ISHIK UNIVERSITY

FACULTY OF ENGINEERING

Department of INTERIOR DESIGN

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INDS 414 SUSTAINABILITY and the INTERIOR ENVIRONMENT

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MSc in Sustainable Building Technology

Natural Ventilation

Natural Ventilation – Design Strategies

1. Understanding the Principles

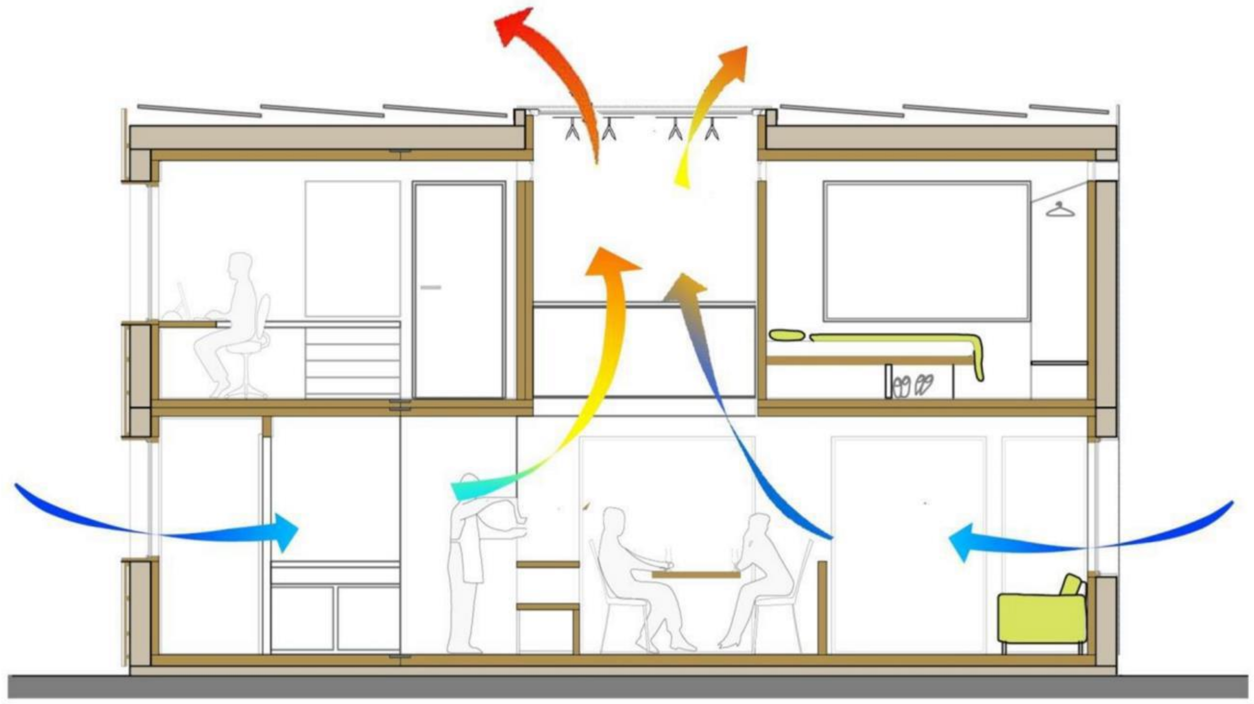
2. Natural Ventilation Strategies

3. Learning from precedent

4. Urban Air Pollution & Noise

5. Component Design - from Strategy to Detail Design

1. Principles of Natural Ventilation



Why is natural ventilation important?

1. To supply fresh air (to meet physiological requirements & to remove unpleasant odours).

2. To provide convective cooling (large volumes of air required)

3. To provide physiological cooling (air movement will increase convective heat loss & evaporation from the skin)

4.To save capital & running costs +carbon emissions
BUT, ventilation can be undesirable:

- Heat loss in winter

- Heat gain in summer

$$Qv = 1200/3600.N.V.(Ti - To)$$

Where Qv = ventilation heat loss/gain

N = Number of air changes/hour

V = Volume of the building or room

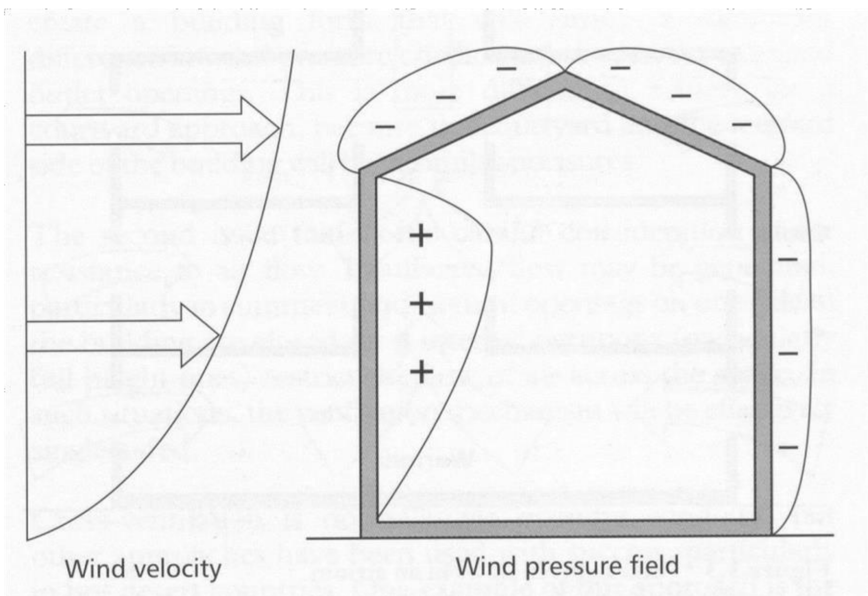
Designing for Natural Ventilation

Design Process

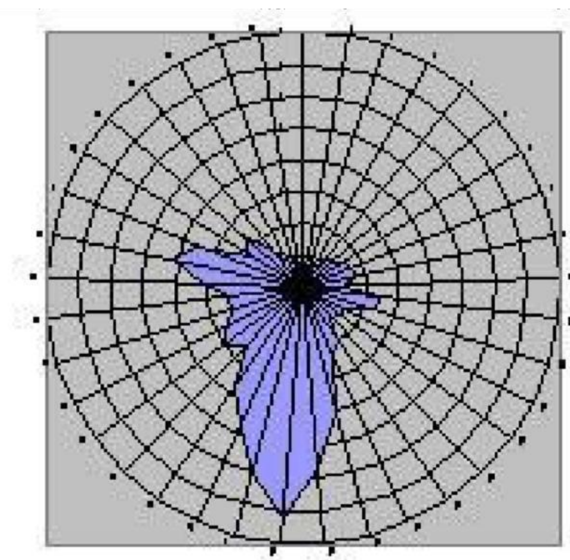
- Analyse site and micro-climate
- Define a ventilation strategy
- Test the strategy
- Finalize the design

