Airflow in Mid to High-rise Multi-Unit Residential Buildings

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Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

AIA Credits – Learning Objectives

Participants will:

1. Learn how to link the performance of individual building enclosure components in a holistic framework to achieve high-performance buildings.

2. Explore, through built case studies, how building envelope design determines overall energy conservation and sustainability capabilities

3. Learn innovative practices for avoiding heat loss as well as moisture and air infiltration in enclosure design for healthy new and existing buildings.

4. Understand the role of building enclosure commissioning in the design, construction, and operation and maintenance of commercial facilities.

Outline

- → Introduction & Background
- → Testing and Measurement Program
  - → Measured Ventilation Rates (PFT testing)
  - → Cause of Ventilation Rates
- → Extension of Study Findings
- → Conclusions & Recommendations

Introduction & Background

- Most apartments/condos (multi-unit residential buildings) are ventilated using **pressurized corridor systems**

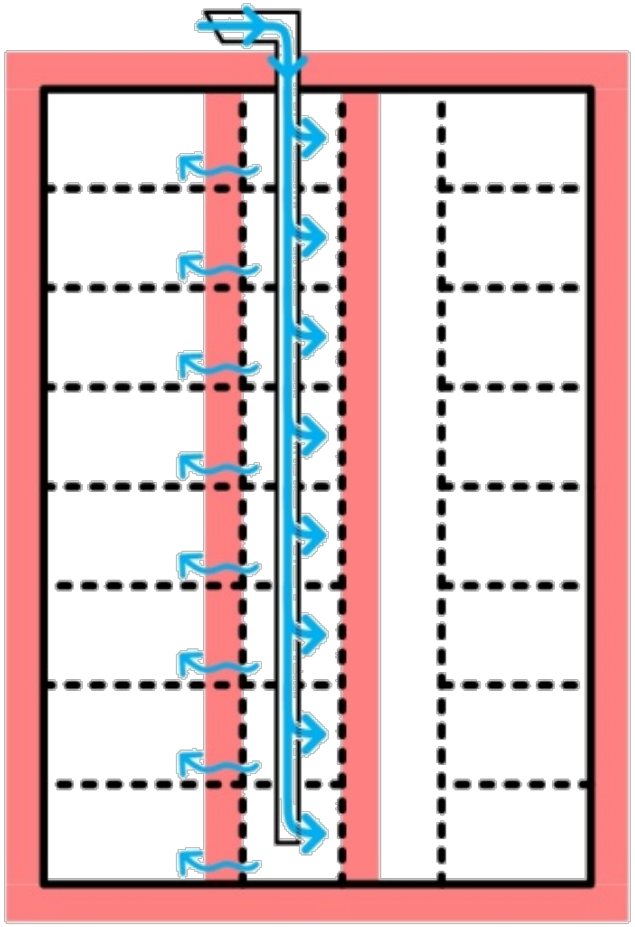
- Decades of research and experience indicates that this system likely does not work very well
  - Still most common system
  - **Few physical measurements**

- Particularly relevant now, as newer more airtight building have **less tolerance for poorly performing ventilation systems**
  - Less infiltration and exfiltration to supplement ventilation

Introduction & Background

Pressurized Corridor Ventilation System

- DESIGN INTENT
  - **Provide ventilation** air to all zones
  - **Control flow of air contaminates** between zones
- HOW
  - **Provides air to corridors** directly via a vertical shaft which **pressurizes the corridor**
  - Corridor pressurization forces air **into suites via intentional gaps** under the entrance doors



Introduction & Background

Case Study Building

- → **13-storey** multi-unit residential building in Vancouver, Canada with **37 residential suites**
- → Constructed 1986
- → Enclosure renewal 2012
- → Below grade parking garage located under the building
- → Ventilated using **pressurized corridor system** by a single make-up air unit (MAU) on the roof

Overall, is **typical** of high-rise multi-unit residential buildings

Measured Ventilation Rates

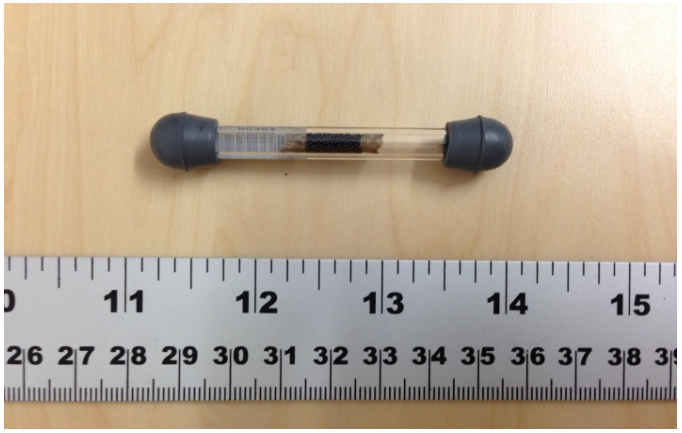
Perfluorocarbon (PFT) Testing

Two component system:

- → **PFT Sources** (7 distinct types)
- → Capillary absorption tube samplers **(CATS)**

→ Sources release **distinct PFT tracer gasses in different zones** and use **CATS to sample the concentrations**

