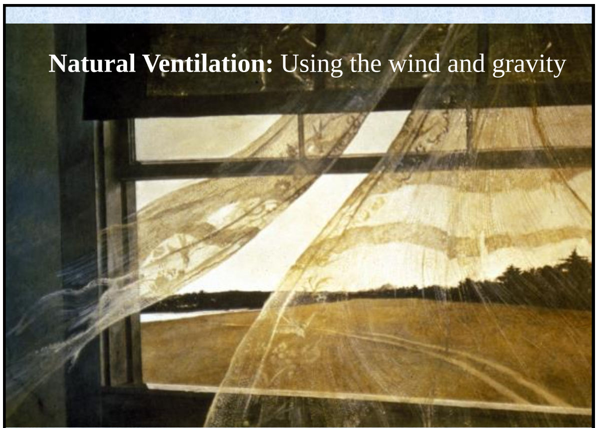
Natural Ventilation: Using the wind and gravity



1

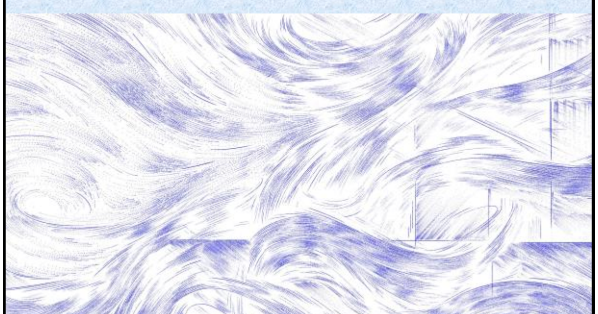
General Guidelines

Wind Direction	1. On-site observation 2. Hourly weather data* 3. Wind roses 4. Average and mean data
Nature of Wind	It's gusty: varies over short time periods in both speed and direction
Site Considerations	Take heed of microclimatic effects—topography, water bodies, surface materials, buildings, heat sources…

* NOAA TMY data or Energy Plus weather (EPW) files.

2

"Heaven's Breath – Wind"



−Hyunjung Huh

3

Why?

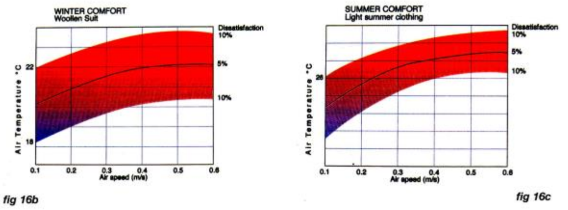


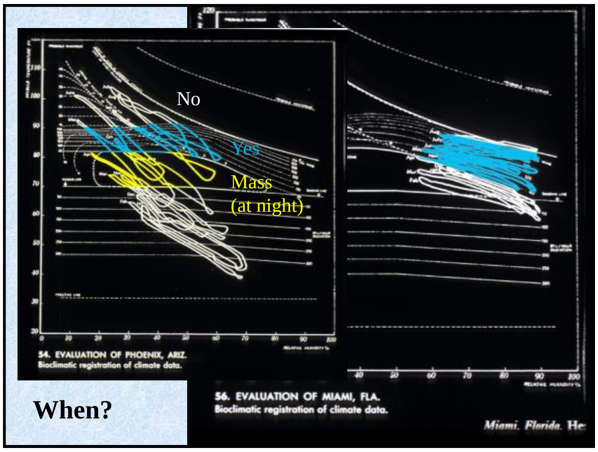
fig 16b

fig 16c

Acceptable air temperature will increase as air speed increases. This reaches a limit at 0.8 m/s when air movement becomes uncomfortable.

Note: 15ºC = 59ºF; 20ºC = 68ºF; 25ºC = 77ºF; 30ºC = 86ºF
0.8 m/s = 2.5 fps = 150 fpm = 1.7 mph

4



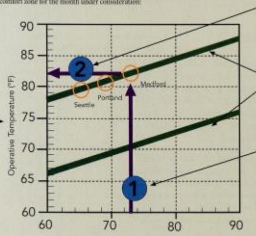
When?