Understanding the Principles of natural ventilation

Natural ventilation is driven by either wind or thermal forces (or a combination of both)



Wind pressure differences



Wind Rose

Wind Forces

Pressure Difference (Δp) across building induces air movement via cracks & openings

Air flow rate (Q_w) is directly proportional to the area of opening (A) but proportional to the $\sqrt{\Delta p}$

$$Q_w = 0.827 \times A \times \sqrt{\Delta p}$$

Pressure difference (Δp) across a building approx = P_w

where P_w = wind velocity pressure, and

$Pw = 0.612 \times v^2$

where v = wind velocity m/s

Thermal Forces

In absence of wind, air will move between low and high level openings driven by inside – outside temperature difference (Δt) which generates a pressure difference (Δp)

$$\Delta p = 3462h\ [1/to + 273 - 1/ti + 273]$$

Where Δp = pressure arising N/m^2

h = height between inlet & outlet

m t_o = outside temperature °C t_i =

inside temperature °C

Buoyancy driven airflow

How to calculate the vent area required to remove internal heat gains.

2. Natural Ventilation Strategies

The area A of each opening required to give a ventilation rate q for a specified value of h is:

$$A = \frac{q}{C_d} \sqrt{\frac{(T_I + 273)}{\Delta T\, g\, h}} \quad (4.12)$$

where A is the area of each opening (m^2), q is the ventilation rate ($m^3 \cdot s^{-1}$), C_d is the discharge coefficient, T_I is the internal temperature (°C), ΔT is the difference between the internal and external air temperatures (K), g is the gravitational force per unit mass ($m \cdot s^{-2}$) and h is the height between the openings (m).

A typical value for C_d is 0.6.

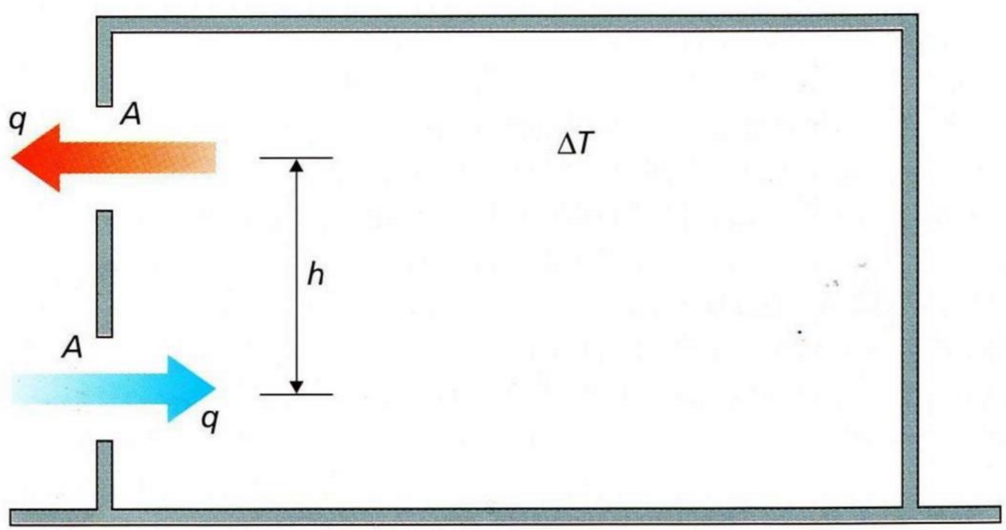
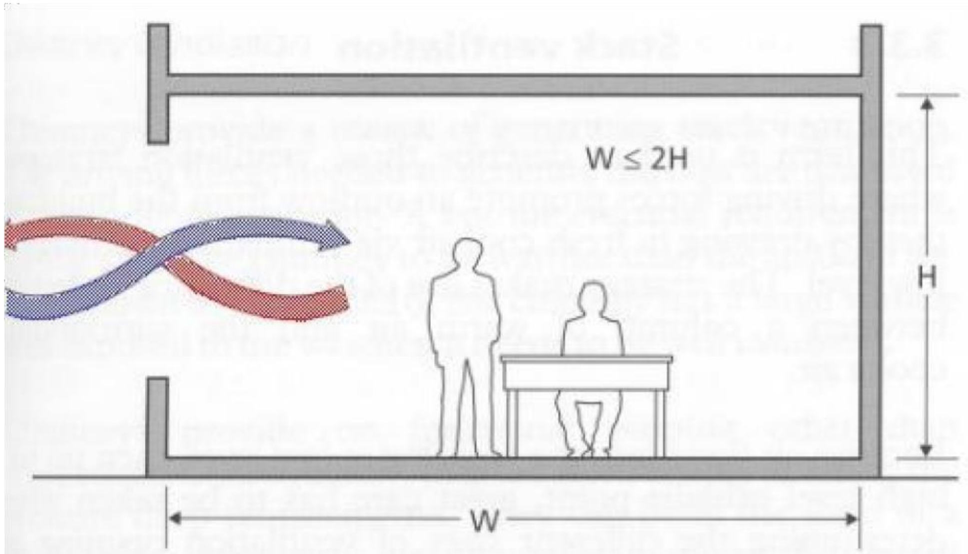
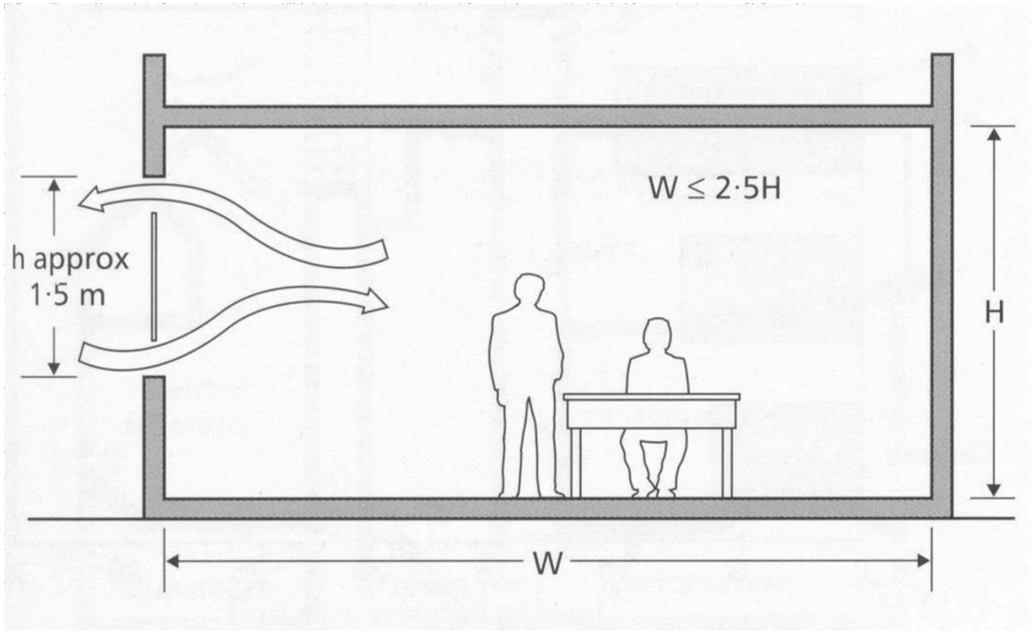