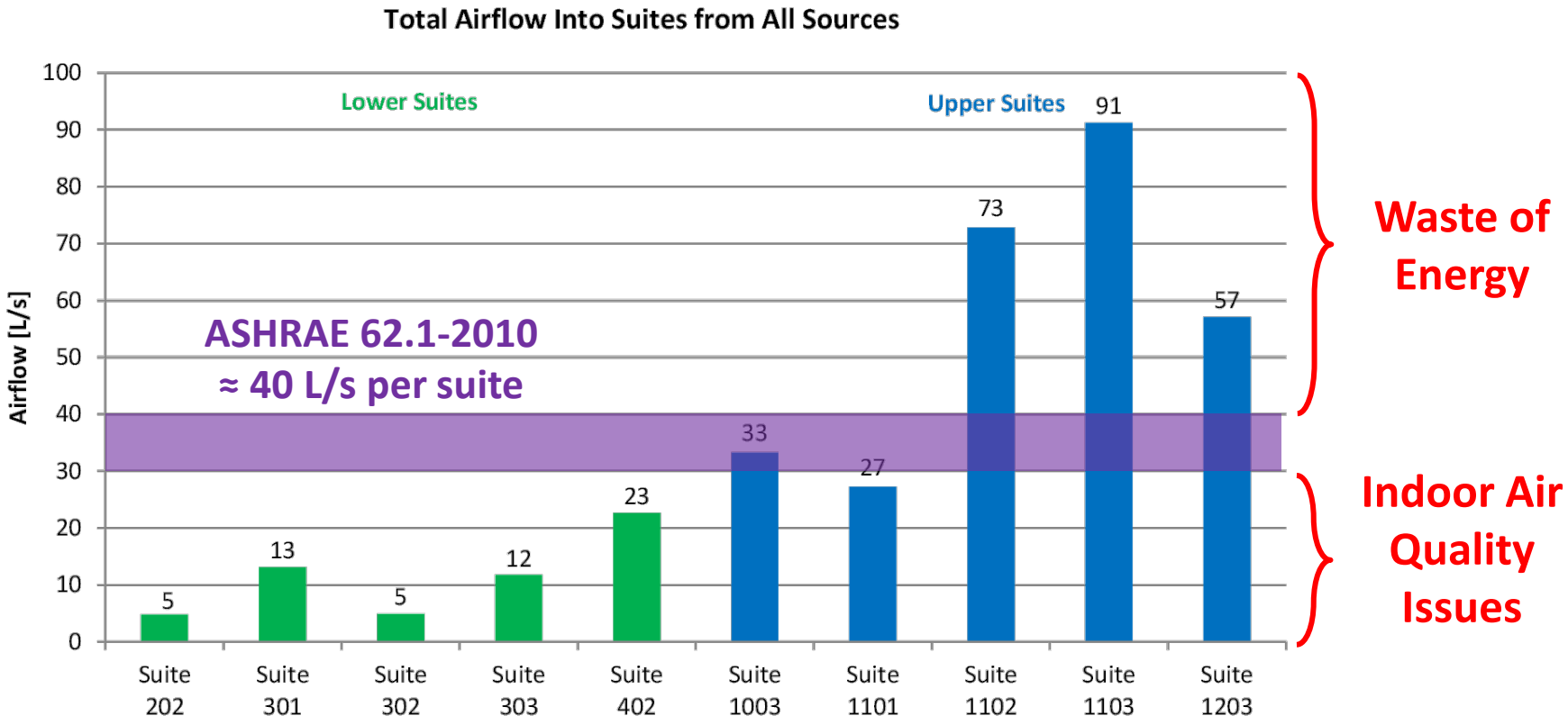
Sources



CATS

Measured Ventilation Rates

- → Order of magnitude variation in the ventilation rates
- → Significantly higher rates for upper suites than lower suites
- → Most suites under-ventilated or over-ventilated



Measured Ventilation Rates

- Summary:
  - Over ventilation and under ventilation of most suites
  - Higher ventilation rates in upper suites than lower suites
  - Better indoor air quality in upper suites than lower suites

Why is this happening?

Cause of Ventilation Rates

Maybe the MAU isn't working correctly?

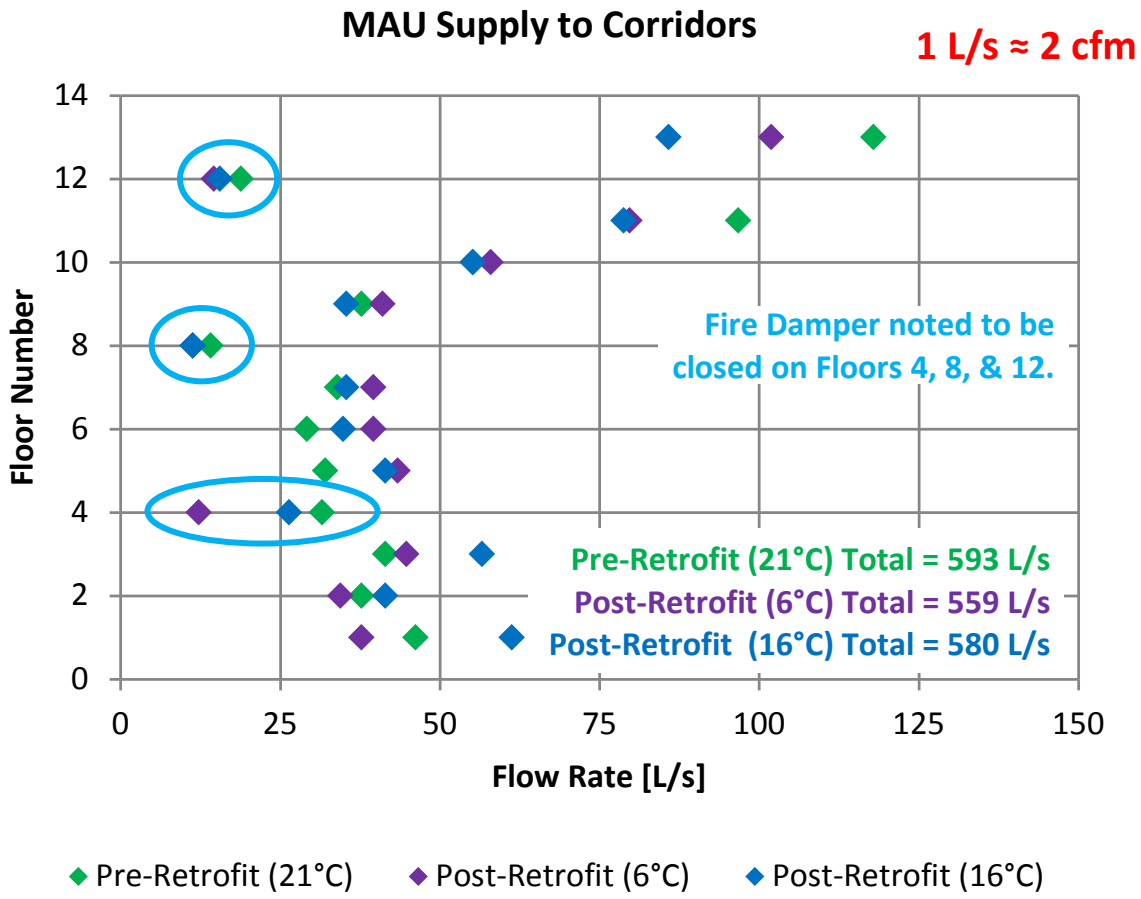
→ Custom powered flow hood used to measure intake flow rate of the make-up air unit