5

WHAT IS ADAPTIVE COMFORT?

The adaptive comfort model (ASHRAE - DRAFT- 55-1992R) refers to "naturally conditioned spaces regulated primarily by the occupants opening and closing windows" and is based on the relationship of indoor or acceptable temperature ranges to outdoor climatological characteristics. To determine the upper limit of the comfort zone for the month under consideration:

The operative temperature is defined as "the uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment" (ASHRAE 1992, p.4).



2 At the intersection project horizontally to the vertical axis, which is the upper limit (operative temperature) of the comfort zone as defined by the adaptive model.

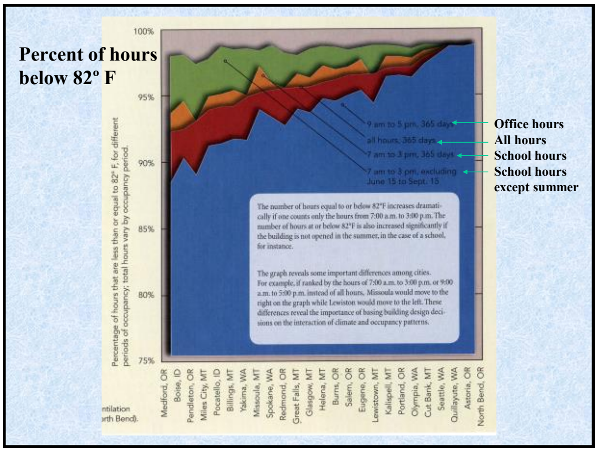
The limits of the adaptive comfort zone are a function of the arithmetic average of the mean daily minimum temperature and the mean daily maximum temperature for the month.

1 Enter the graph on the horizontal axis with the average of the mean minimum and maximum temperatures for the location, and project vertically to the highest sloping line.

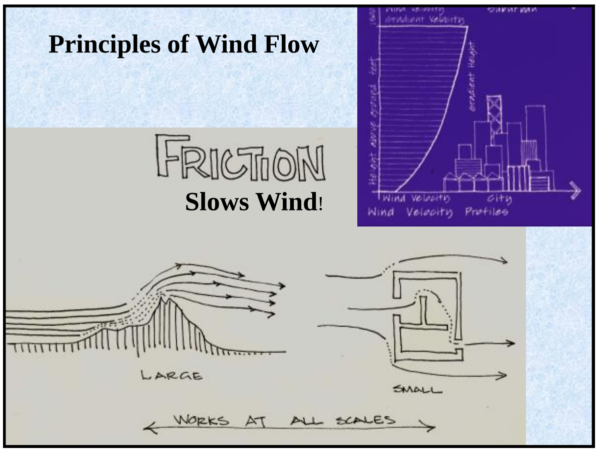
Mean monthly temperature (°F)

	Mean minimum temperature for August	Mean maximum temperature for August	Average of mean minimum and maximum temperatures for August	Maximum operative temperature (80% acceptable) using the adaptive comfort model
Medford	55.4° F	90.5° F	73.0° F	82° F
Portland	57.7 ° F	80.5° F	69.1° F	81° F
Seattle	56.3° F	73.9° F	65.1° F	80° F

