



**PLEA 2006**

**25TH INTERNATIONAL CONFERENCE ON  
PASSIVE AND LOW ENERGY ARCHITECTURE**

**GENEVA, SWITZERLAND 8 SEPTEMBER 2006**

# **Assessment of the Effects of Environmental Factors on Air Flow In and Around Buildings**

---

Khee Poh Lam<sup>1</sup>, Sean Hay Kim<sup>1</sup>, Prasasto Satwiko<sup>2</sup>, John Jennings<sup>3</sup>, Jeff Cole<sup>4</sup>

<sup>1</sup>School of Architecture, Carnegie Mellon University, Pittsburgh, PA 15213, USA

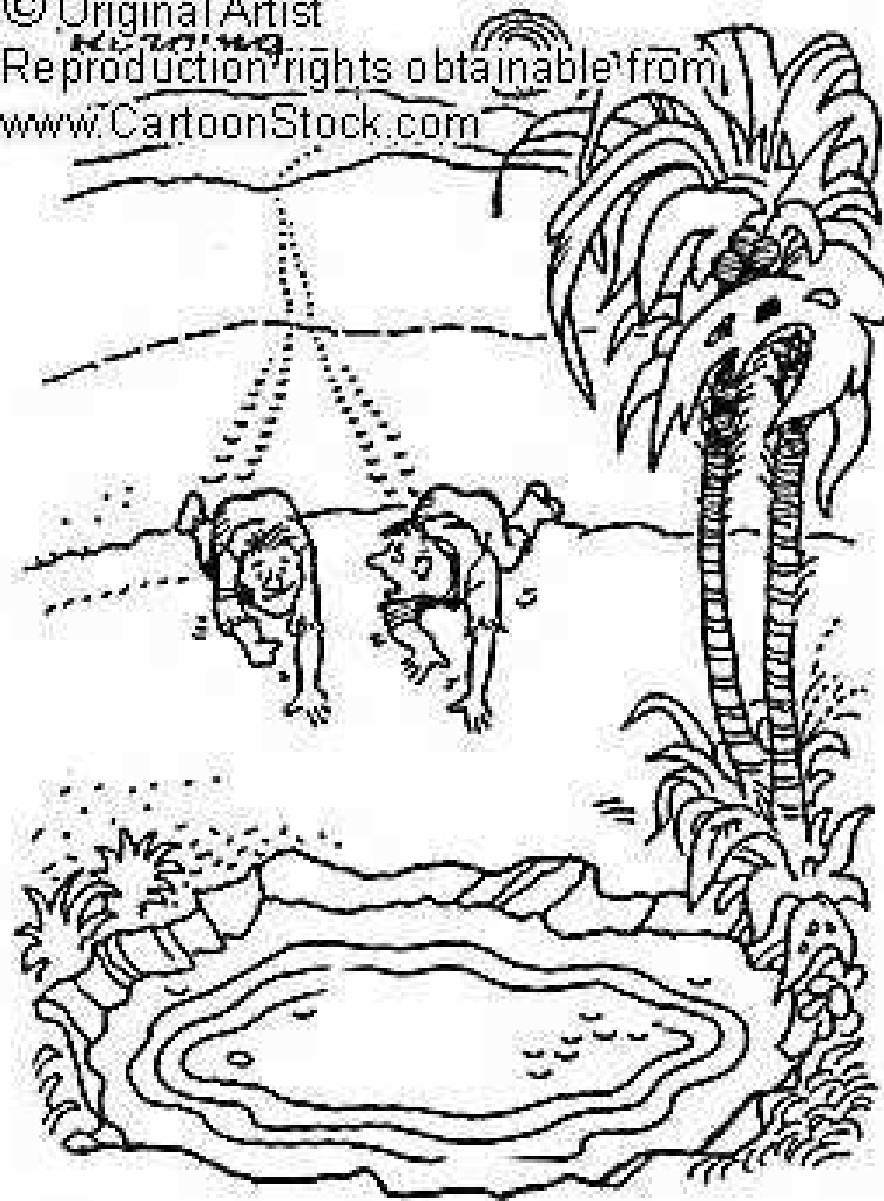
<sup>2</sup>Architecture Study Program, Atma Jaya Yogyakarta University, Yogyakarta 55281, Indonesia

<sup>3</sup>Northwest Energy Efficiency Alliance, Portland, OR 97212, USA

<sup>4</sup>Konstrukt, Portland, OR 97212, USA



© Original Artist  
Reproduction rights obtainable from  
[www.CartoonStock.com](http://www.CartoonStock.com)



'GAREFUL CARRUTHERS, IT COULD BE A  
COMPUTER SIMULATION'

# *Clever Design....??*

- Implies knowledge-based
- 

## *Questions....??*

- What is the essence of this knowledge?
- How is this knowledge represented / transmitted / acquired?