Figure 4.9 Case 1: single-sided ventilation, two identical openings, driven by buoyancy alone

Developing a Ventilation Strategy - rules of thumb for single sided ventilation

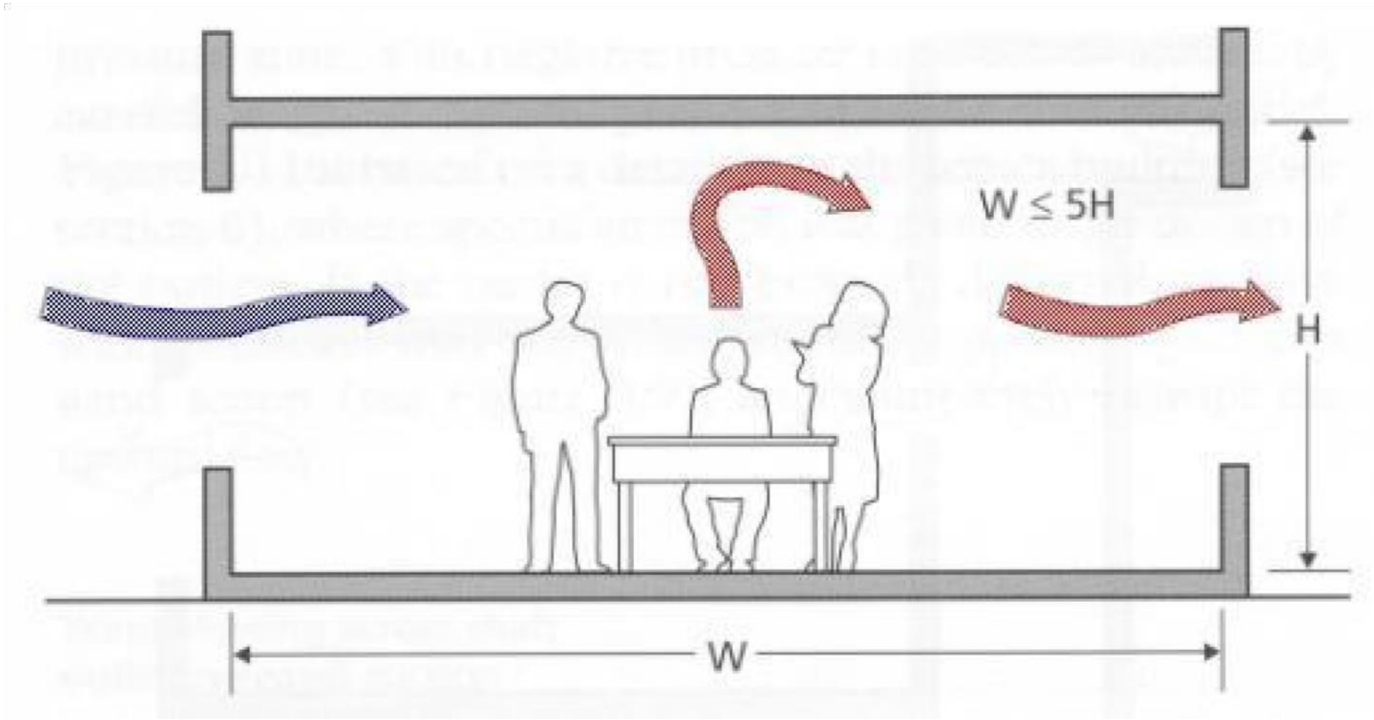


Ventilation through a single opening



Ventilation through two openings

Developing a Ventilation Strategy - rules of thumb for cross ventilation



Cross ventilation W≤ 5H

Defining the Air Flow Path

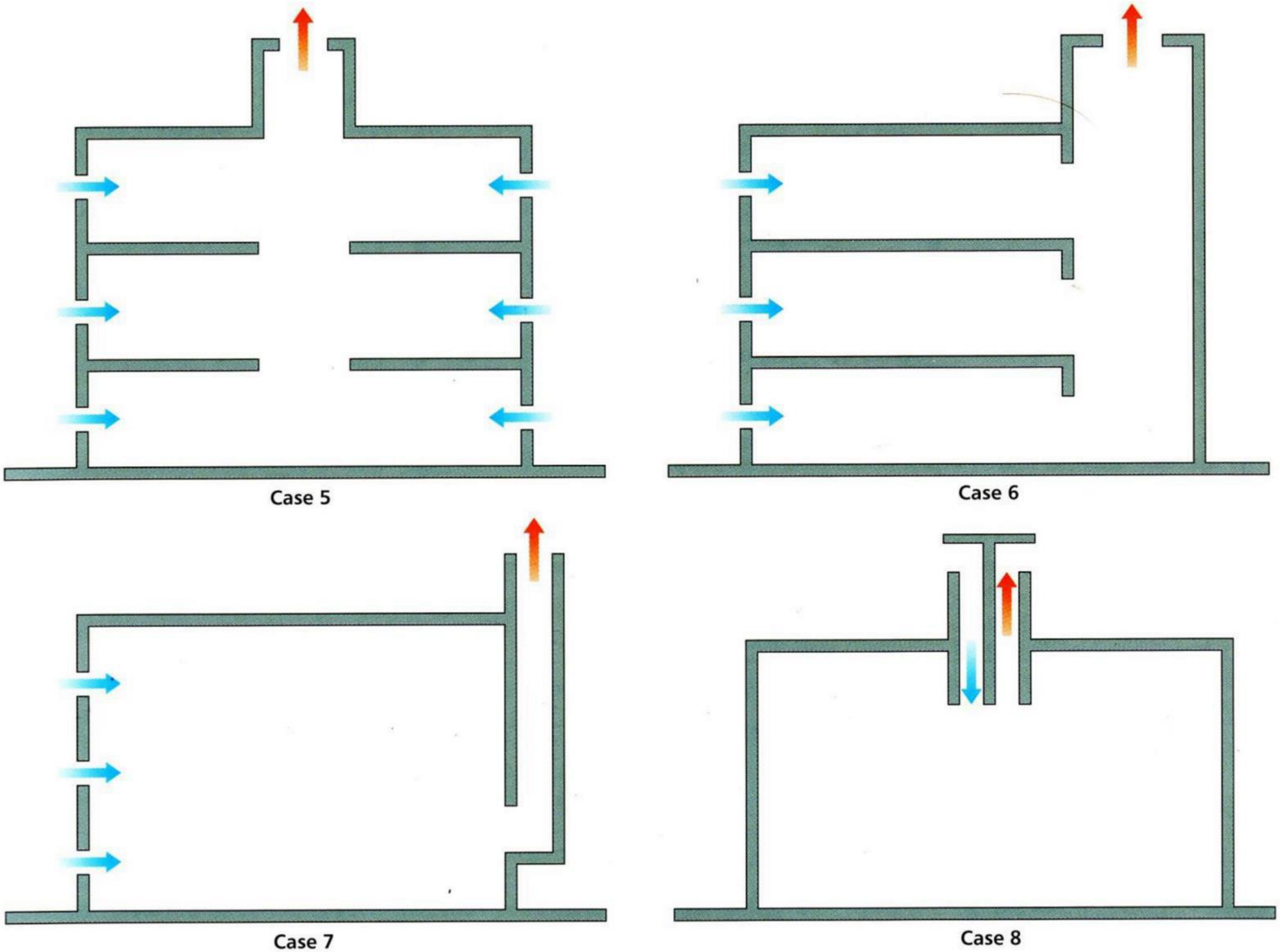


Figure 4.13 Examples of single-cell buildings

Natural Ventilation Strategies – single cell

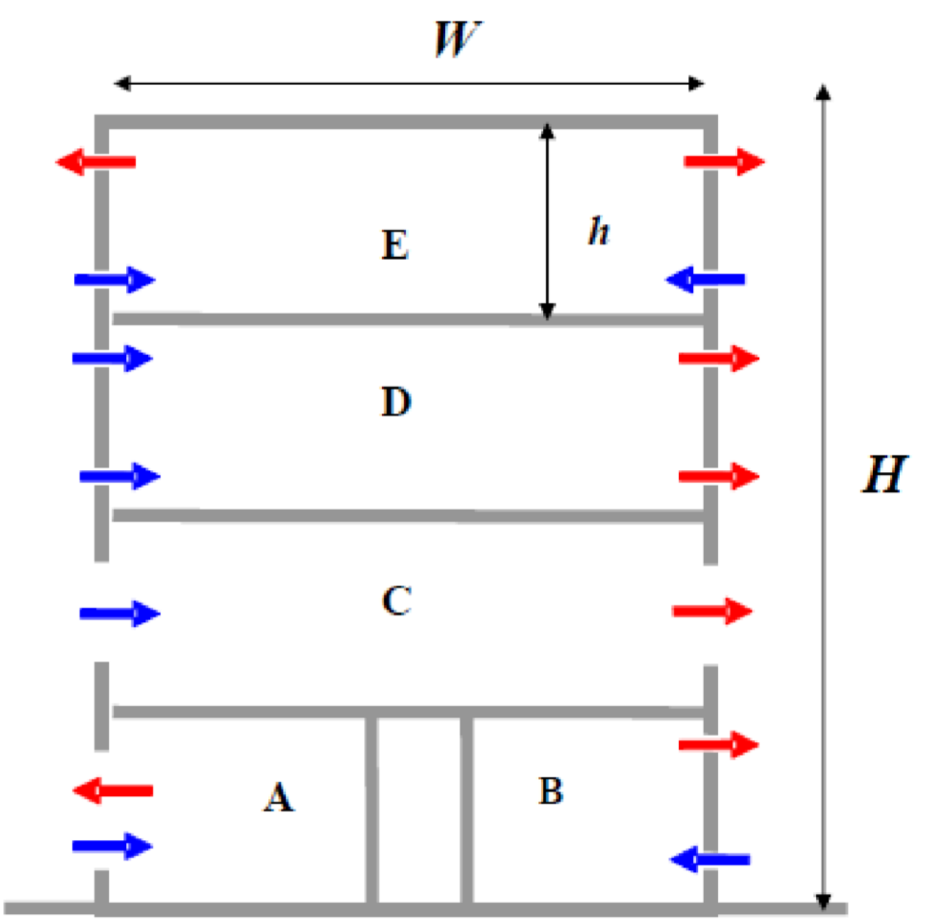
A & B - single sided ventilation openings at different heights

C & D - crossflow ventilation
(isolated floors)

E - buoyancy only

Ventilation patterns for isolated spaces (based on CIBSE, 2005)