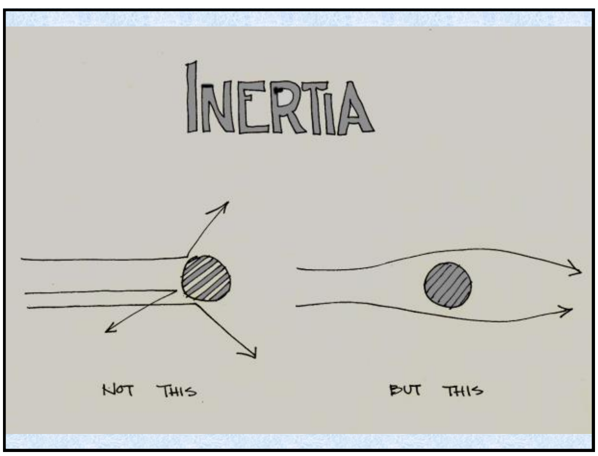
6


Percent of hours below 82º F
100%
95%
90%
85%
80%
75%
Percentage of hours that are less than or equal to 82° F, for different periods of occupancy; total hours vary by occupancy period.
9 am to 5 pm, 365 days
all hours, 365 days
7 am to 3 pm, 365 days
7 am to 3 pm, excluding June 15 to Sept. 15
Office hours
All hours
School hours
School hours except summer
The number of hours equal to or below 82°F increases dramatically if one counts only the hours from 7:00 a.m. to 3:00 p.m. The number of hours at or below 82°F is also increased significantly if the building is not opened in the summer, in the case of a school, for instance.
The graph reveals some important differences among cities. For example, if ranked by the hours of 7:00 a.m. to 3:00 p.m. or 9:00 a.m. to 5:00 p.m. instead of all hours, Missoula would move to the right on the graph while Lewiston would move to the left. These differences reveal the importance of basing building design decisions on the interaction of climate and occupancy patterns.
Medford, OR
Boise, ID
Pendleton, OR
Miles City, MT
Pocatello, ID
Billings, MT
Yakima, WA
Missoula, MT
Spokane, WA
Redmond, OR
Great Falls, MT
Glasgow, MT
Helena, MT
Burns, OR
Salem, OR
Eugene, OR
Lewistown, MT
Kalispell, MT
Portland, OR
Olympia, WA
Cut Bank, MT
Seattle, WA
Quillayute, WA
Astoria, OR
North Bend, OR

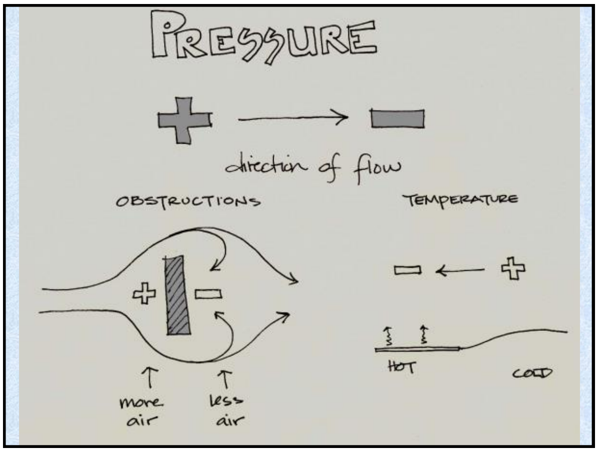
7


Principles of Wind Flow
FRICTION
Slows Wind!
Gradient Velocity
Gradient Height
Wind Velocity
City
Wind Velocity Profiles
LARGE
SMALL
WORKS AT ALL SCALES