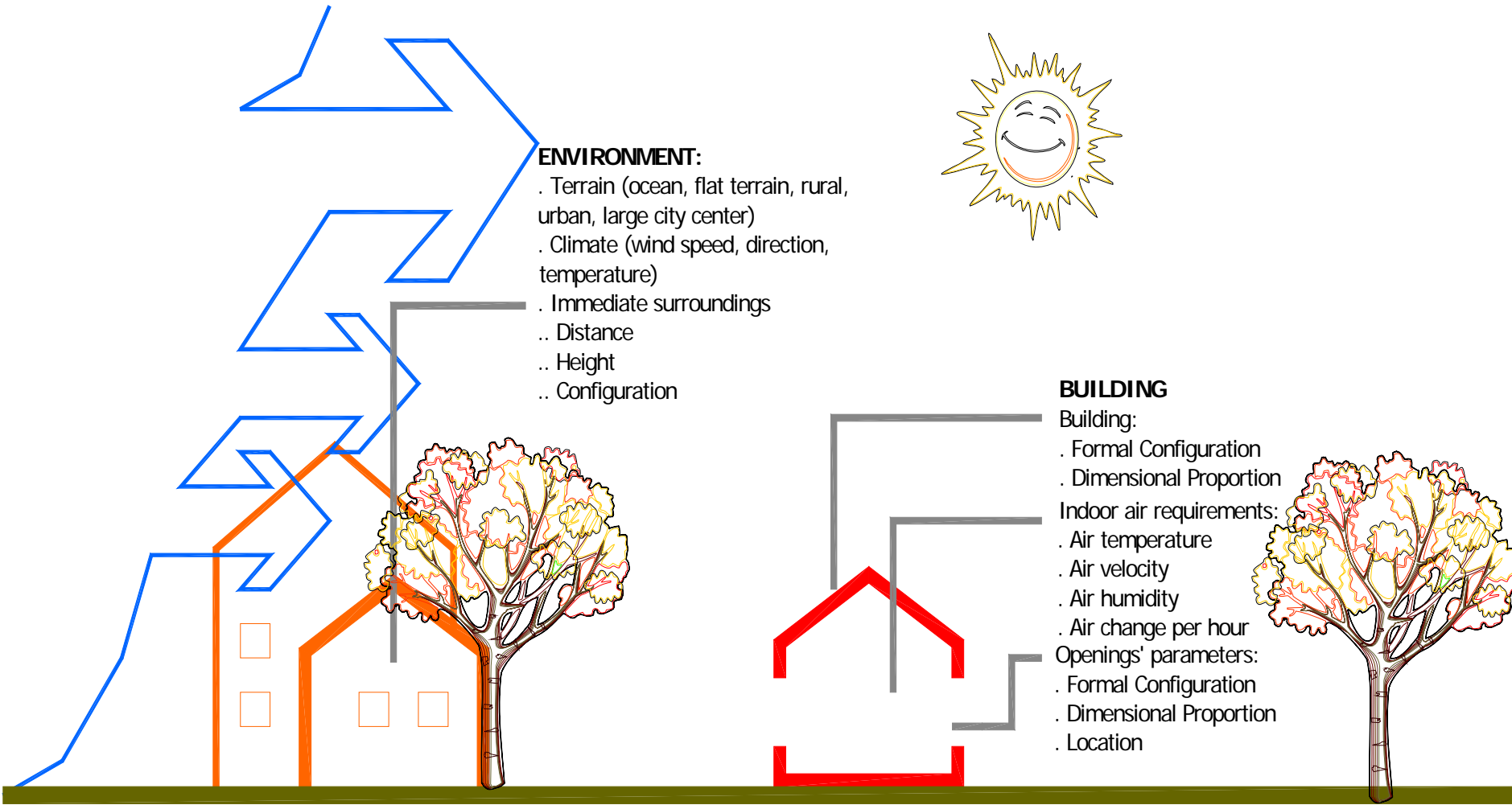
*in the design context.....*

# *Knowledge Acquisition*

- Intuitive / Experiential
  - Impact more evident in some domains than others
  - Repertoire of “live” projects
- “Formal” education
  - Reliance on printed media ?



# Air Flow Input Parameters

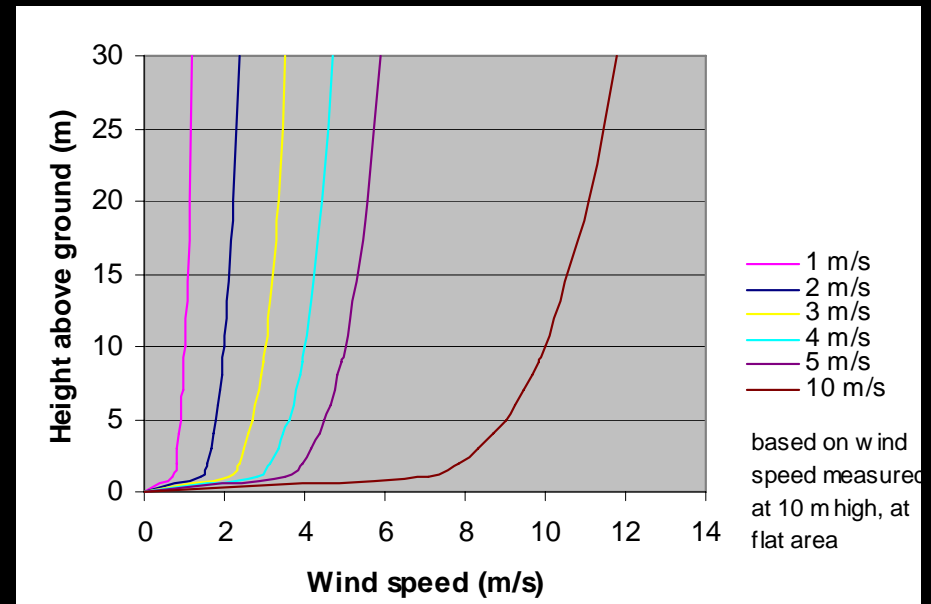
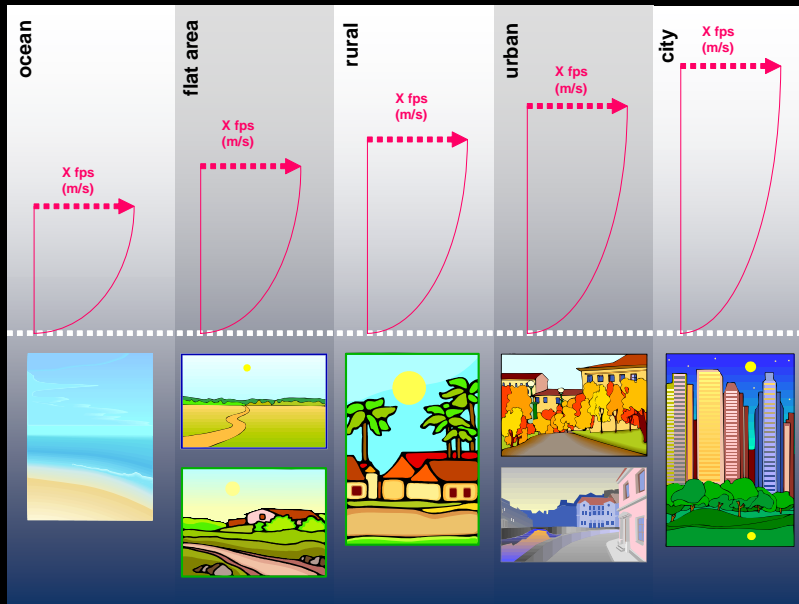


# Air Flow Input Data

mph (m/s)	General description	Specifications
< 1 (<0.45)	Calm	Smoke rises vertically.
1 – 3 (0.45 – 1.34)	Light air	Wind direction shown by smoke drift but not by vanes
4 – 7 (1.79 – 3.13)	Slight breeze	Wind felt on face; leaves rustle; ordinary vane moved by wind.
8 – 11 (3.58 – 4.92)	Gentle breeze	Leaves and twigs in constant motion; wind extends light flags.
12 – 16 (5.36 – 7.15)	Moderate breeze	Dust and loose paper moved; small branches are moved.
17 – 22 (7.60 – 9.83)	Fresh breeze	Small trees with leaves begin to sway.
23 – 27 (10.28 – 12.07)	Strong breeze	Large branches in motion; whistling in telephone wires.
28 – 34 (12.52 – 15.20)	Moderate gale	Whole trees in motion.
35 – 41 (15.65 – 18.33)	Fresh gale	Twigs broken off trees; progress generally impeded.
42 – 48 (18.78 – 21.46)	Strong gale	Slight structural damage occurred; chimney pots removed.
49 – 56 (21.90 – 25.03)	Whole gale	Trees uprooted; considerable structural damage.
57 – 67 (25.48 – 29.95)	Storm	Very rarely experienced; widespread damage.
> 68 ( > 30.40)	Hurricane	Extremely rare; extensive damage common.

