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Engineering of Structures and Building Enclosures

Stack Effect and Mechanical Exhaust System Impacts on Building Pressures and Envelope Air Leakage

Presented by Matthew J. Monaghan
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Air Leakage Basics

- Air leakage in buildings is detrimental for many reasons
  - Energy performance (heating/cooling loads)
  - Occupant comfort
  - Contaminant transport
  - Noise ("whistling" from air movement, high frequency sound transmission)
- Air leakage is driven by differences in air pressure
- Air pressure differentials occur due to three phenomena

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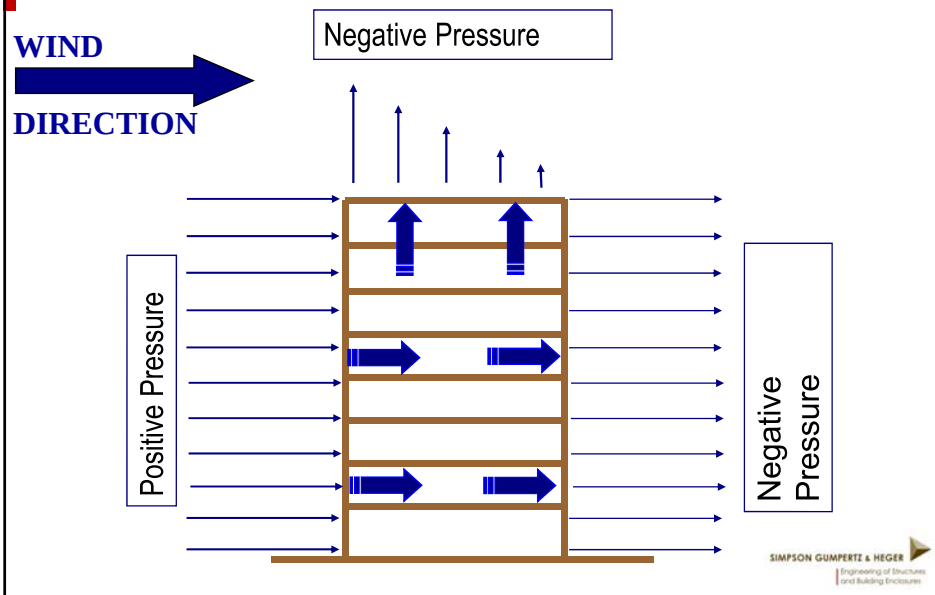
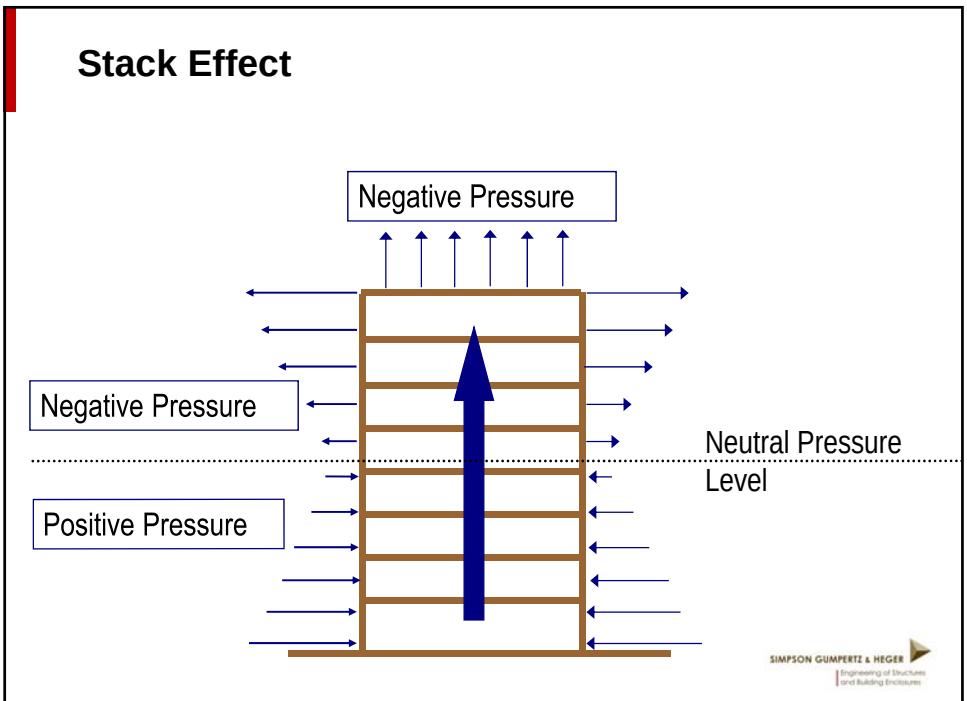
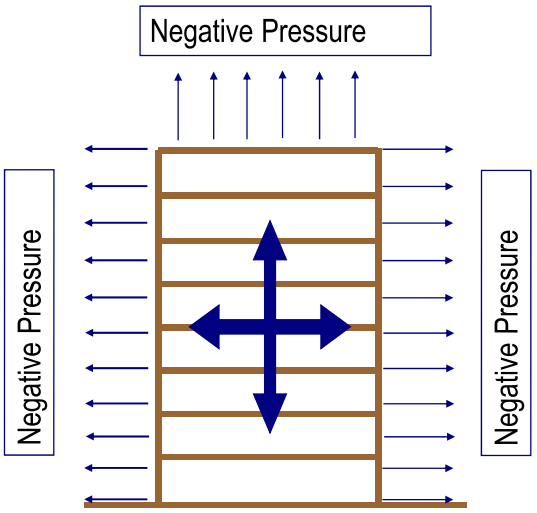
Wind Effect