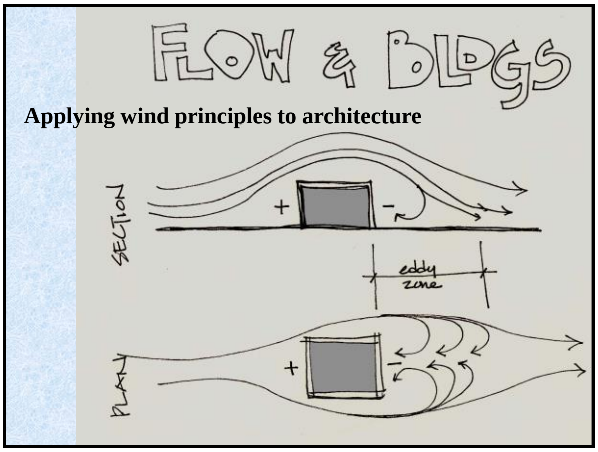
8


INERTIA
NOT THIS
BUT THIS

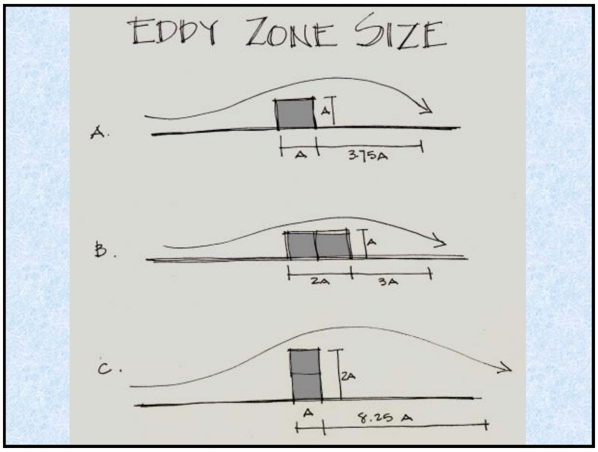
9


PRESSURE
direction of flow
OBSTRUCTIONS
TEMPERATURE
more air
less air
HOT
COLD

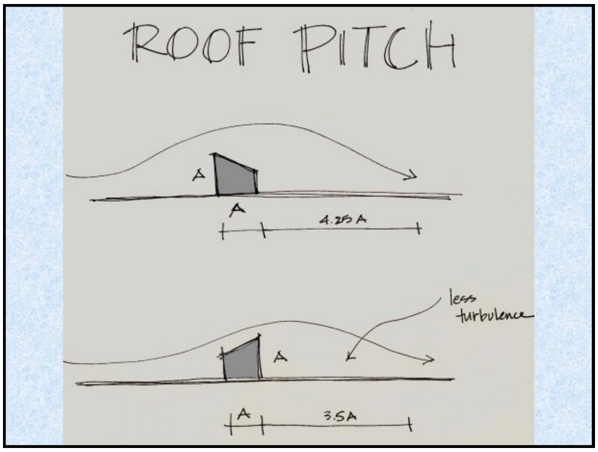
10


FLOW & BLDGS
Applying wind principles to architecture
SECTION
eddy zone
PLAN

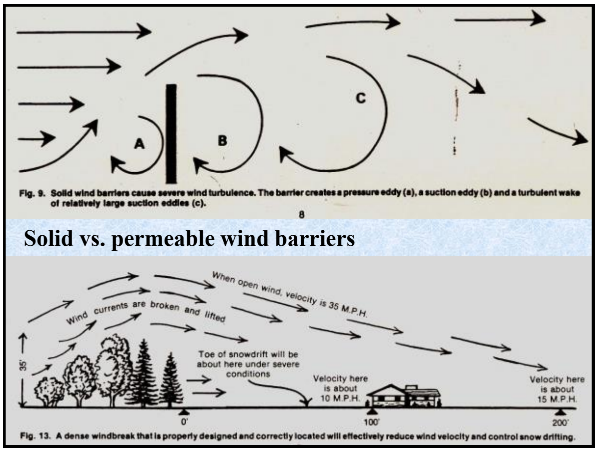
11


EDDY ZONE SIZE
A.
A
3.75A
B.
2A
3A
C.
2A
A
8.25 A

12


ROOF PITCH
A
A
4.25 A
less turbulence
A
A
3.5A

13

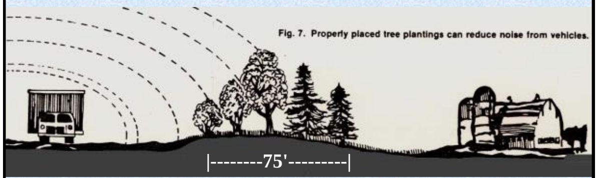

A
B
C
Fig. 9. Solid wind barriers cause severe wind turbulence. The barrier creates a pressure eddy (a), a suction eddy (b) and a turbulent wake of relatively large suction eddies (c).
8
Solid vs. permeable wind barriers
When open wind, velocity is 35 M.P.H.
Wind currents are broken and lifted
35'
Toe of snowdrift will be about here under severe conditions
Velocity here is about 10 M.P.H.
Velocity here is about 15 M.P.H.
0'
100'
200'
Fig. 13. A dense windbreak that is properly designed and correctly located will effectively reduce wind velocity and control snow drifting.

14


Wind-driven ocean spray helps visualize wind flow.