→ MAU airflow **approximately the same** as design flow rate of 1,560 L/s (3,300 cfm)

Cause of Ventilation Rates

Maybe the ventilation air isn't reaching the corridors?

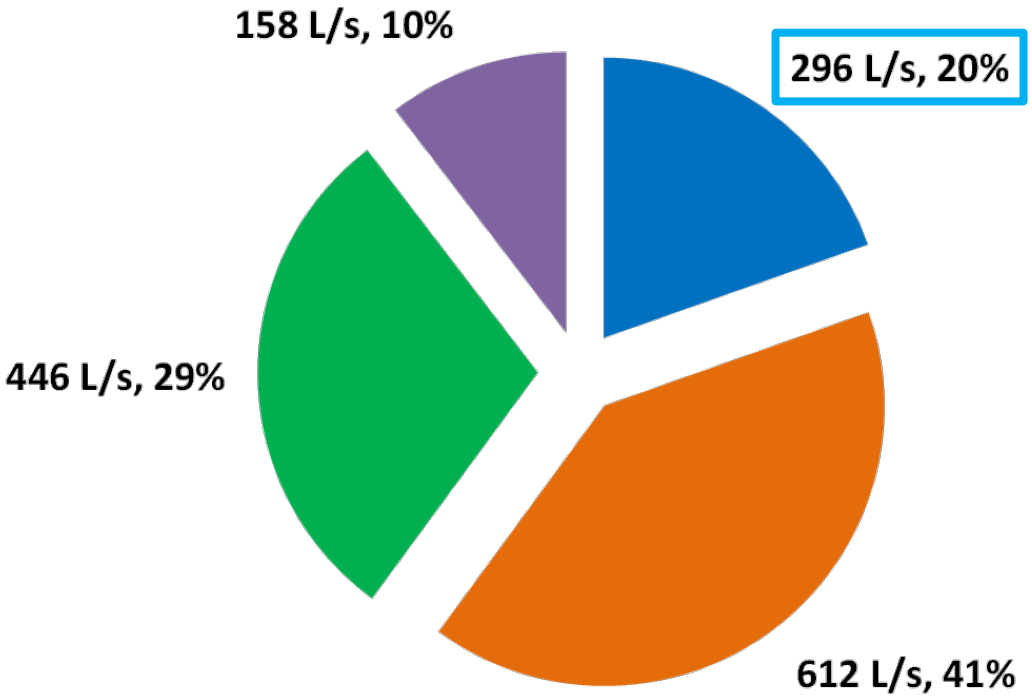
→ Only **40%** of intake flow reaches the corridors directly



Cause of Ventilation Rates

Maybe the air isn't reaching the suites from the corridors?

→ Airtightness tested corridors and found significant flow paths other than to the suites through the suite entrance doors. **Only 20% to the suites**



Airflow Rates at 75 Pa

"Other" includes flow to floors above and below, flow through the electical closets, and flow in to the garbage chute.

Cause of Ventilation Rates

→ If only 40% of the flow rate reaches the corridors
And, only 20% of that air reaches the suites…

$$\mathbf{40\% \times 20\% = 8\%}$$

→ Theoretically, only **8%** of intended ventilation actually goes where it is supposed to! Waste of ventilation air, and the energy needed to move and condition it.

