURB sector, specifically
- It’s hard to collect these data (see test methods on prior slide)
- Sample sizes are typically very small and test methods and metrics vary between

studies so it’s often hard to compare directly



Here is an example of how the area normalized air leakage test data may be presented. This is a building that underwent an energy retrofit where there the windows were replaced and the envelope was overclad with exterior insulation – both of which improved the suite-level air tightness. However these are results of the whole suite test which includes both the interior partition walls and the exterior walls.

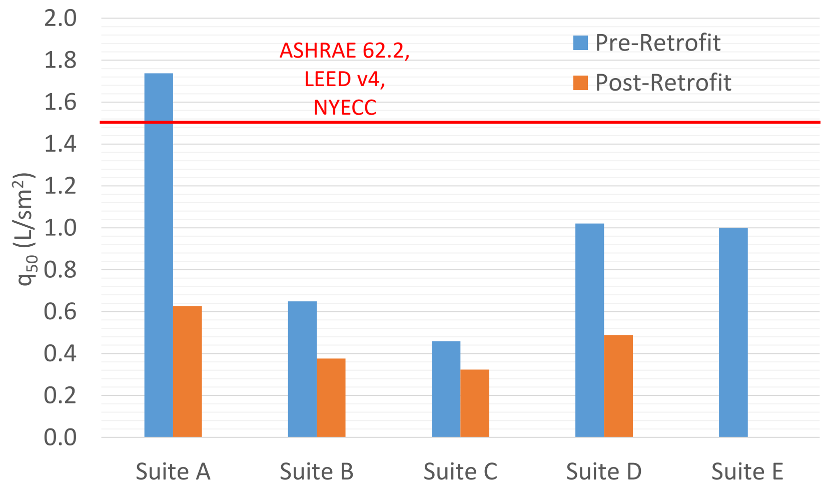
Existing Interzonal Air Leakage Standards

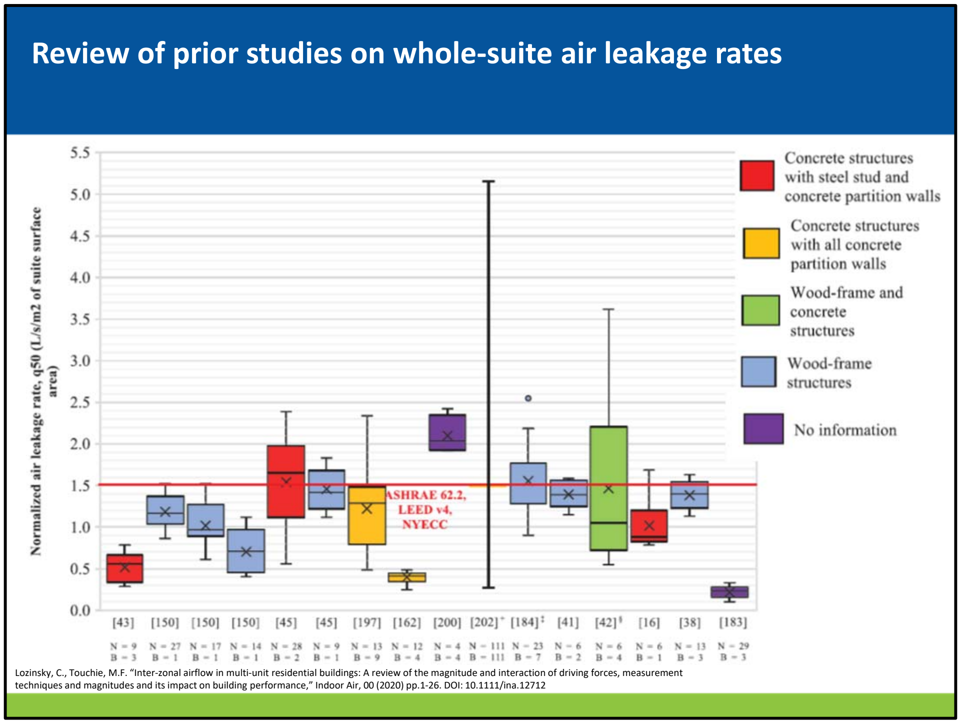
Compartmentalization Standard		Performance Target	Referenced Standard
New York State Energy Conservation Code (NYECC)		q_{50} = 0.3 cfm/ft^2 of zone surface area (1.53 L/s/m^2)	ASTM E779
LEED v4	Pre-Requisite: Compartmentalization	q_{50} = 0.3 cfm/ft^2 of zone surface area (1.53 L/s/m^2)	ANSI/ASTM E779, ANSI/ASTM E1827 or ANSI/RESNET/ ICC 380
	Enhanced Compartmentalization	q_{50} = 0.23 cfm/ft^2 of zone surface area (1.17 L/s/m^2)	
	Enhanced Compartmentalization (Exemplary Performance)	q_{50} = 0.15 cfm/ft^2 of zone surface area (0.67 L/s/m^2)	
ASHRAE 62.2-2019		q_{50} = 0.3 cfm/ft^2 of zone surface area (1.53 L/s/m^2)	ANSI/RESNET/ ICC 380