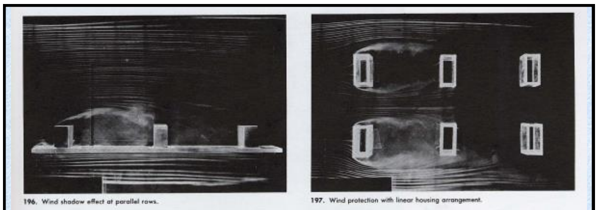
15

Additional benefits:
Shade, acoustic barrier, moisture, wildlife, air quality…

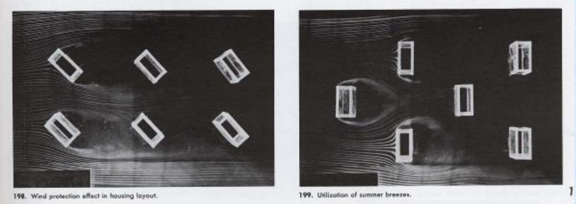


For effective wind and sound mitigation,
swath of vegetation must be at least 75'.

16



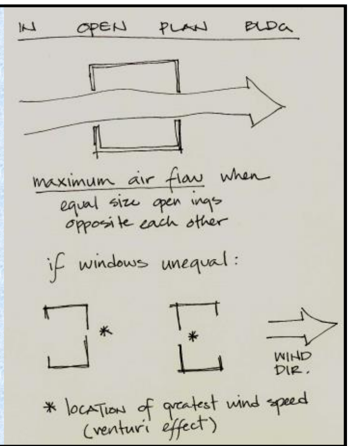
Wind patterns through groups of buildings



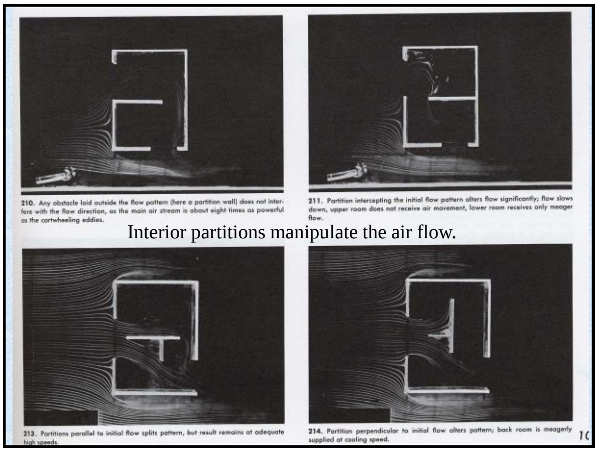
17

Ventilation Strategies

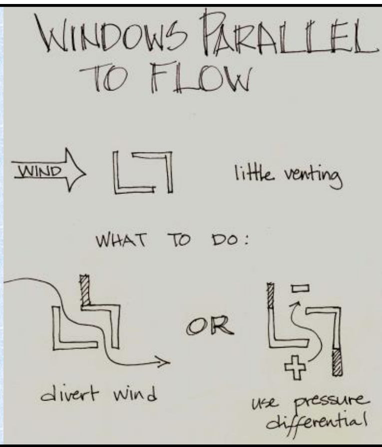
* Not Robert Venturi!