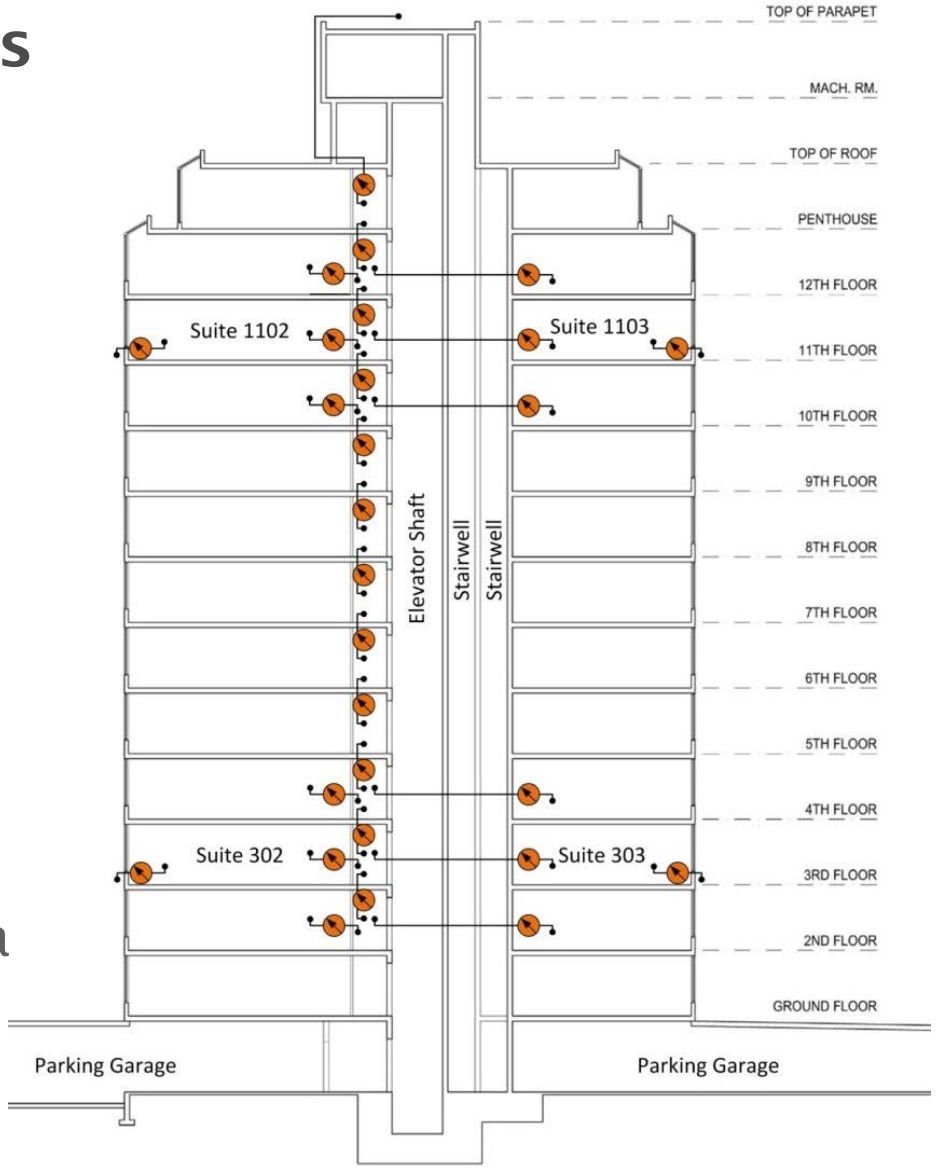
Leakage of air along ventilation flow path is a major issue.

Cause of Ventilation Rates

Maybe pressure differences are an important factor?

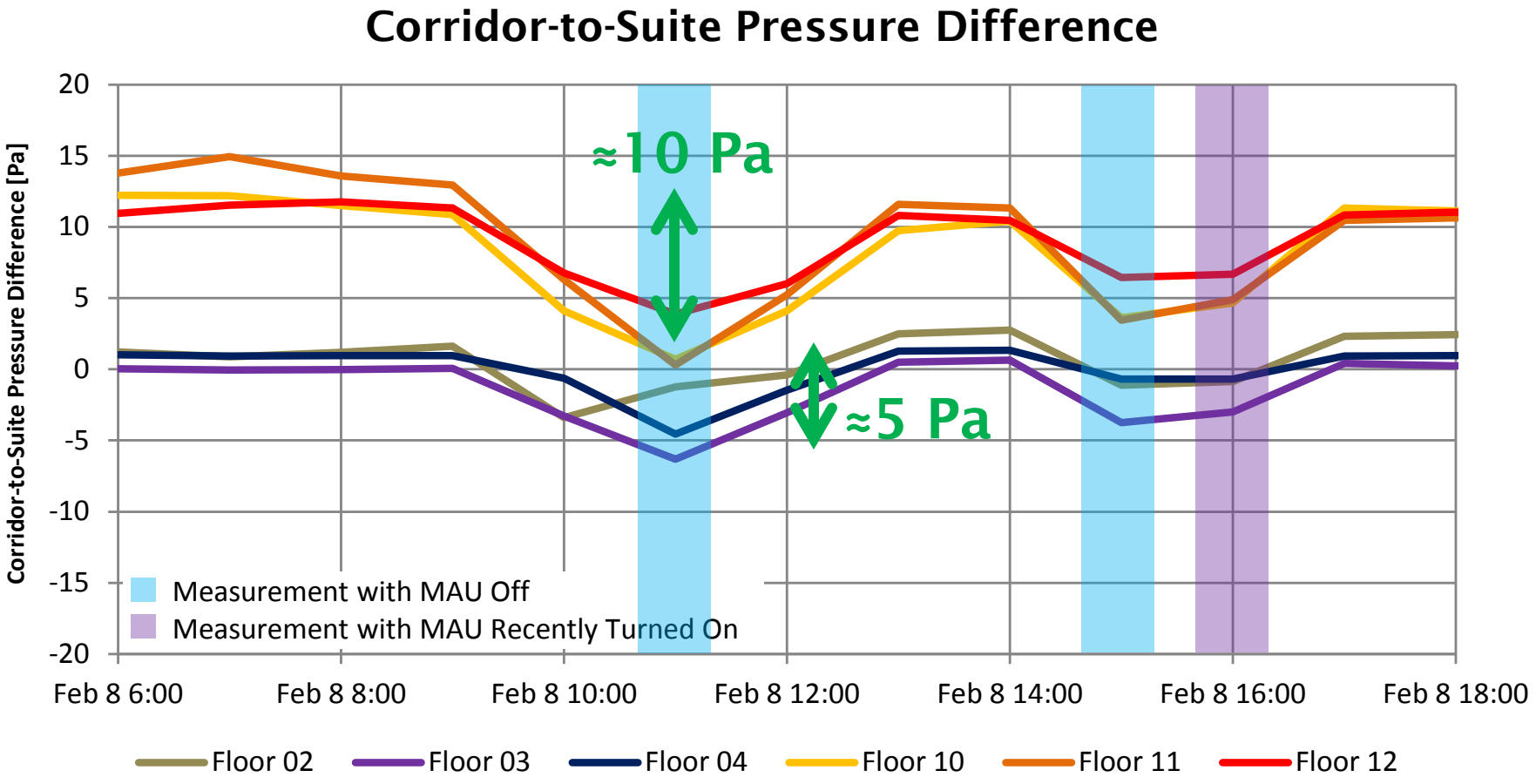
- Pressure differences were monitored with a focus on an upper floor and a lower floor (Floors 11 & 3)