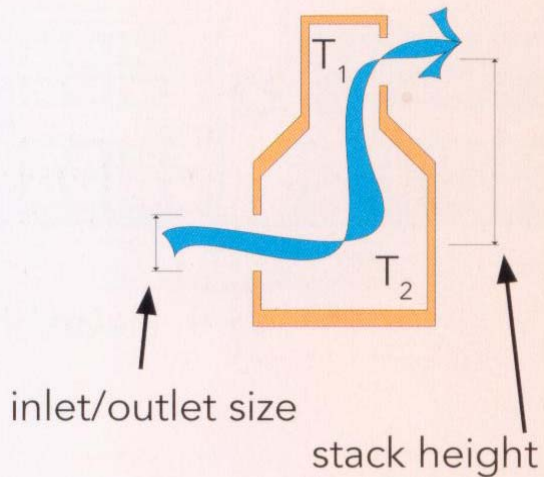
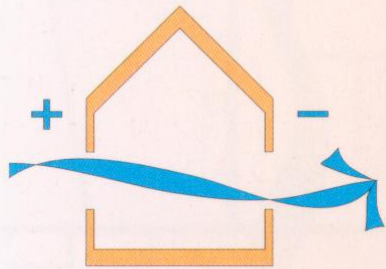
# Air Flow Input Data

$$v/v' = \alpha (H / 10)^{\gamma} / [\alpha' (H' / 10)^{\gamma'}]$$

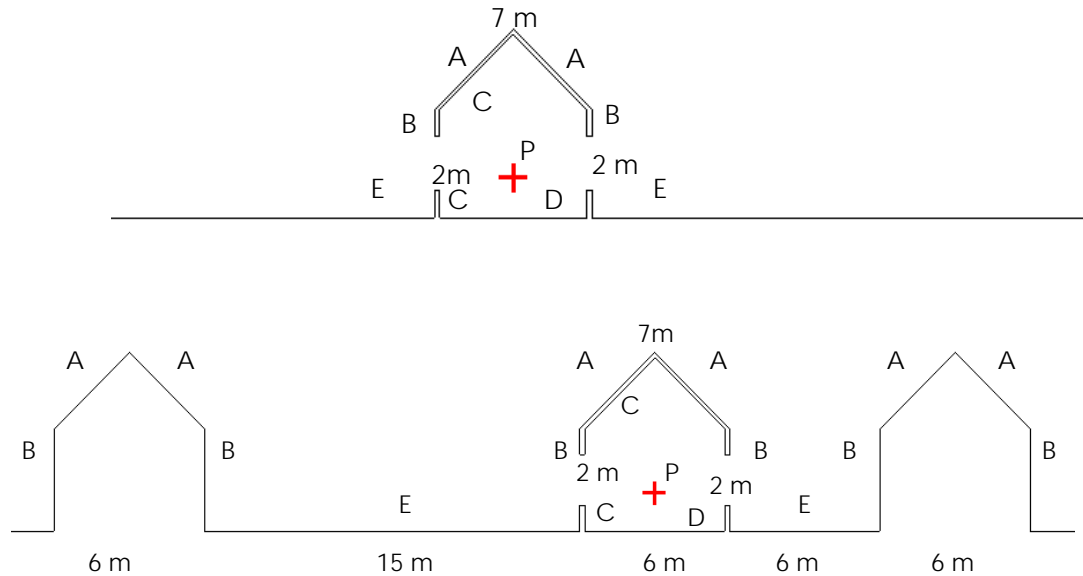


# Experimental Configurations

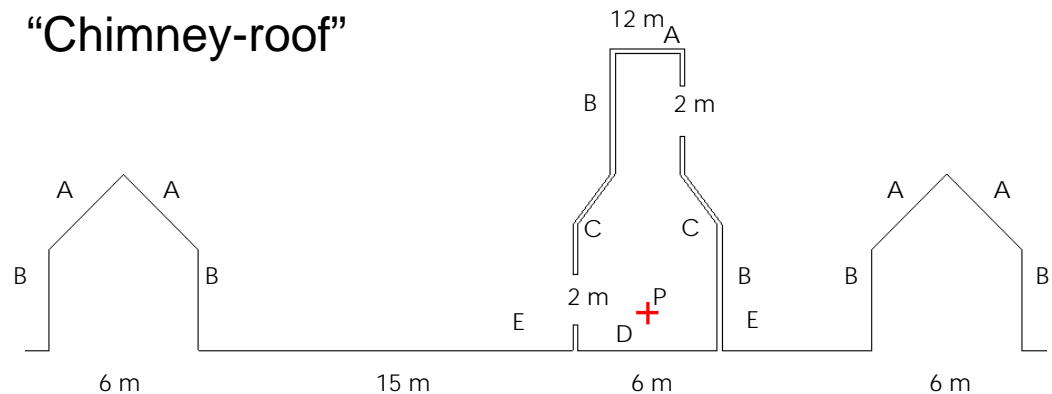
Brown, 2004



“Gable-roof”



“Chimney-roof”

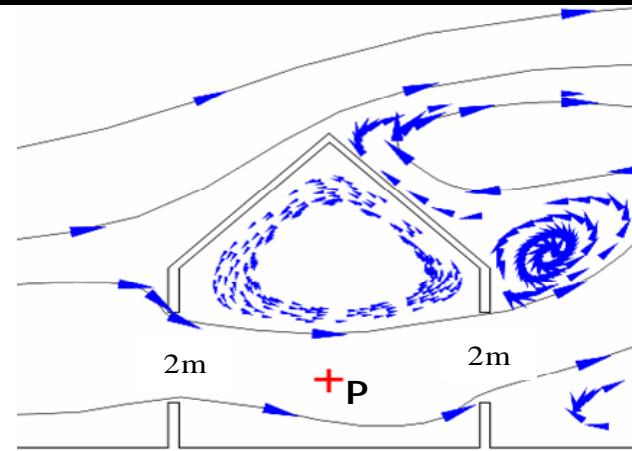


Inlet = Outlet

$$V_P = 1.57 \text{ fps (0.48 m/s)}$$

$$T_P = 71.06^\circ\text{F (21.7 }^\circ\text{C)}$$

Rotating airflow under the roof, which brings heat from the warm roof, is above the occupants' zone.