Stack Effect



Mechanical Pressurization



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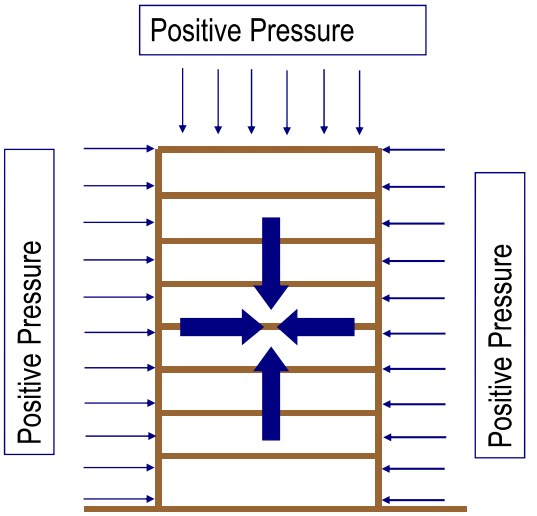
Mechanical Pressurization



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Low vs. Mid/High Rise Buildings

- In low rise buildings, wind is the primary driver of air leakage
- A “leaky” low rise building will experience very little air leakage during calm conditions

- In mid-and high rise buildings, stack pressure and mechanical system operation are the primary drivers of air leakage
- In zero-wind conditions, mechanical system operation can result in significant air leakage

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Mechanical Code Issues

- Most mechanical codes require ventilation for all spaces
  - Ventilation can be mechanical or natural

- Natural ventilation is often provided in lieu of mechanical due to lower construction costs, especially in mid- and high-rise residential buildings

- Natural ventilation is typically used in conjunction with mechanical exhaust. The systems can be balanced, but who will typically:
  - Open their windows in Boston in January?
  - Open their windows in Florida in August?

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Typical Problems

- With windows closed, constant exhaust systems for bathrooms, dryers, kitchens, etc. creates negative pressure in spaces.
- Negative pressure exacerbates air infiltration and may lead to airflows between units or other interior spaces
- Fresh air often provided via pressurized corridors
  - Technically not allowed by most building and fire codes, but commonly done
  - Can be used to balance out exhaust flows if properly designed

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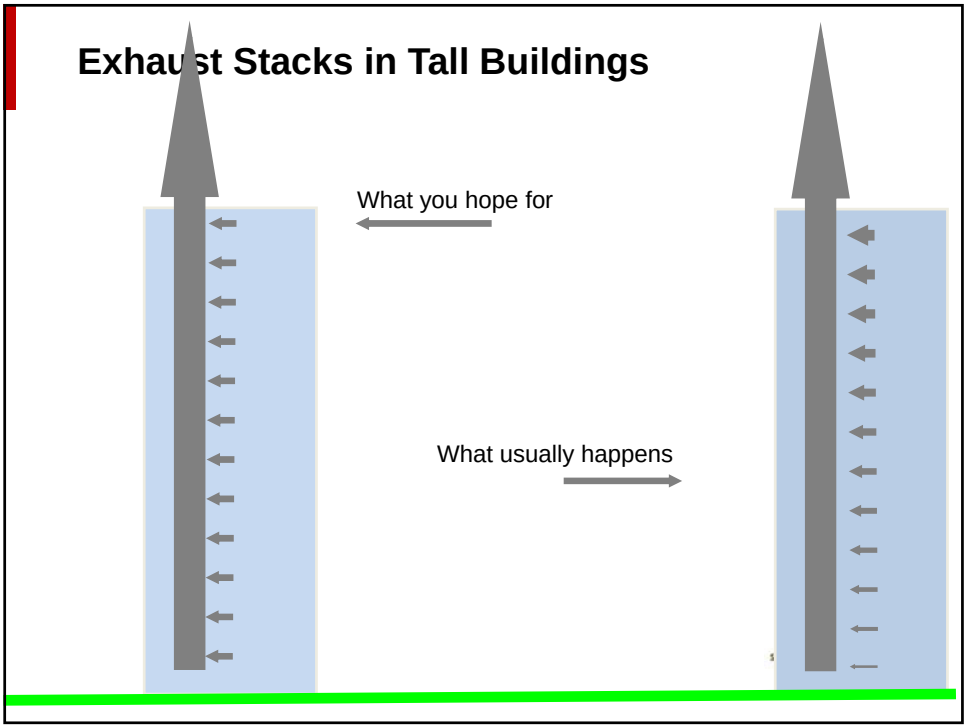
Exhaust Stacks in Tall Buildings



