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Rawand Muzafar Rasheed
Portland State University

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Deposition Velocity Dependence on Urban Morphology

Rawand Rasheed and Raúl Bayoán Cal

Department of Mechanical and Materials Engineering, Portland State University

Introduction

- Total population living in urban cities has increased drastically over the last century.
  - Most people spend a majority of their time indoors, especially in urban cities.
- Increased number of densely populated urban cities with many urban structures of varying shapes and sizes.
- Raises concerns for sustainability and human health:
  - Pollution accumulation in urban cities.
  - Increased energy consumption from growing number of buildings.
- Objective: To study the effects of boundary layer interactions on deposition velocity of varying urban morphology.
- In order to provide new insights into
  - Cooling and heating loads of building.
  - Natural ventilation techniques.
  - Pollution deposition and dispersion on/from urban structures.

Figure 1 – Image of the boundary layer wind tunnel.

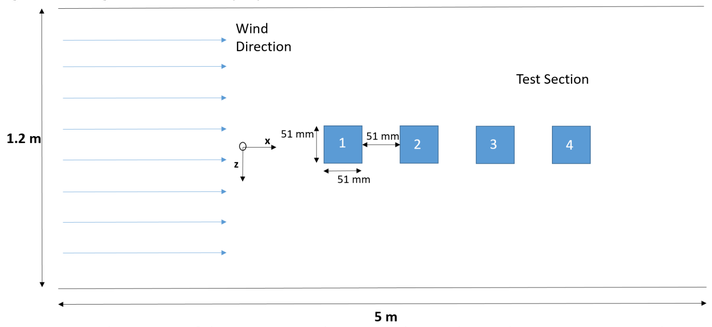
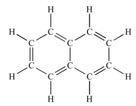


Figure 2 – Top down view of the experimental set up in the wind tunnel. Series experimental set up is shown where cubes two and four are investigated.

Methods

- The naphthalene sublimation method is implemented.
  - Tried and tested method for many experiments involving heat and mass transfer (technique from Smith 2010).
  - Provides repeatable results.
- Method involves dipping cube surfaces into molten naphthalene.
  - Provides even coating on surface.



- Naphthalene is a hydrocarbon that sublimates very at room temperature.
  - Passive mass transfer of naphthalene to air is very slow.
  - Convective mass transfer of naphthalene, caused by bulk fluid motion, increases mass transfer rate by many folds.
- Experimental Procedure:
  - Measure mass of cubes after coating with naphthalene.
  - Place cube into wind tunnel set up and run wind tunnel at a set speed for a set duration of time.
  - Measure mass of cube after experiment to obtain change in mass of naphthalene for the surface being investigated.
- Deposition velocity is calculated from the change in mass of naphthalene.
  - Mass transfer of naphthalene is related to flow field through the fundamental momentum diffusion equation, Equation 2, and fundamental mass transfer equation, Fick's Law, Equation 3
- Deposition Velocity: $V_d = \frac{F}{C} = \frac{Pollutant\ Flux}{Pollutant\ Concentration}$ (1)
- Fluid shear stress: $\tau = -\mu \nabla u$ (2)
- Fick's Law: $J_i = -\rho D_{AB} \nabla yi$ (3)

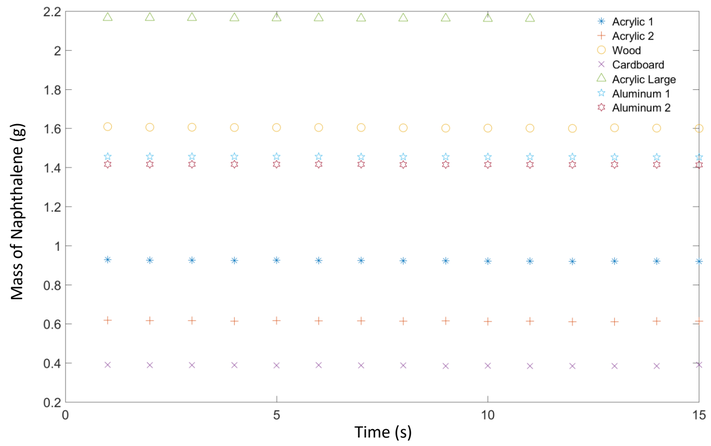


Figure 3 – Passive sublimation of naphthalene for various materials including, aluminum, acrylics, wood, cardboard, and steel. Passive naphthalene sublimation is show to be negligible. Weak passive sublimation, and relatively high convective sublimation makes naphthalene an ideal substance for this study.