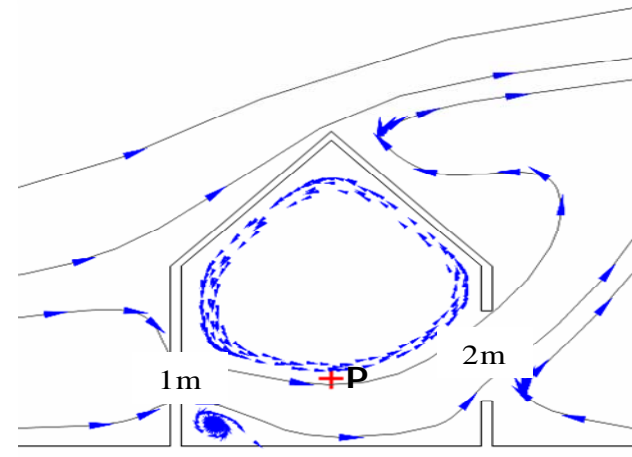


Inlet < Outlet

$$V_P = 1.18 \text{ fps (0.36 m/s)}$$

$$T_P = 72.14^\circ\text{F (22.3 }^\circ\text{C)}$$

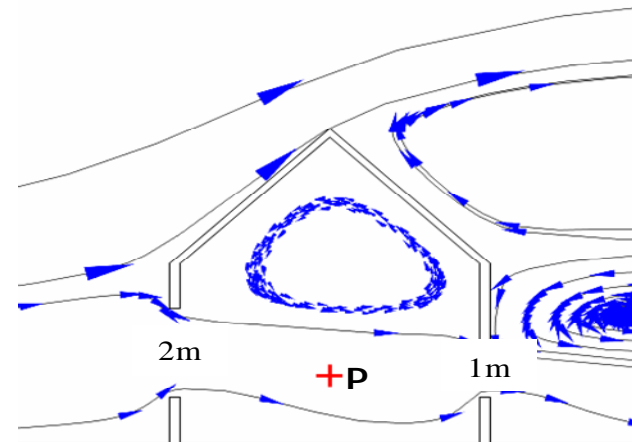
Rotating airflow under the roof, which brings heat from the warm roof, reaches upper part of the occupants' zone



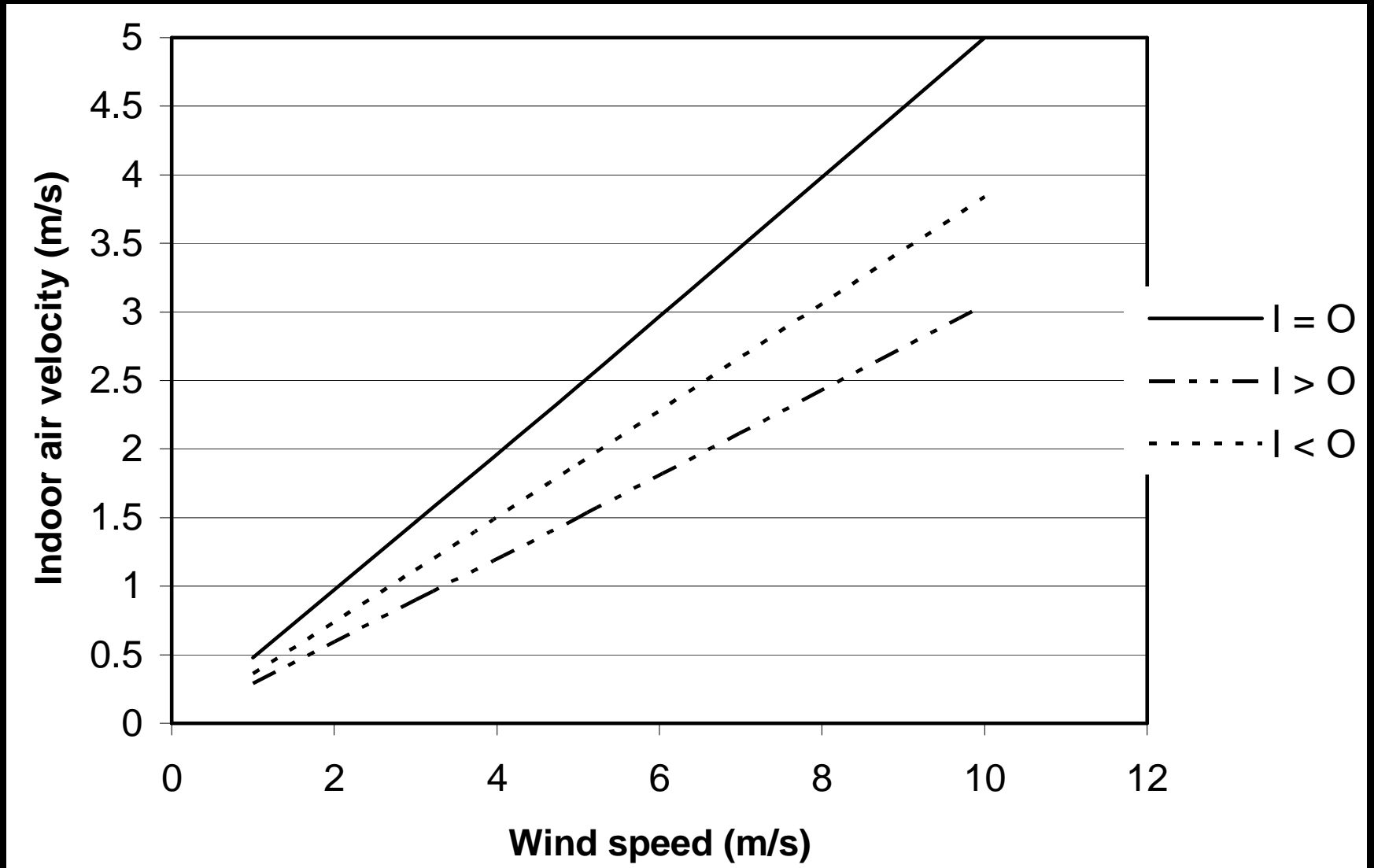
Inlet > Outlet

$$V_P = 0.95 \text{ fps (0.29 m/s)}$$

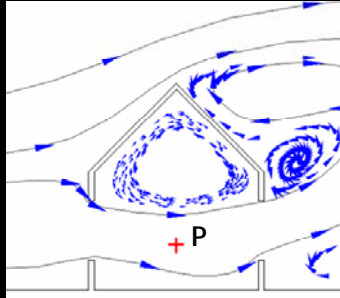
$$T_P = 71.96^\circ\text{F (22.2 }^\circ\text{C)}$$