Natural Ventilation Strategies – multi-cell

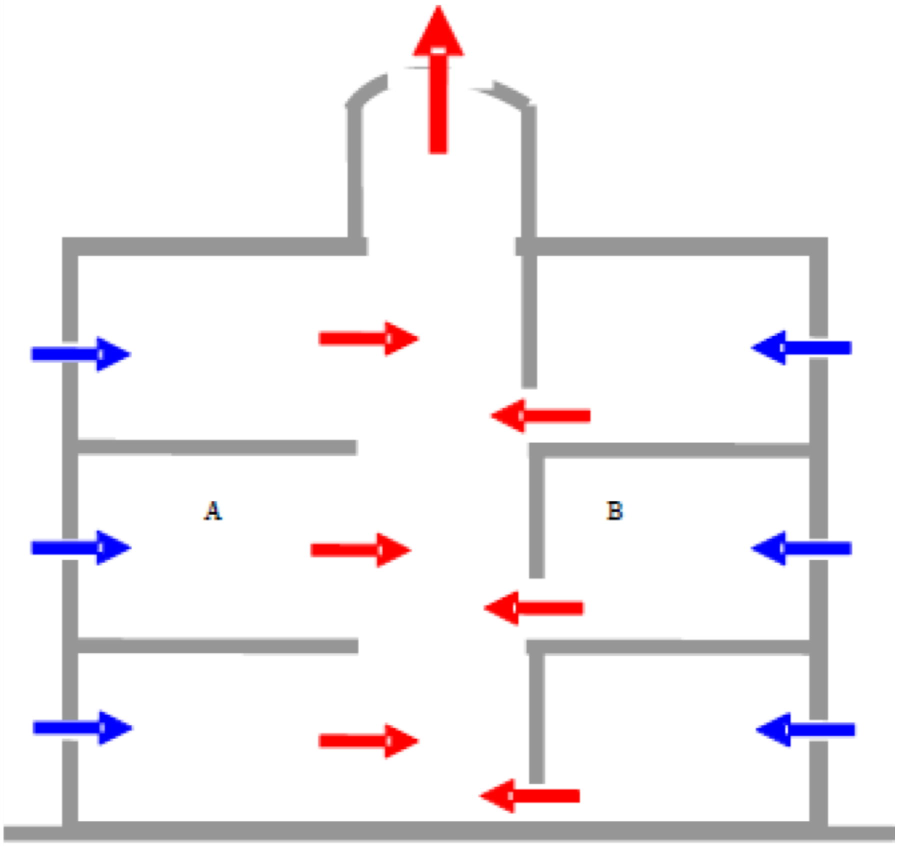


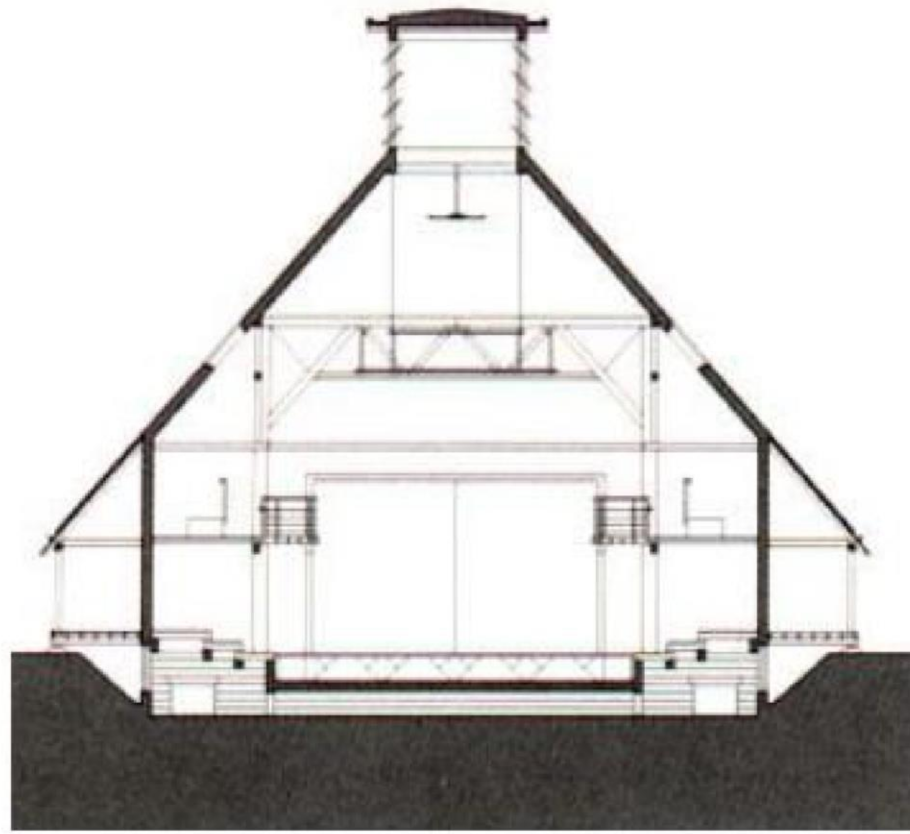
Atrium promotes crossflow ventilation – wind & buoyancy act together – better control

Ventilation patterns using an atrium

BEDALES SCHOOL THEATRE, HAMPSHIRE

Tower vents face four directions to ensure exhaust





irrespective of the wind direction.

6. Component Design & Integration

Why is this important ?

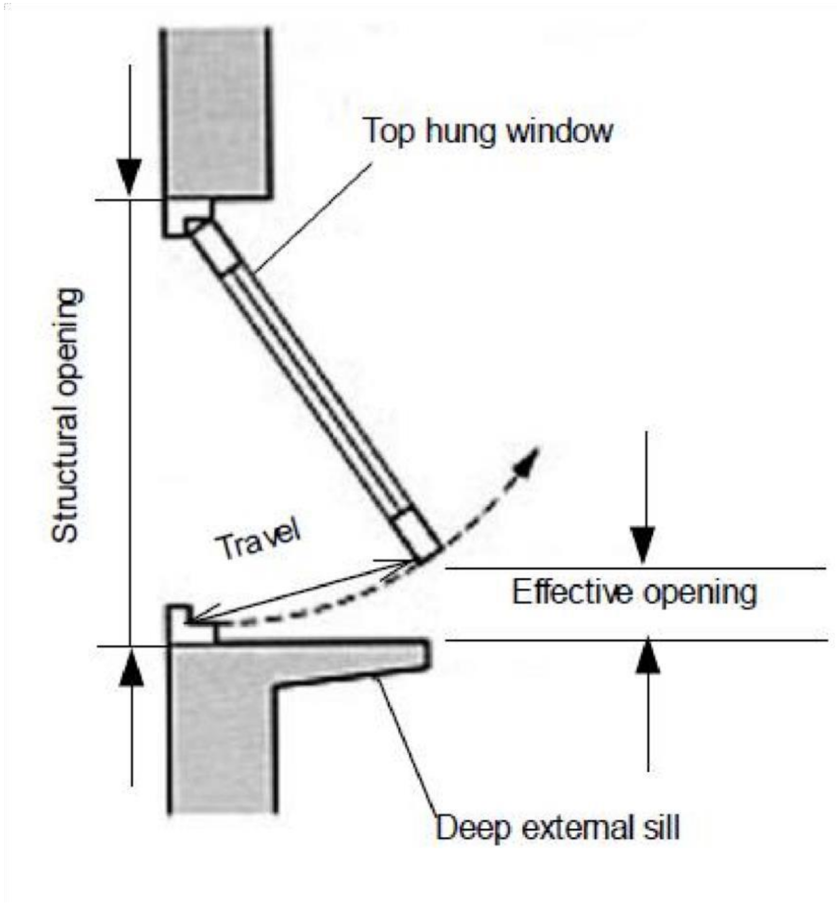
•To ensure the strategy is carried through in detail

What are the frequent problems ?