International Code Council Inc. International Energy Conservation Code (New York State). 2015
U.S. Green Building Council. LEED v4.1 Residential BD+CMultifamily Homes. 2019. https://build.usgbc.org/multi famclean41. Accessed August 2, 2019.
ASHRAE. ANSI/ASHRAE Standard 62.2: Ventilation and Acceptable Indoor Air Quality in Residential Buildings. 2019.

- There are both prescriptive and performance-based code requirements for interzonal air Tightness
- While there are many exterior air tightness requirements, there are only a few standards which require interzonal, as shown here
- So now let's look at how these standards compare to our results

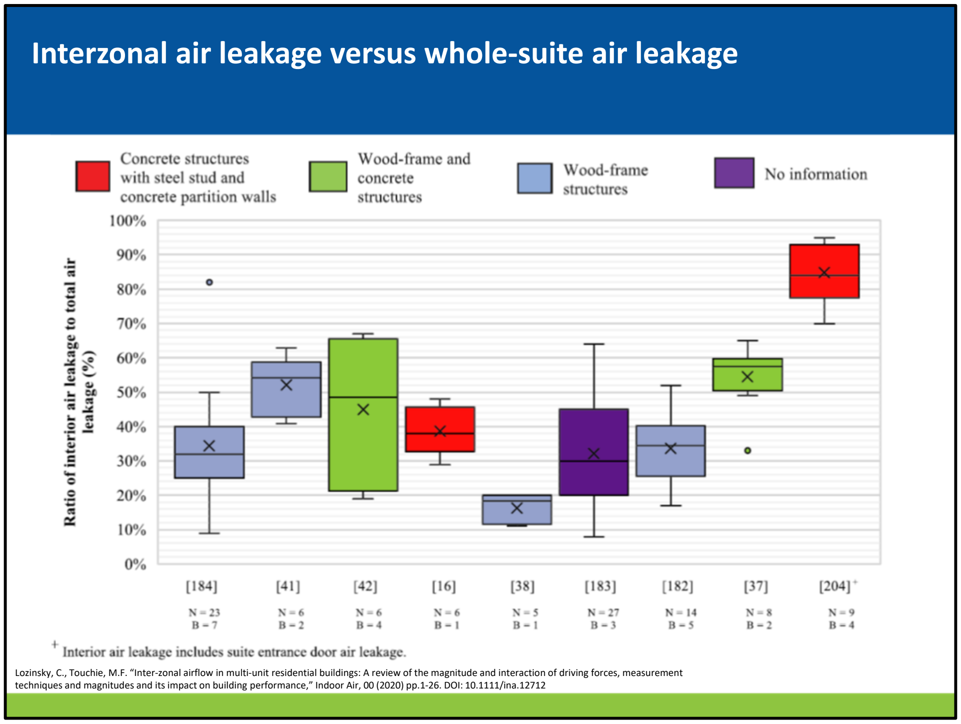
Field Testing in Toronto, Canada





- To provide a bit more context, we reviewed 44 previous studies where data were collected via unguarded or guarded BDT or differential pressure methods
- This plot summarizes the results of 13 of those studies, separated out by building construction type, which we hypothesized would have a impact on air tightness
- For most of the studies, the medians vary between 0.5-1.5 L/s/m² at 50Pa but there is significant variation both within and between studies