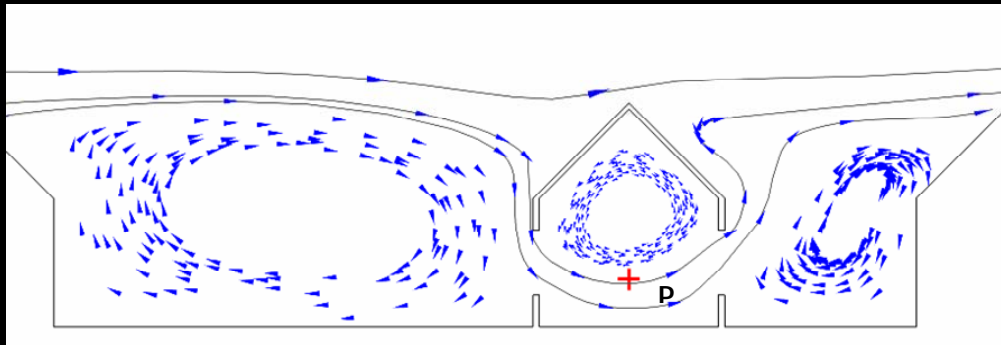
# ***Correlation between indoor air velocity and wind speed (measured at open terrain)***



# Air flow pattern in and around a “gable-roof” building



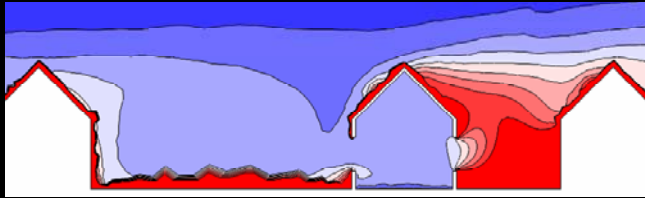
at wind speed 3.28 fps (1 m/s)  
 $V_P = 1.57$  fps (0.48 m/s),  $T_P = 71.06^\circ\text{F}$  (21.7 °C)  
At wind speed 9.84 fps (3 m/s)  
 $V_P = 4.82$  fps (1.47 m/s),  $T_P = 70.52^\circ\text{F}$  (21.4 °C)



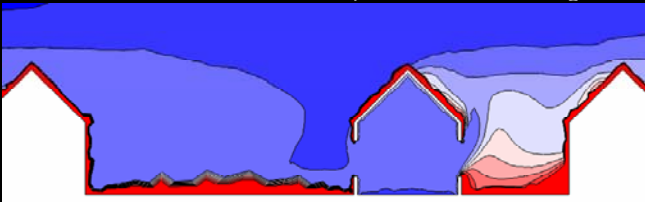
at wind speed 3.28 fps (1 m/s)  
 $V_P = 0.33$  fps (0.1 m/s),  $T_P = 71.65^\circ\text{F}$  (22.03 °C)  
At wind speed 9.84 fps (3 m/s)  
 $V_P = 0.98$  fps (0.3 m/s),  $T_P = 70.7^\circ\text{F}$  (21.5 °C).

Surrounding objects deflect indoor airflow path downward and cause rotating airflow under the roof to reach occupants' zone.

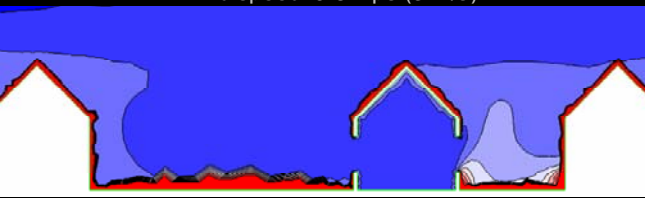
# Temperature and Air velocity profiles outside and inside “gable-roof” building



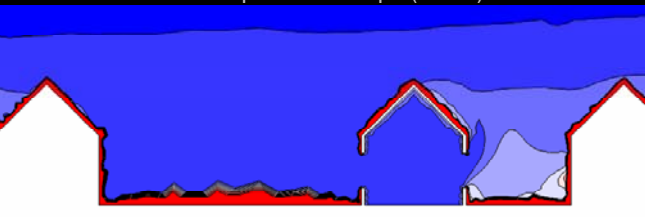
Wind speed: 3.28 fps (1 m/s). Lower wind speeds give time for heat to accumulate and create heat pool between buildings.



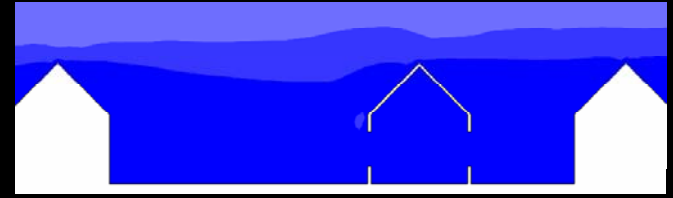
Wind speed: 9.84 fps (3 m/s)



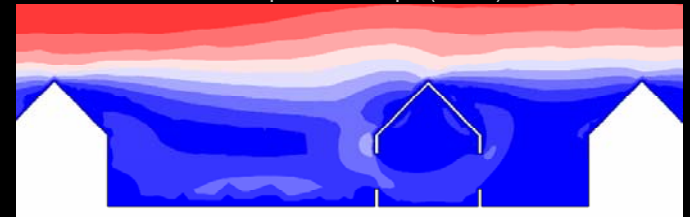
Wind speed: 16.40 fps (5 m/s)



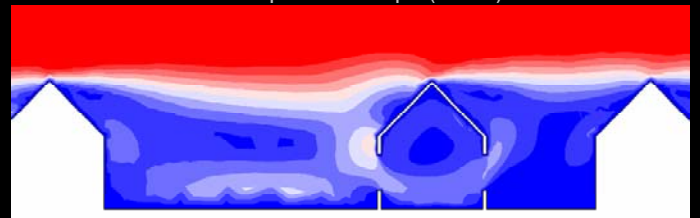
Wind speed: 32.8 fps (10 m/s). Higher wind speeds help dispersing heat pool between buildings.