- Assessed relationship between exterior temperature (stack effect) and wind events using a weather station on the roof



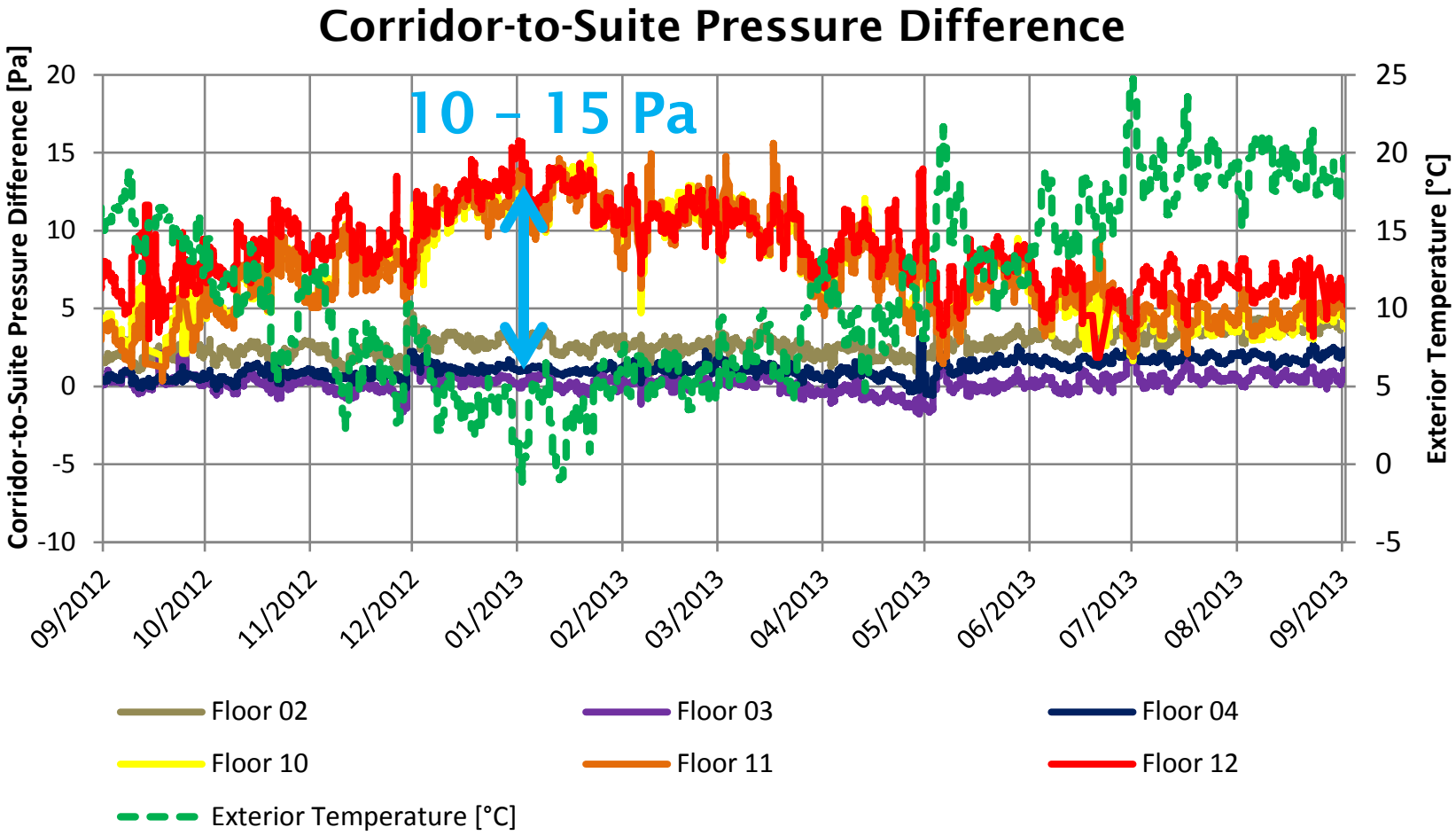
Cause of Ventilation Rates

→ Mechanical ventilation system creates pressure of **5 to 10 Pa**



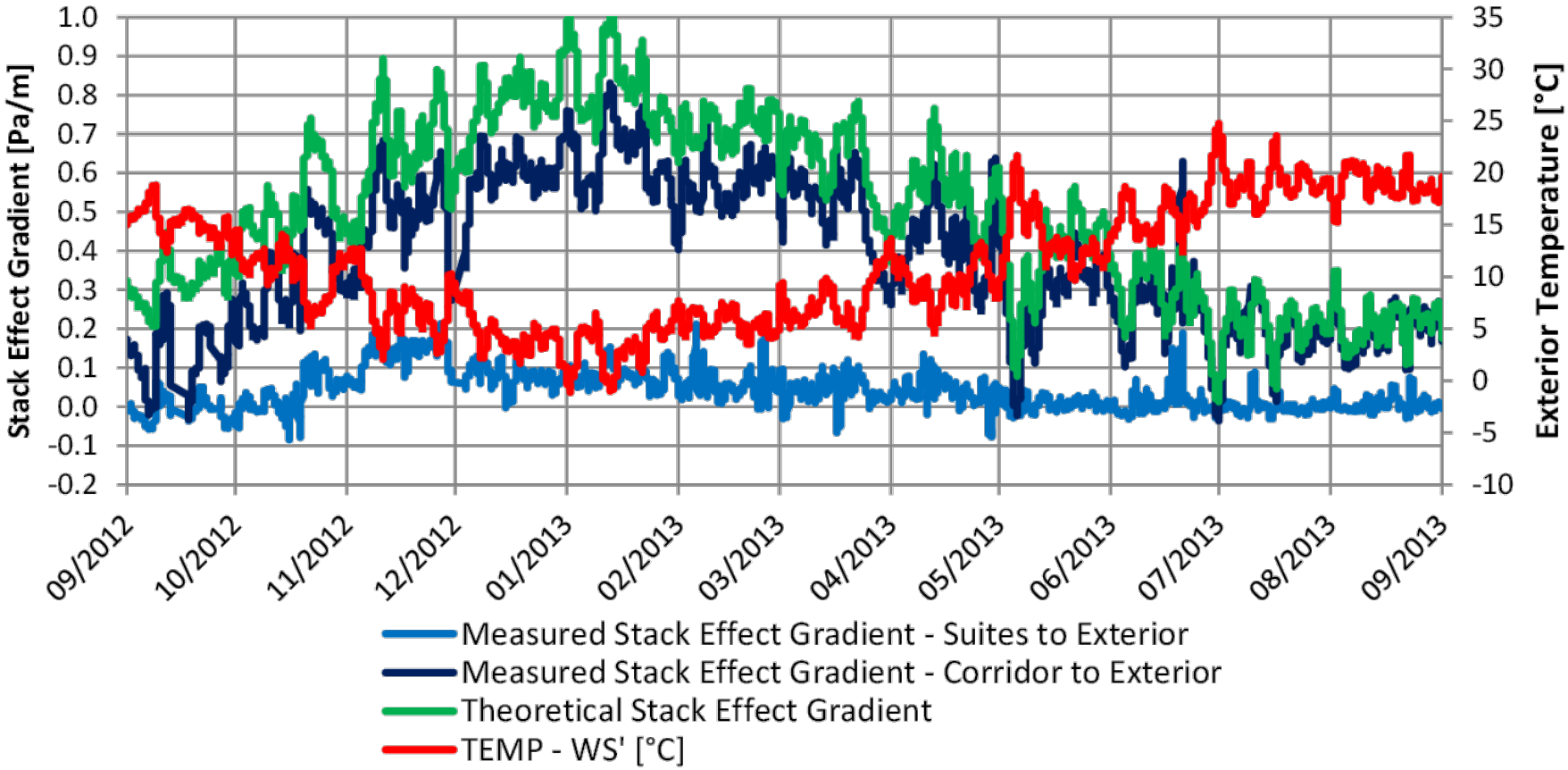
Cause of Ventilation Rates

→ Pressures created by stack effect found to be of similar magnitude (10 to 15 Pa) as mechanical pressures