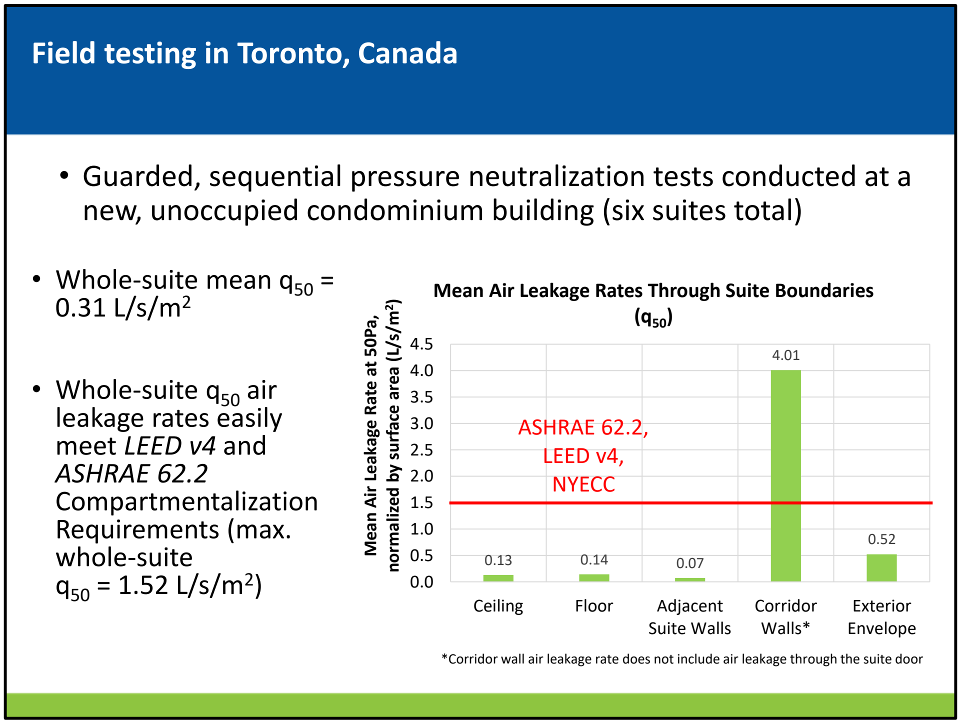
- Based on the medians alone, most would pass the ASHRAE 62.2 requirement, however, the building data presented here indicates that many of the suites would not pass the requirement.
- From these data, it’s obviously possible to meet the requirement but it requires careful planning and testing to ensure compliance
- However note that much of these data are collected via a whole suite test which means both the interior partition and exterior air leakage values are combined into a single normalized value. Therefore, it may be possible to meet the whole suite standard but still have substantial interzonal air leakage so it’s important to examine these results in terms of interzonal vs total air flow results



- of these studies, 9 of them completed guarded BDT so the interzonal air leakage contribution could be separated out from the total which are presented in the figure here. Where the y-axis is the ratio of interior air leakage to total suite air leakage.
- You can see that the medians range widely from 15-85% which is a result of building construction type, but also building age and whether or not performance was governed by an air tightness standard.
- Without a specific requirement for interzonal air

tightness as well as a simple test method to assess this, designers and constructors are ‘flying blind’ without specific guidance on where to improve air tightness.

- Also, because of the wide intra building variability, we need large sample sizes to get an accurate picture of current airtightness, but little guidance is provided in the current standards on sampling
- So we wanted to dig a little deeper and look at how the air tightness varied on each of the individual surfaces of the suite enclosure



- As part of a study to measure inter-zonal air leakage rates in newly-constructed MURBs and develop cost-effective and easy-to-implement test methods for measuring inter-zonal air leakage
- Conducted sequential pressure neutralization testing in six suites, which meant that one-by-one we neutralized the pressure difference across each of the six sides of the suite, such that we could determine the normalized air leakage rate for each of the six sides individually. The whole suite mean q50 was 0.31L/sm2 which easily met the ASHRAE 62.2

compartmentalization requirement, the suite corridor wall did not. I also want to point out that this value does not include leakage through the suite door (which is where the blower door apparatus was) so in reality it's even leakier

- This really important because the even though the suite as a whole passed the compliance test, it still may experience performances issues.
- Other studies suggest that performance issues still occur, even in compliant buildings so we need to better understand the connection between interzonal air tightness and all of the performance issues I mentioned at the beginning.
- Our group is currently investigating these impacts and also to develop simpler test methods so that we can more easily separate out the exterior air leakage from the leakage of interior partitions, which are both very important to know but for different reasons: exterior air leakage for energy performance and thermal comfort and interzonal air leakage for a host of other performance issues including ventilation system performance, transfer of smoke, odors, pests and of course noise transmission.

Conclusion and next steps

- Interzonal air leakage is highly variable
- We don't have sufficient data to support current standards
- Need a testing approach specifically for interzonal air tightness
- Need to understand the impact of interzonal airtightness on inter-suite air transfer and building energy use

So I hope this brief presentation has given you a sense for some of the challenges that we face with respect to measuring air leakage in multi-unit residential buildings and specifically the importance of separating interior and exterior air leakages. Some of the key points I hope you'll take away from this are that … describe bullets and mention that our group is continuing to work on all three.

Questions?

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