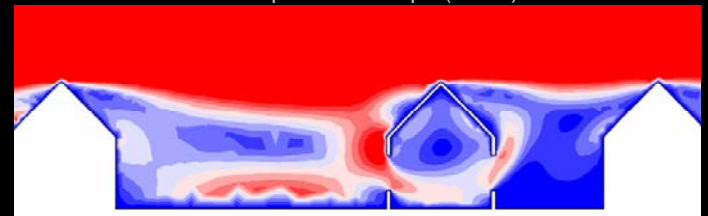
Wind speed: 3.28 fps (1 m/s)



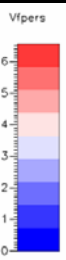
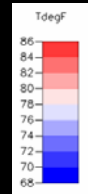
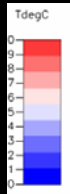
Wind speed: 9.84 fps (3 m/s)



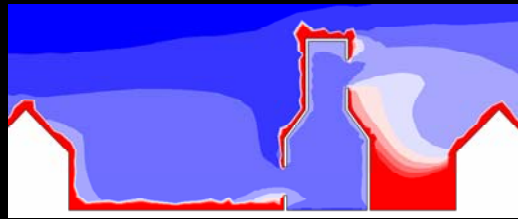
Wind speed: 16.40 fps (5 m/s)



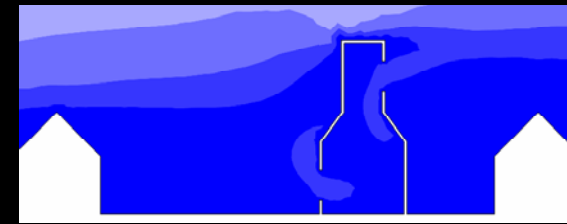
Wind speed: 32.8 fps (10 m/s)



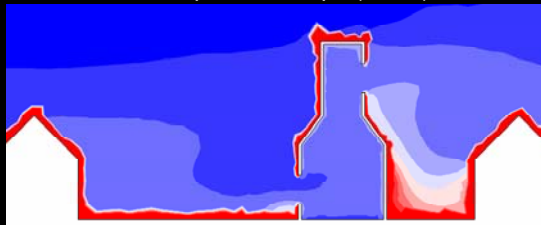
# Temperature and air velocity profiles outside and inside “chimney-roof” building



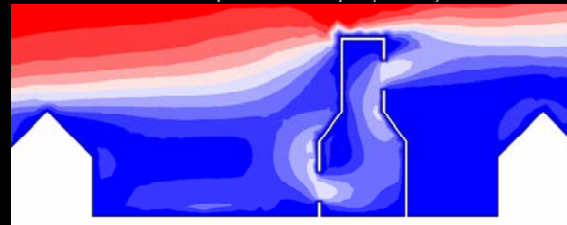
Wind speed: 3.28 fps (1 m/s)



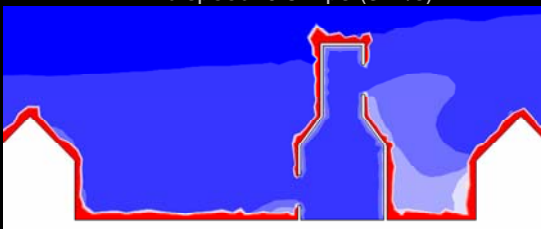
Wind speed: 3.28 fps (1 m/s)



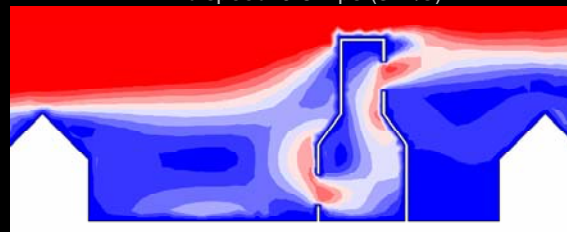
Wind speed: 9.84 fps (3 m/s)



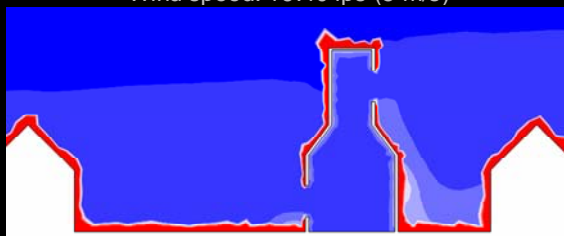
Wind speed: 9.84 fps (3 m/s)



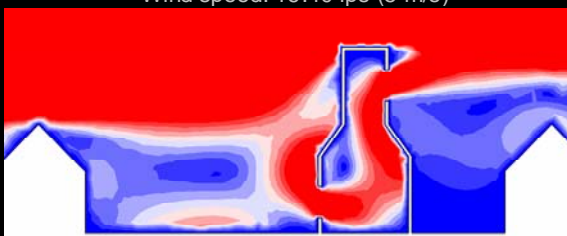
Wind speed: 16.40 fps (5 m/s)



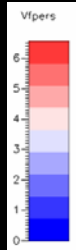
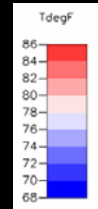
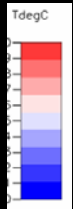
Wind speed: 16.40 fps (5 m/s)