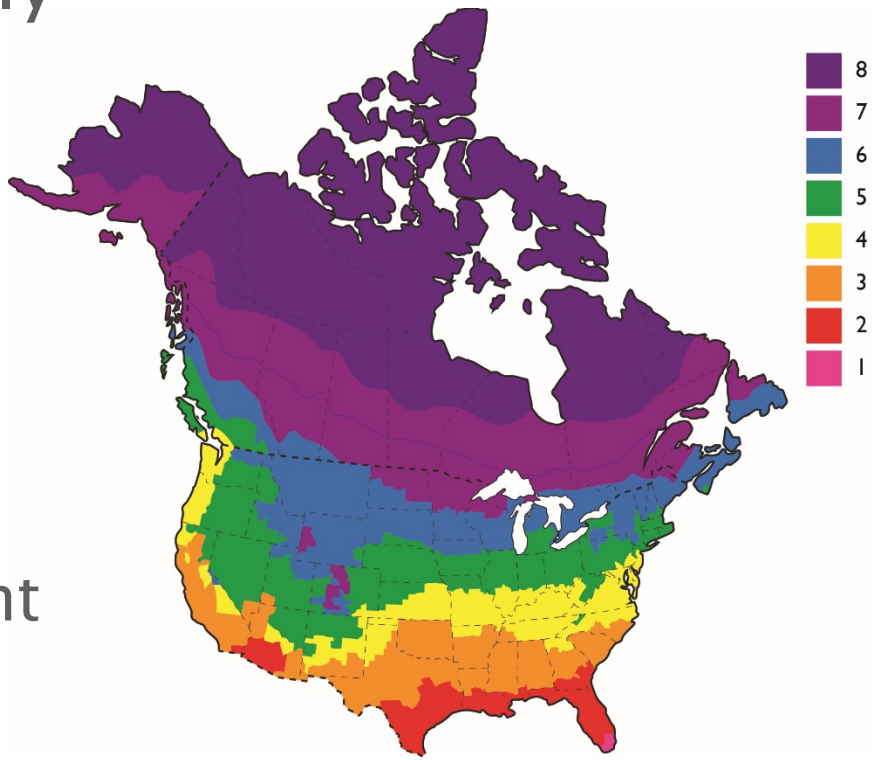
Cause of Ventilation Rates

- → Stack effect pressures found to distribute **69% across the corridor to suite boundary** and **9% across exterior enclosure**
- → Stack effect pressure **acts primarily in the same location as mechanical pressures** intended to provide ventilation and control contaminate flow