Results

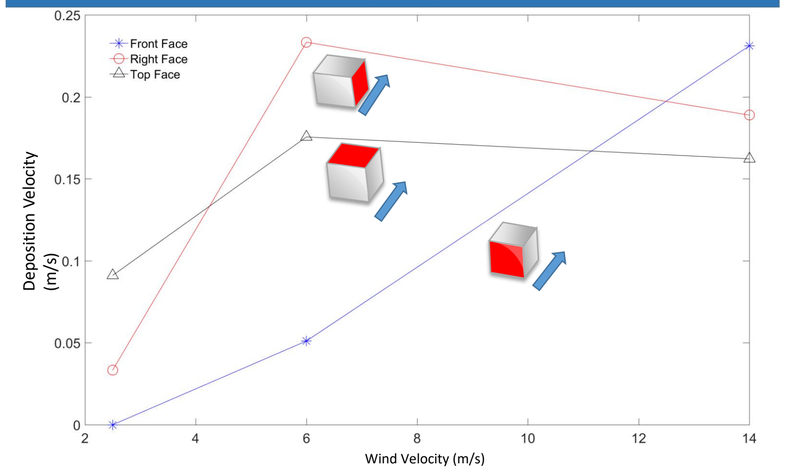


Figure 4 – Deposition velocity rates for individual cube wind tunnel experiments for front, right, and top surfaces. Relative deposition velocity of the cube surfaces is shown to vary noticeably with wind velocity. This is characteristic of changes in flow behavior around the cube.

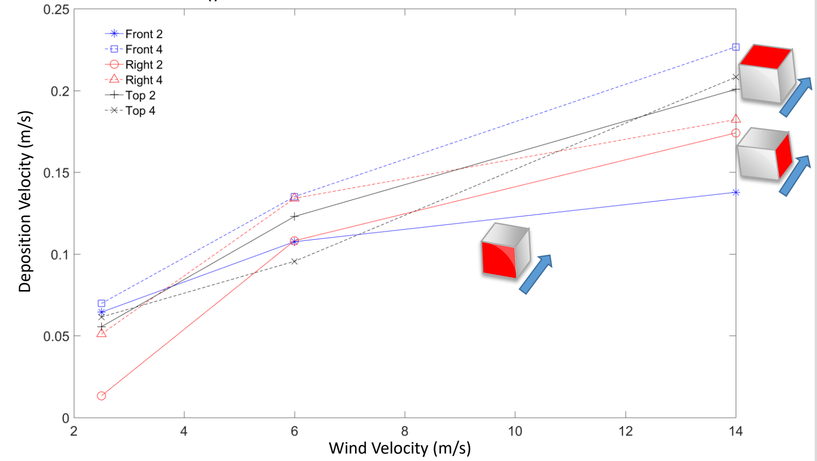


Figure 5 – Deposition velocity is shown to be greatest for the fourth cube in a series of four cubes, and most noticeably at higher wind velocities. The fourth cube in the series experiences flow disturbances from boundary layer interactions of all four cubes compared to flow disturbances from boundary layer interactions of only two cubes, at the second cube. These interactions cause the flow to become more turbulent, which increases mass transfer of naphthalene to air.

Future Work and Conclusions

- Deposition velocity has been shown to increase with increased boundary layer interactions.
  - Also has been shown to strongly depend on wind velocity, where increase wind velocity increases deposition velocity.
- Current work involves investigating a parametric variation in urban layout and morphology where a full scale model city is being investigated.

Contact

Rawand Rasheed
Portland State University
rawand@pdx.edu

References

Smith, J., Determination of the convective heat transfer coefficients from the surfaces of buildings within urban street canyons. University of Bath. (2010)

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