- Poor performance & control of windows
- Thermal mass obscured
- Poor integration of vent, actuator & control
- Lack of understanding by occupants

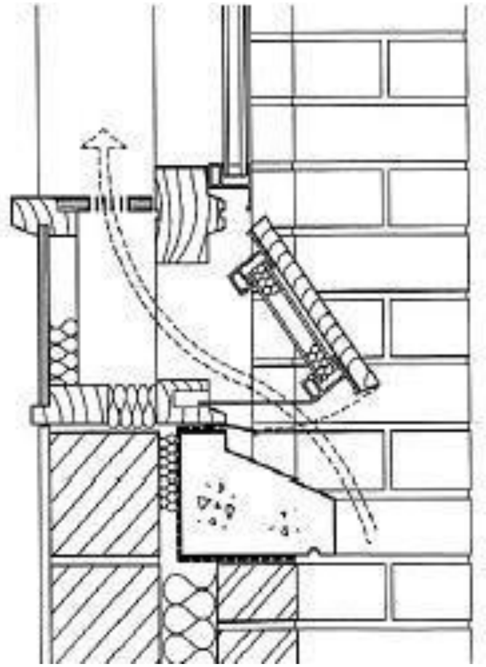
Ventilator design

Distinction between structural opening, effective opening area and travel distance. As a design develops, widow sills, reveals, internal and external blinds have a major impact on the final effective area which is achieved. Continuity in the design team is vital.

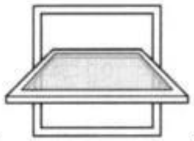
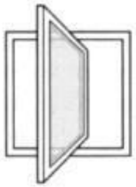
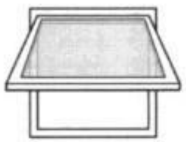
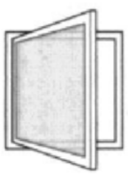
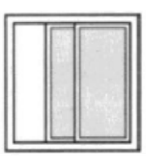