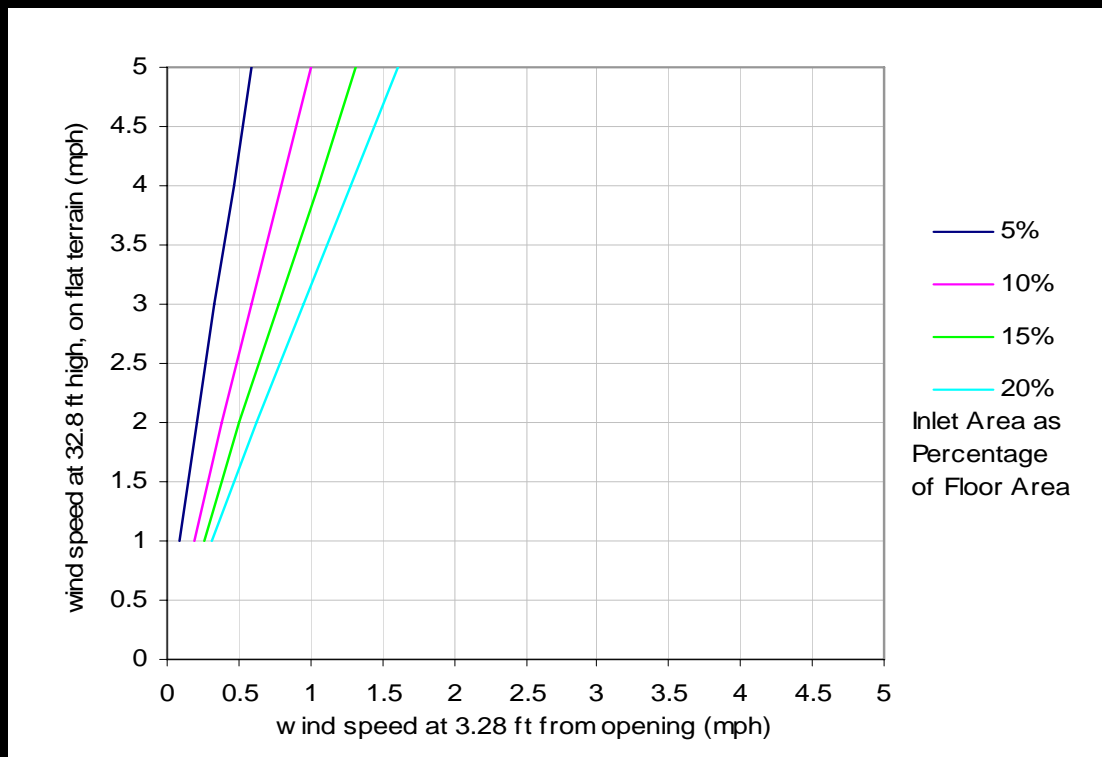
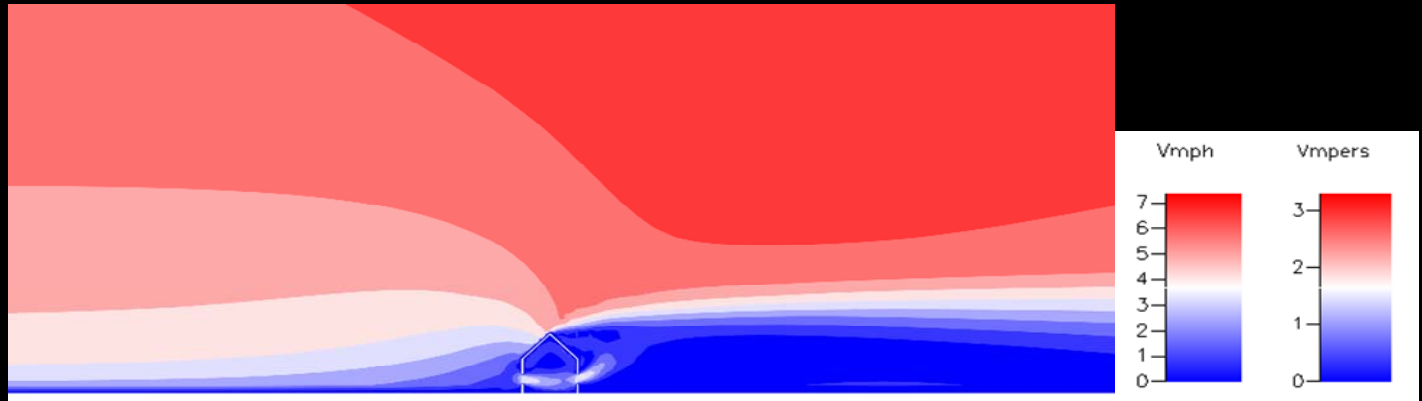
Wind speed: 32.80 fps (10 m/s)



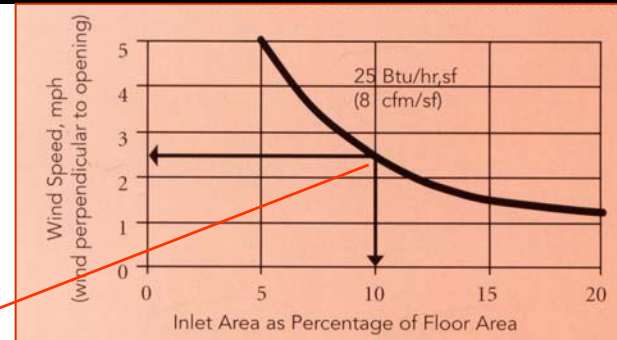
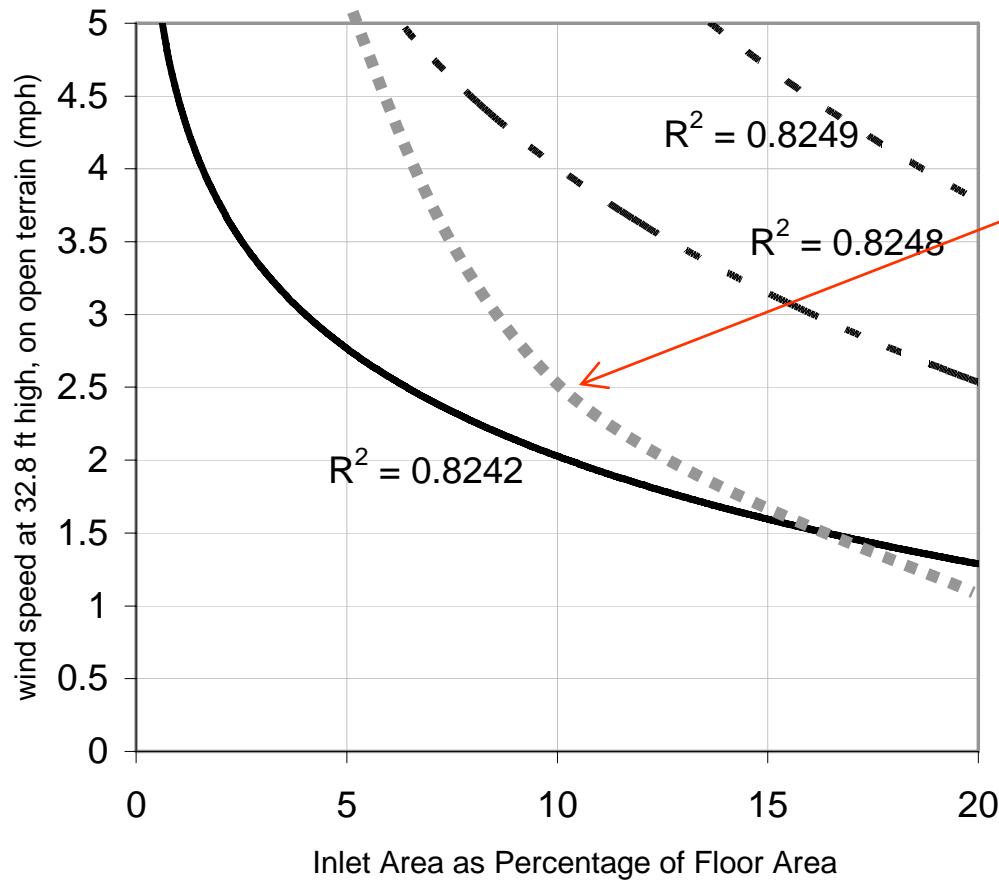
Wind speed: 32.80 fps (10 m/s)