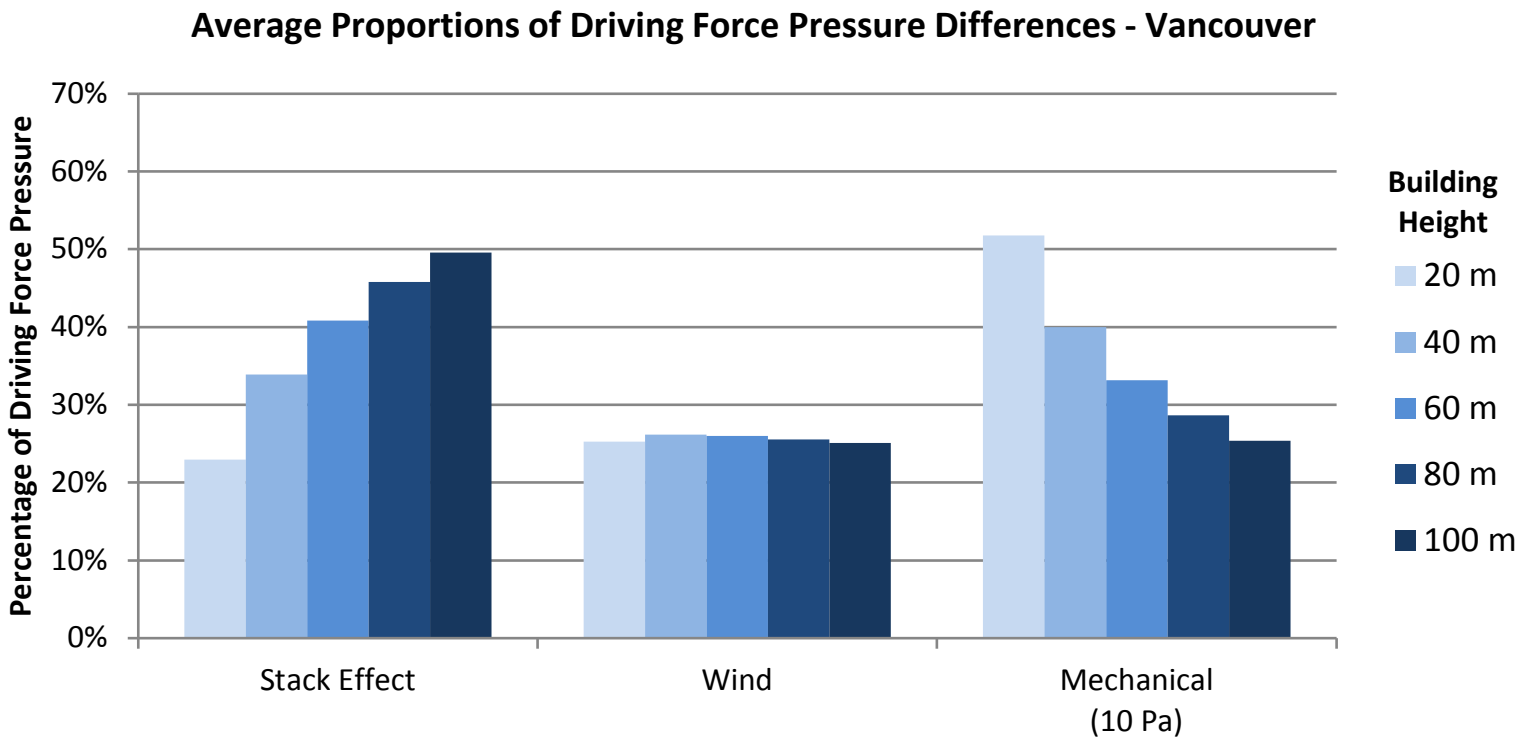
Extension of Study Findings

- → Vancouver is a relatively moderate climate
  - → Should consider other climates
- → Case study building is 13 storeys
  - → Should consider different building heights



Extension of Study Findings

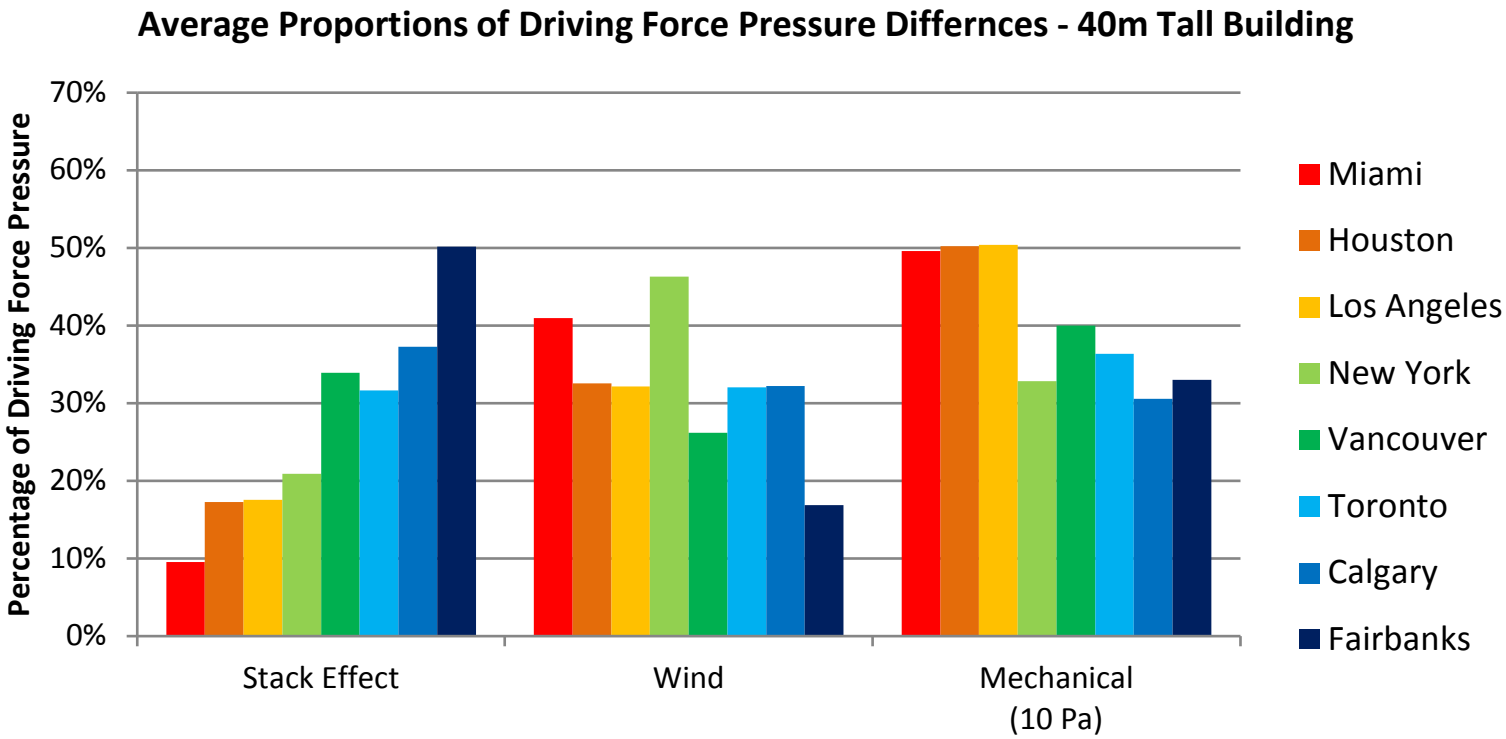
- → Stack effect is more significant in taller buildings
- → Proportion of wind pressures remains relatively the same
- → Relative magnitude of mechanical pressures decreases as height increases