18

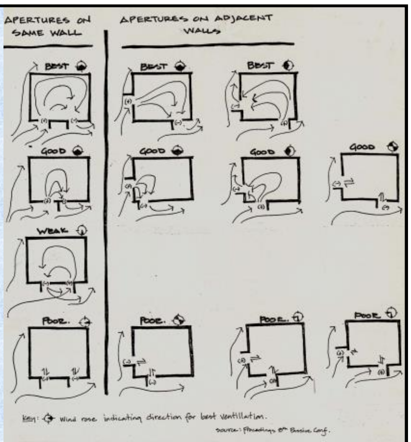


19

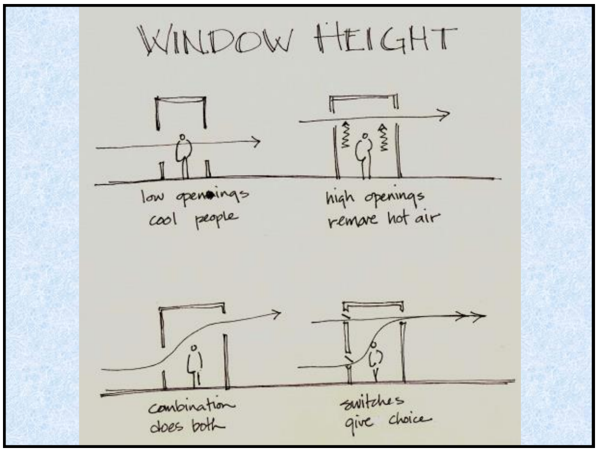


20

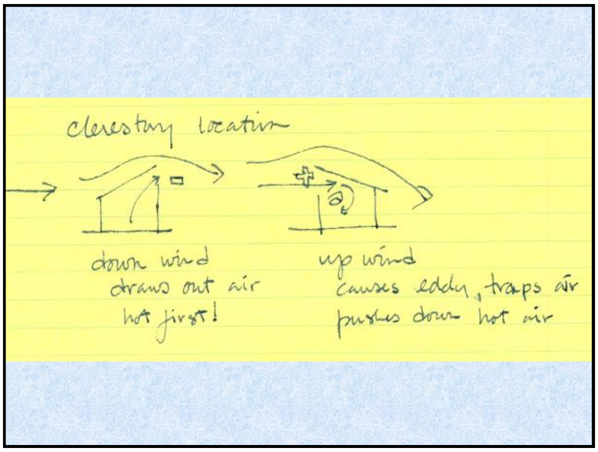
Windows on single or adjacent walls



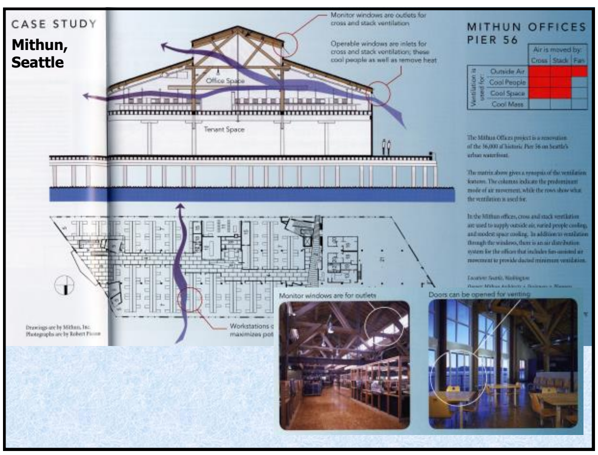
21


WINDOW HEIGHT
low openings
cool people
high openings
remove hot air
combination
does both
switches
give choice

22


clerestory location
down wind
draws out air
hot first!
up wind
causes eddy, traps air
pushes down hot air

23


CASE STUDY
Mithun,
Seattle
Monitor windows are outlets for cross and stack ventilation
Operable windows are inlets for cross and stack ventilation; these cool people as well as remove heat
Office Space
Tenant Space
MITHUN OFFICES
PIER 56
Air is moved by:
Cross
Stack
Fan
Ventilation is used for:
Outside Air
Cool People
Cool Space
Cool Mass
The Mithun Offices project is a renovation of the 56,000 sf historic Pier 56 on Seattle's urban waterfront.
The matrix above gives a synopsis of the ventilation features. The columns indicate the predominant mode of air movement, while the rows show what the ventilation is used for.
In the Mithun offices, cross and stack ventilation are used to supply outside air, varied people cooling, and modest space cooling. In addition to ventilation through the windows, there is an air distribution system for the offices that includes fan-assisted air movement to provide ducted minimum ventilation.
Location: Seattle, Washington
Drawings are by Mithun, Inc.
Monitor windows are for outlets
Doors can be opened for venting

24

Ventilation Calculations

Finding the required ventilation rate

$$Q = \frac{H}{1.08\,\Delta T}$$

where H = heat to be remove BtuH
(heat gain internal & external)
ΔT = inside to outside
(inside > outside for cooling)
Q = rate of heat removal cfm