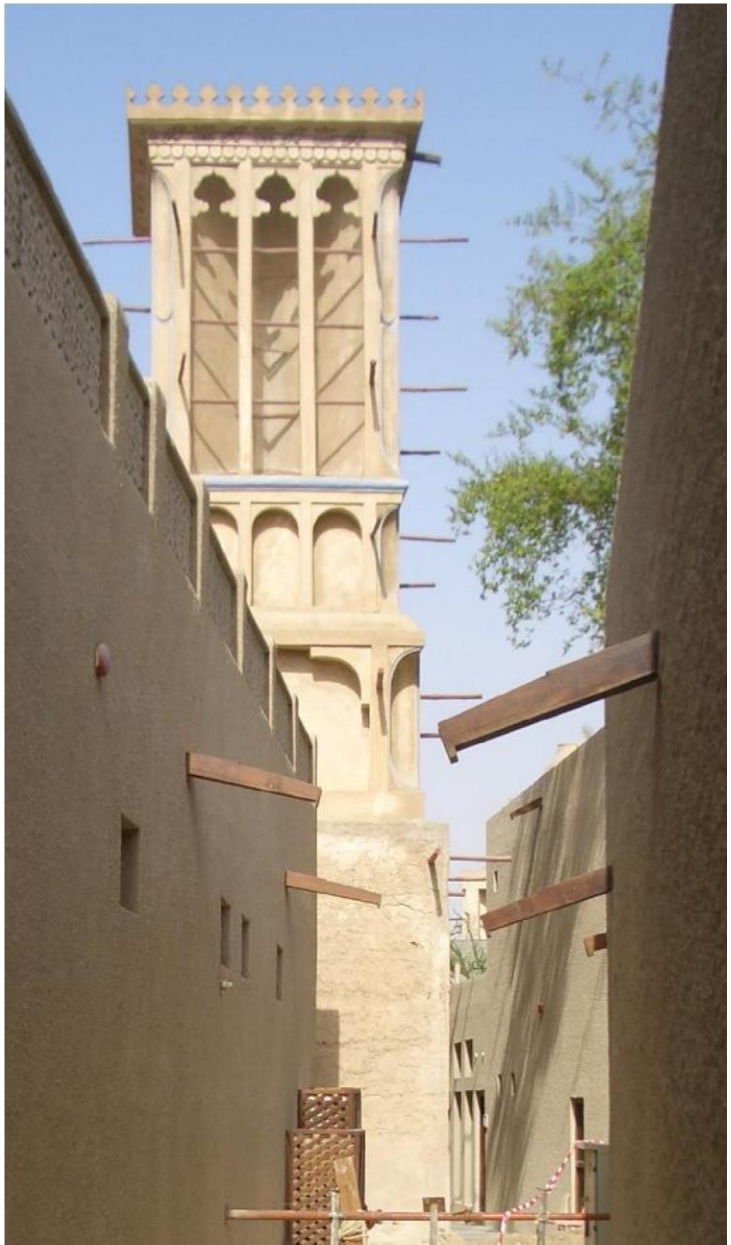
OFFICES FOR A HOUSING ASSOCIATION

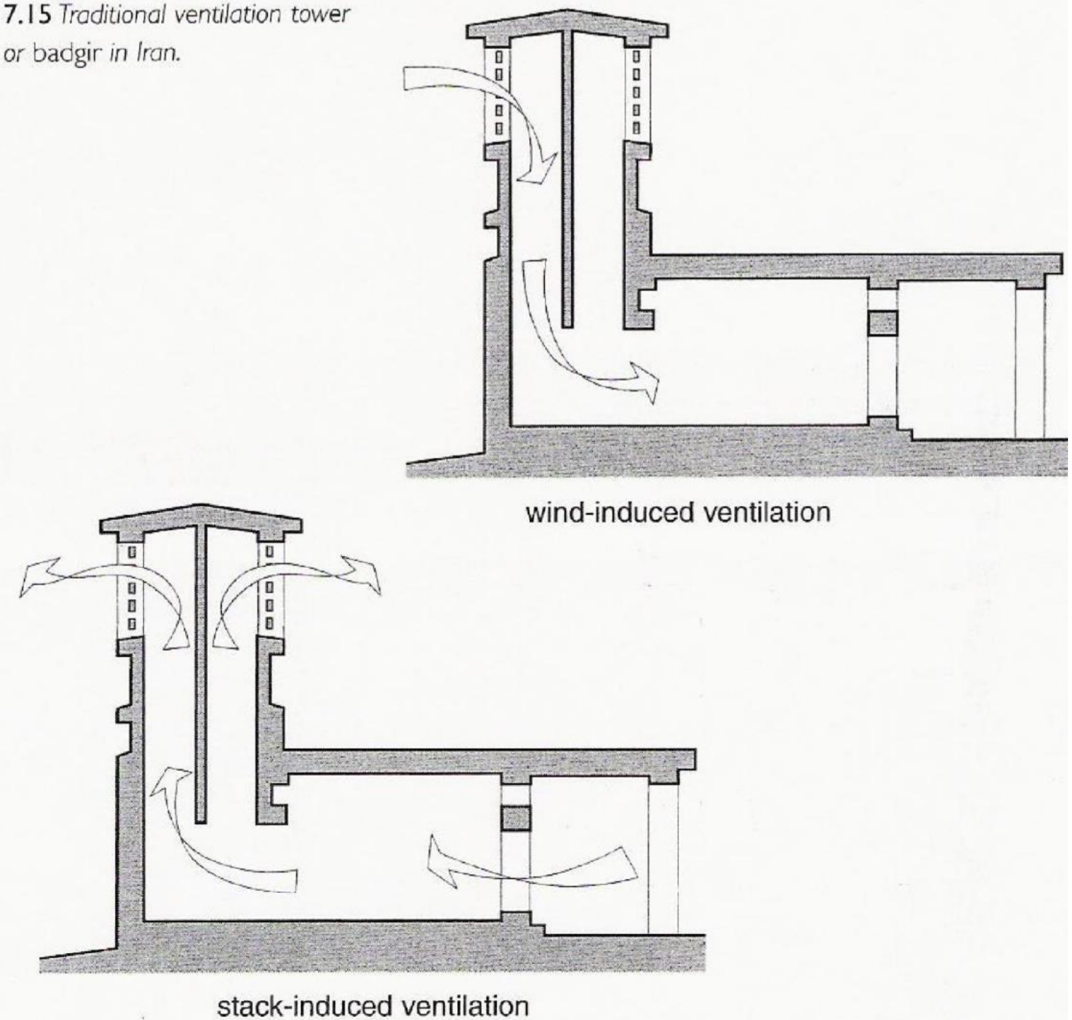
- Velfac' windows on the south side include fixed, manually-operable and motorised elements with concealed actuators, controls and wiring.
- The actuator's chain drive attaches to the window at the same point as the manual latch, making secure fixing easier and helping the windows to close tightly.
- Integrated Factory-assembled components – installation & operation has been trouble-free.



- north side purpose-made motorised flaps and concealed dampers in site built enclosures beneath louvres in the window cills.
- integration less easily achieved: - air leakage both through and around the dampers; and unclear indication of control status caused problems.

Window Type		Actuator Type Options if automatic control is required	Comments
HORIZONTAL PIVOT		▪Linear ▪Chain	These windows have a high ventilation capacity and the geometry promotes good distribution of supply air. Internal blinds are not practical but interpane blinds may be a useful alternative. For an opening of 22° then the effective area is 34% of the area of the structural opening. Shorter stay length compared with casements, reduces wind pressures on actuators.
VERTICAL PIVOT		▪Linear ▪Chain	This type provides a similar effective area as horizontal pivot. Internal blinds are also not practical Vulnerable to driving rain, and will provide a 'wing wall' effect (either positive or negative) in response to the prevailing wind.