Extension of Study Findings

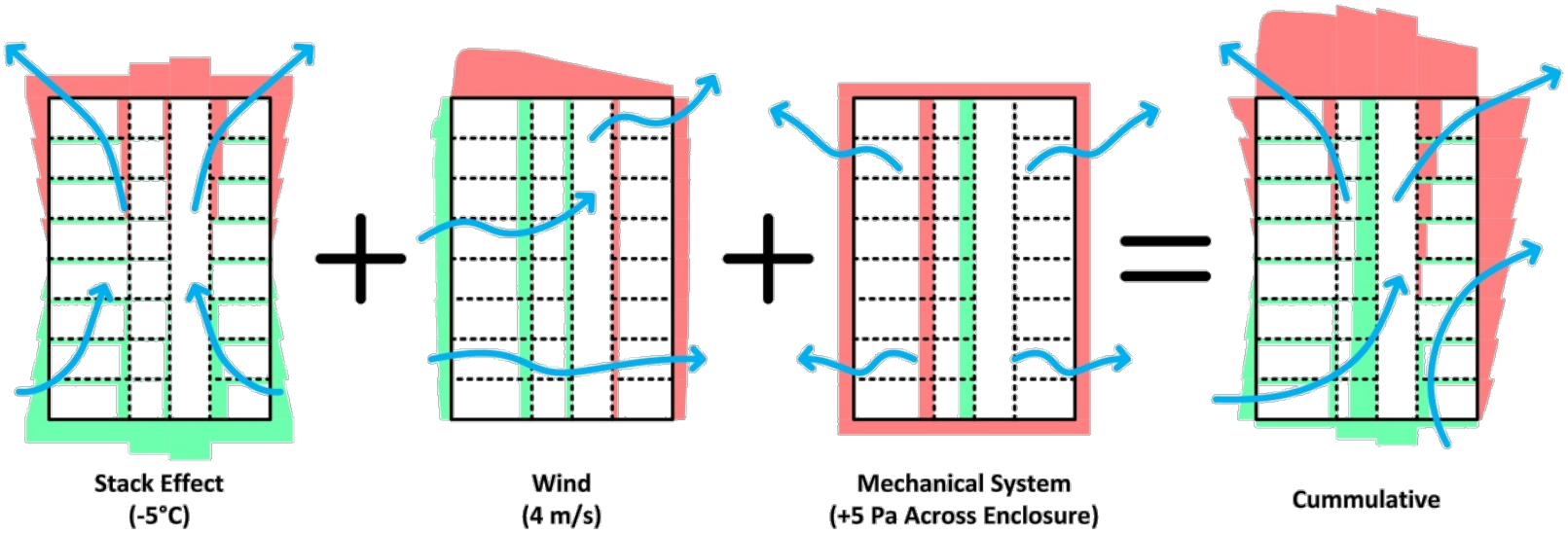
→ Stack effect more significant in cold climates

→ Wind highly variable, but typically more significant in warm climates



Comparison of Driving Forces

- Since all of the pressure differences created by the driving forces (stack effect, wind, & mechanical systems) are of similar magnitude, it is possible that **any one could dominate**
- This is exaggerated for buildings located in more extreme climates than Vancouver



Ventilation system can not practically overwhelm nature.

Conclusion

- Corridor pressurization **does not provide intended ventilation rates** to a large number of suites
  - Some significantly over ventilated while others significantly under ventilated
- Significant **leakage along the ventilation air flow path** from the duct and the corridor (wasted ventilation)
  - Uncontrolled airflow wastes energy and provides poor ventilation
- Stack effect and wind pressures are often similar or greater than mechanically-induced pressures
  - **Ventilation system can not practically overwhelm nature**

Conclusions – Theory & Reality

- → Results could have been readily predicted by physics
  - → i.e These problems were foreseeable

- → When designing ventilation systems, need to design **building as a system** and account for all factors
  - → Enclosure and compartment airtightness
  - → Driving forces: stack effect and wind
  - → Mechanical system
  - → Occupants

Recommendations for Ventilation System Design

Mid- to High-Rise Multi-Unit Residential Buildings

→ Ventilation air should be **directly supplied** to suites to limit the potential of loss along the flow path and of the system being overwhelmed by stack effect and wind

→ The **exterior enclosure should be airtight**, and suites and vertical shafts should be **compartmentalized** (airtight) to limit the impact of wind and stack effect on ventilation

Questions

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