# Profile of wind speed approaching a building

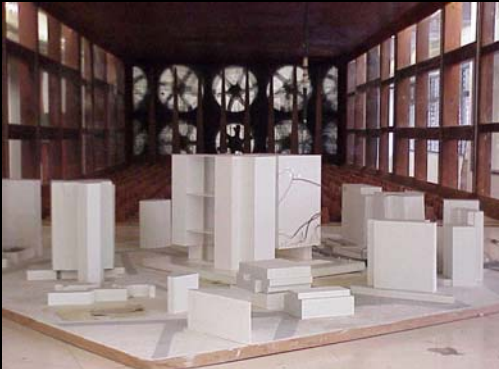
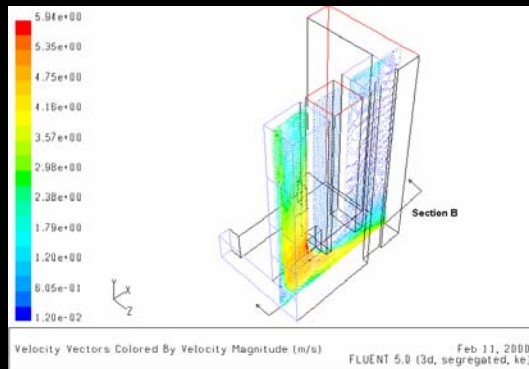
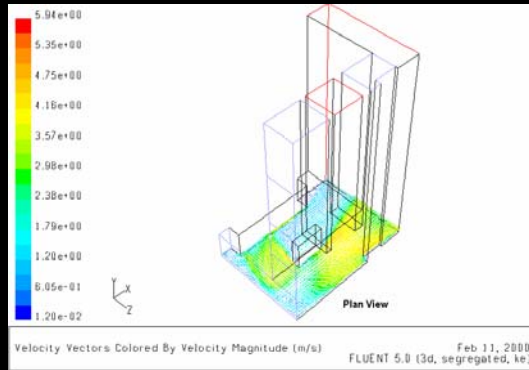


# Correlation between wind speed and inlet size with respect to airflow rate



- Log. (3 cfm/sf)
- Log. (2 cfm/sf)
- Log. (1 cfm/sf)

Brown 2004



Title : National Library Bid To Save Power Rewarded  
Medium : The Straits Times  
Date : 17 May 2005  
Section : Home  
Page : 14  
Size : 3col x 24cm, 2col x 11cm

BCA'S GREEN MARK AWARDS

# National Library bid to save power rewarded

Building gets top Platinum rating; savings of up to 25% expected

By DARYL LOO

THE new National Library in Victoria Street has been named one of two top winners of a new award for "green" buildings, given out by the Building and Construction Authority (BCA).

The award, given out under its Green Mark Scheme, rates projects using green criteria like energy and water-saving potential and protection of the environment.

The new \$203 million National Library was recognised for its use of features like daylight sensors that automatically activate blinds on sunny days, thereby reducing the need for air-conditioning. As many as 14 gardens were also added throughout the building to maintain a cool ambience.

The National Library Board's assistant director for properties, Mr Michael Ng, said: "We wanted to include 'green' elements from the outset, along with the Government's push for greener buildings."

He estimated that the energy-saving features could cut the building's power bill by up to 25 per cent. This achievement earned the library a Platinum Award.

The other Platinum win-

ner this year was Nanyang Polytechnic's campus in Ang Mo Kio.

Companies retain the award for two years, after which they are reassessed.

The BCA classifies buildings in three grades: Platinum, Gold and the Green Mark. The grades are based on the total scores a project receives across the BCA's environmental criteria.

Mr Wong Wai Ching, director of BCA's building plan and management division, said the two-year limit will encourage building owners to maintain standards even after the buildings have been completed.

Nine projects received the Gold award, including four City Developments condominium projects, two CapitalLand office towers and Alexandra Hospital. Another six projects were given the Green Mark.

BCA also announced three other awards yesterday, for buildability, construction excellence and energy efficiency. Buildability measures the extent that a project can be easily built, and yet remain aesthetically pleasing. Five projects received the prize for buildability.

Of these, one was the sprawling new ITE College East campus in Simei, which made extensive use of prefabricated materials for its staircases, link bridges and roads. The project ended up costing nearly 45 per cent less to build than other similar projects.

Mr Tan Tian Chong, director of BCA's technology development division, said the main advantages of using prefabricated materials are reduced costs, less labour and quicker construction times.

Prefabricated components are gaining popularity among developers here, Mr Tan added. Around 72 per cent of projects now make use of them, compared to 14 per cent five years ago.

The Construction Excellence Award, introduced in 1986 and given to contractors for their building capabilities, went to four companies this year, three of which are multinationals. One is a local firm.

The local winner is Singaporean contractor SembCorp Engineers and Constructors, for its work on Phase 2 of Tembusu Finance Park. The company managed to complete the project in 16 months, three months ahead of schedule.

According to BCA, SembCorp managed this in spite of construction difficulties. The firm was also commended for clinching a number of overseas contracts. SembCorp president Wong Heung Fing said that more than half of the firm's new contracts last year came from overseas markets like China, India and the Middle East.

All the awards will be given out at a ceremony next Thursday.





Gone out...here is a computer simulation of your dinner

*I hear, I forget;  
I see, I understand;  
I do, I remember.*

*Homer*

*Thank you*

*Khee Poh Lam*