TOP/BOTTOM HUNG		▪Linear ▪Chain ▪Rack and pinion ▪Lead screw ▪Lever arm ▪Cable driven (drawbridge)	Wider range of actuator options. Length of throw is significantly increased relative to pivot windows. (ie more costly and more vulnerable under high winds). Although bottom hung inward opening is a useful geometry located adjacent to the ceiling for night vent cooling, top hung is a better geometry at low level to direct flow towards occupants for daytime ventilation[SJI1].
SIDE HUNG (CASEMENT)		▪Chain ▪Rack and pinion	These windows are not easy to link to automatic opening gear (lever arm must rotate as it extends). Also ventilation characteristics are strongly influenced by wind speed and direction (as with vertical pivot windows).
TILT AND TURN		▪Cannot be linked to actuator	These ventilation characteristics have been studied in several buildings, where it was reported that the 'tilt' setting provides too much ventilation in winter and insufficient cooling for occupants in summer.
SASH (SLIDING)		▪Linear ▪Linear sleeved cable or rod	These windows have ventilation characteristics similar to the vertical and horizontal pivot window. The effective area is maximum 50% of the structural opening[SJI2].
LOUVRES		▪Rotary ▪Linear	Usually glazed or aluminium. Advantages are that they can be made secure and still function satisfactorily, and therefore has potential application for night ventilation. However when closed, louvres generally have a very poor seal. This is the case with most louvre or damper installations.





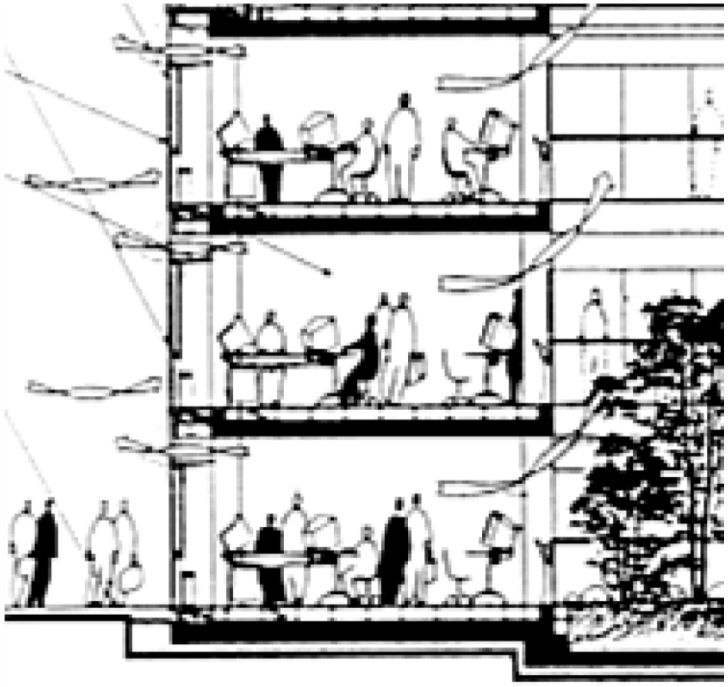
7.15 *Traditional ventilation tower or badgir in Iran.*

Exercise:

Objective:

Preliminary calculation of the area of vent openings required in an office in summer and winter

Simple cross ventilation through cellular office to provide convective cooling



Exercise:

to calculate the area of vent openings
required in an office in summer and winter My office is 5m deep x 3m wide and 3m high.