Exhaust stacks

- Straight / constant cross-section ducts often used for tall exhaust stacks due to low first cost
- Results in high flows nearest to fan, little to no flows at base of stack
- We investigated a project where imbalanced exhaust risers led to negative pressures of 60 to 80pa at top floor units
  - Pressures near ground floor were closer to neutral
  - 100+N force exerted on doors, making operation difficult
  - Noise complaints of whistling noises due to high air flow around doors

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Internal/Unit-to-Unit Flows

- Poorly constructed air shafts (exhaust or supply) can lead to inter-unit flows and internal pressure differentials
- We reviewed a project where leakage around exhaust grilles allowed exhaust shafts in one stack of units to impact pressures in adjacent stacks as well

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Gaps Around Exhaust Intake

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Magnitude of Air Leakage

- Due to their relatively constant operation, mechanical exhaust systems can lead to significant, sustained airflows
- Even small differentials, when constant in nature, can produce air leakage much greater than due to wind alone
- For a sample high-rise residential building, we used Washington DC weather data to calculate air leakage and resulting heat loss, including losses from conduction alone

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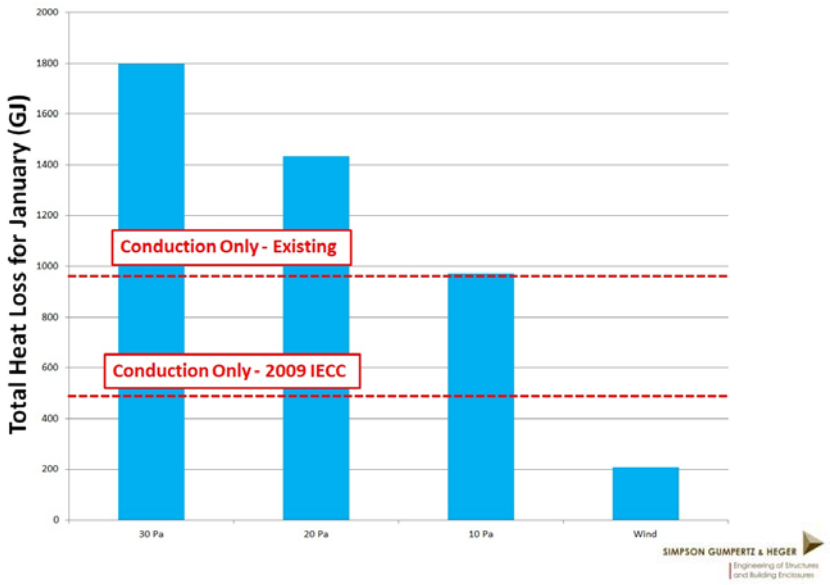

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Magnitude of Air Leakage

- In terms of overall building air leakage, we used the same weather data and compared wind-driven air leakage to mechanically driven leakage at 10, 20, and 30 Pa.
- Results show even 10 Pa differential, when constant, results in significantly greater air leakage than from the intermittent effects of wind alone

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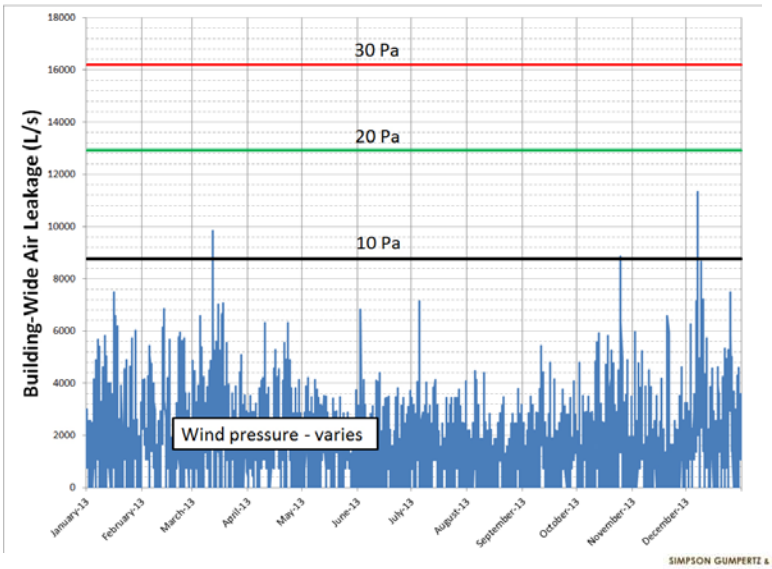

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Conclusions

- Mechanical system operation, especially in taller buildings, can result in much greater pressure differentials than wind alone
- This results in higher sustained air leakage and heat losses/gains
- Balanced ventilation and exhaust are critical to reducing air leakage in tall buildings
- Cost is often the primary driver for system selection, resulting in poor design choices which lead to inefficient operation

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