Given:
Peak outside temperature = 78°F
Desired indoor temperature = 80 °F
Heat gain = 12,000 Btuh

Q = 12,000/(1.08)(2) = 5556 cfm

25

Two conditions	
Cross ventilation (breeze)	Stack ventilation (gravity)

CROSS VENTILATION

$$A = \frac{Q}{EV}$$

A = area of inlets or outlets (ft²) (whichever is smaller)
V = velocity of wind (ft/min) from climate data
E = efficiency of opening
use .6 ⊥ to wind
use .3 ∠ to wind
use 0 ∥ with wind

conversion of mph → fpm

$$mph \times \frac{5280\ ft/mi}{60\ min/hr} =$$

mph × 88

Given:
Average wind speed = 8.1 mph

A = 5556/(.3)(8.1)(88) = 5556/214 =26 sqft

26

Wind speed guide:

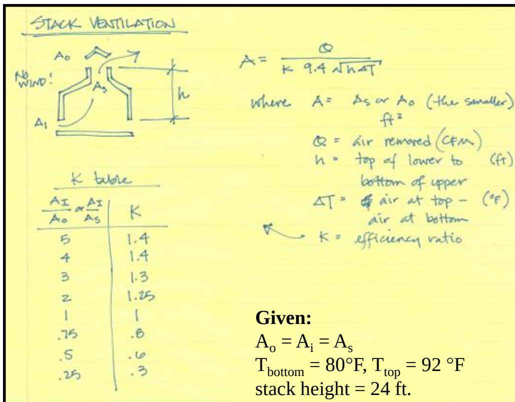
RULE OF THUMB

mph	fpm	
1-3	1-264	mirror surface on ponds (still!)
4-7	265-616	just feel the breeze
8-12	617-1056	leaves and twigs in constant motion
13-18	1057-1584	loose paper blows around
19-24	1585-2112	body feels wind
25+		used in calcs for lateral loads

* upper limit for vent. (Olgyay)

The wind speed in the building was (.3)(8.1)(88) = 214 fpm

27

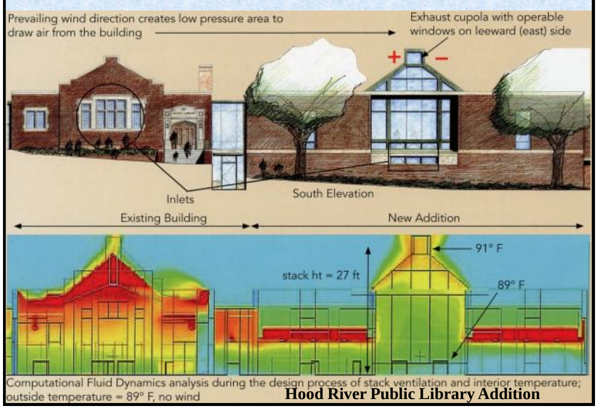


Given:
$A_o = A_i = A_s$
$T_{bottom} = 80°F$, $T_{top} = 92\ °F$
stack height = 24 ft.

A = 5556/(1)(9.4)(√(24)(12)) = 35 sqft

28

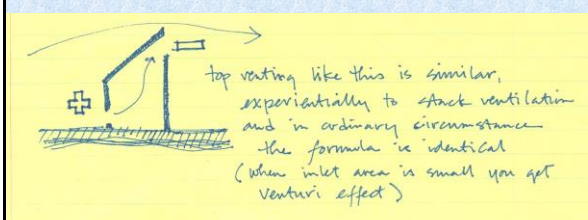
No wind without stack vs. No wind with stack



Hood River Public Library Addition

29

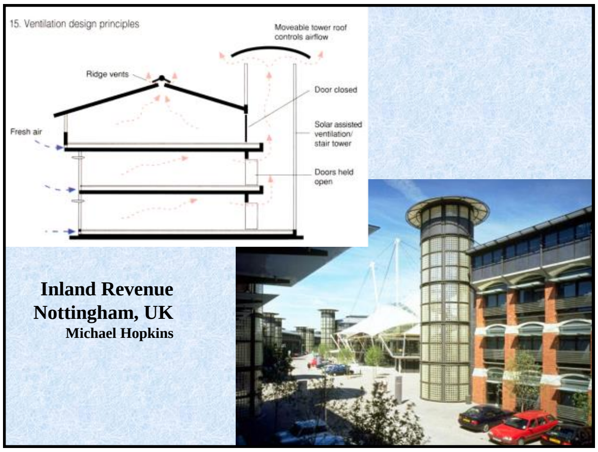
Stack ventilation can be increased by using sun or wind skillfully.