When seated at my desk I generate approx 80 W, and my laptop generates approx 70 W. In the winter these internal gains are useful, but in the summer must be removed to avoid overheating. I can achieve cross ventilation by opening a window on one side of the room and a door on the other.

Q1. Assuming an average air velocity through the openings of 0.3m/s, and that $T_i = 25°C$ and $T_o = 24°C$, how big do these openings have to be in order to remove the internal heat gain ?

To Calculate air flow rate required to remove internal gains :

$$Q_v = [C_{pa}.N.V.(T_i - T_o)] /3600$$

Where Q_v = ventilation heat loss or cooling (watts)

C_{pa} = specific heat of air = approx 1200 (J/kg)

N = Number of air changes/hour

V = Volume of the building or room (m3)

Also,

To calculate the area of the openings required, we need to know the volume flow rate:

Effective Area (A) of opening required

= Volume flow rate (m3/s) / velocity (m/s)

So,

Qv = ventilation heat loss or cooling (watts) = 150W

V = Volume of the building or room (m3) = 45m^3 (Ti

– To) = 25-24 =1°C

N = Number of air changes/hour = ?

Since Qv = 1200/3600.N.V.(Ti –

To) And Qv = [1/3.N.V.(Ti – To)]

then,

N = Qv/ [1/3.V.(Ti – To)]

= 150/[1/3x45x(25-24)]

= 10 air changes/hour (0.125m3/s)

What was the question ?

Q. What is the volumetric flow rate required to remove 150 W ?

A. 10 air changes, or $45m^3$ x10/hr =

$450m^3$/hr = $0.125m^3$/s

Q. What is the effective opening area required to remove internal heat gains ? A. 0.125(m^3/s)/ 0.3(m/s) = $0.416m^2$

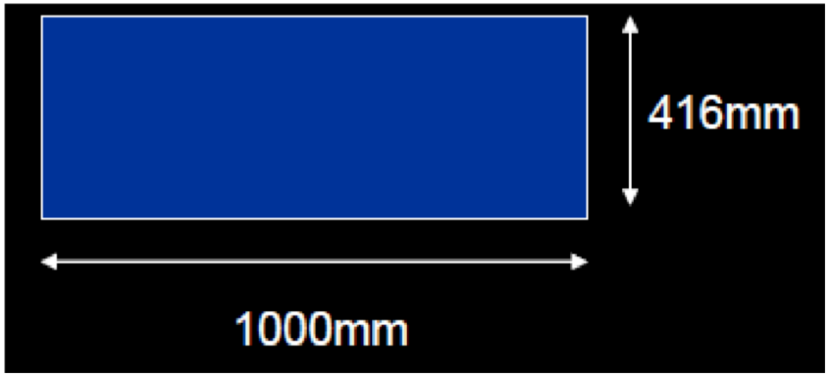
What is the effective opening area required to remove internal heat gains ?

Effective Area (A) of opening required (inlet)

= Volume flow rate (m^3/s) / velocity (m/s)

= 0.125(m^3/s)/ 0.3(m/s)

= 0.416m^2



Q. What area do we need if we double the heat gains (cooling load) ?

What is the vent area of each opening required to achieve the same volume flow rate based on buoyancy driven airflow ?

Where: h = 1 m q = 125 m^3/s Ti = 25 °C To = 20 °C g = 9.8 m.s^{-2}

The area A of each opening required to give a ventilation rate q for a specified value of h is:

$$A = \frac{q}{C_d}\sqrt{\frac{(T_I + 273)}{\Delta T\, g\, h}} \qquad (4.12)$$

where A is the area of each opening (m^2), q is the ventilation rate ($m^3 \cdot s^{-1}$), C_d is the discharge coefficient, T_I is the internal temperature (°C), ΔT is the difference between the internal and external air temperatures (K), g is the gravitational force per unit mass ($m \cdot s^{-2}$) and h is the height between the openings (m).

A typical value for C_d is 0.6.

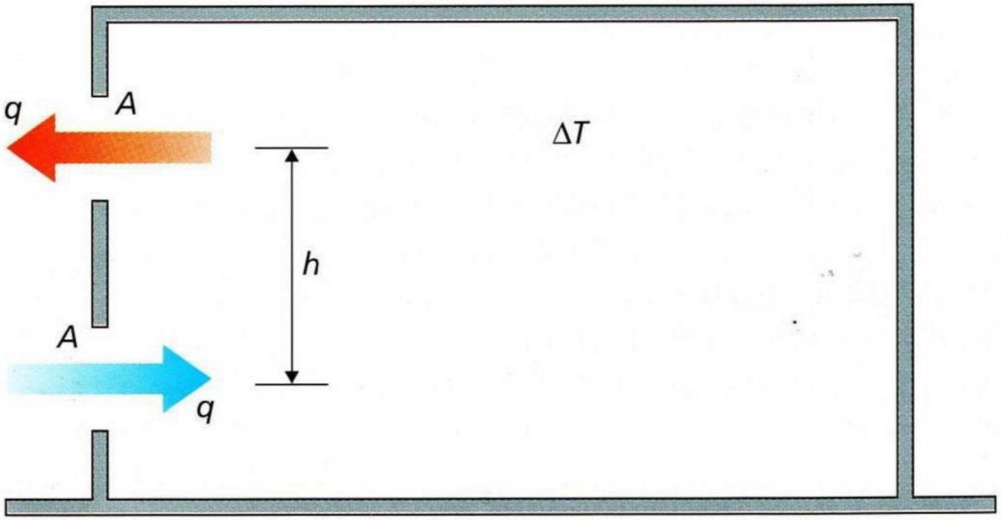


Figure 4.9 Case 1: single-sided ventilation, two identical openings, driven by buoyancy alone