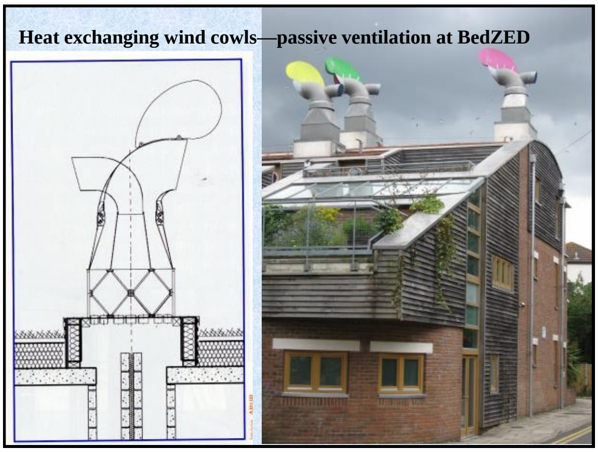
All ventilation techniques are more effective by pre-cooling air:

1. Inlets on the shady side of building
2. Draw air through greenspace
3. Draw air through earth tubes
4. Draw air past water source

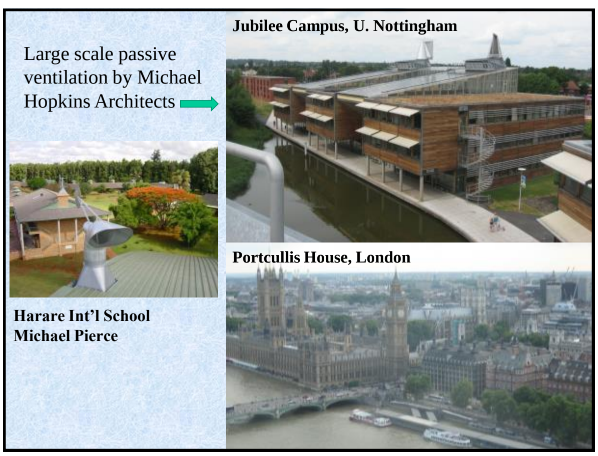
30


15. Ventilation design principles
Moveable tower roof controls airflow
Ridge vents
Door closed
Fresh air
Solar assisted ventilation/ stair tower
Doors held open
Inland Revenue
Nottingham, UK
Michael Hopkins

31


Heat exchanging wind cowls—passive ventilation at BedZED

32


Large scale passive ventilation by Michael Hopkins Architects
Jubilee Campus, U. Nottingham
Portcullis House, London
Harare Int'l School
Michael Pierce

33

Chimneys are stack ventilators!

warmed air from fire rises through chimney

$Q = 9.4 A \sqrt{h \Delta T}$ (same formula solving for Q)

where A = area of flue (ft^2)
h = height of stack
ΔT = between air at top of stack and room temp

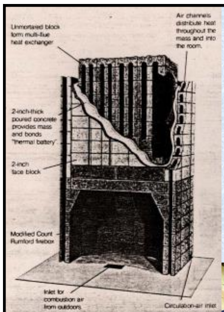
Given:
20' tall chimney, 12" x 12" flue
T_{in} = 65°F; T_{top} = 90°F

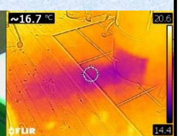
Q = 9.4(1sqft)($\sqrt{20 \times 25}$) =210 cfm
replaced by cold outside air!

34

Energy efficient fireplaces:

1. **Reduce flue-top temperature**
2. **Have own outside air source**





Pitkin Nursery Classroom Bldg.
Chris Patano

35