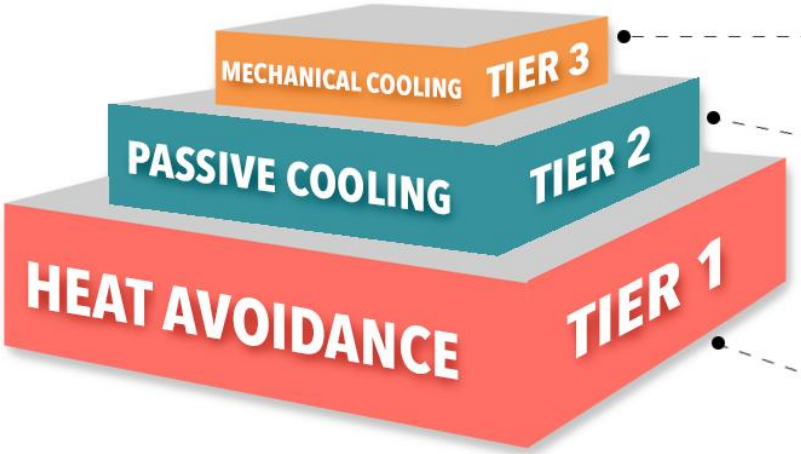
PASSIVE COOLING

BY KALEB NORTDRIGE & VANESSA PARTIDA

WHAT IS PASSIVE COOLING?

Refers to technologies or design features used to cool buildings without power consumption to achieve thermal comfort. To achieve thermal comfort, one should use the **THREE-TIER DESIGN**



MECHANICAL COOLING

Mechanical cooling if not enough

→ NOT PASSIVE

PASSIVE COOLING

Lowering temperatures

→ Mainly through ventilation

HEAT AVOIDANCE

Minimizing heat gain in the building

PASSIVE COOLING SYSTEM

Passive cooling uses:

- Natural forces
- Energy
- Heat sinks

The Thermal Goal is to cool the building and raise the comfort zone sufficiently.

PASSIVE COOLING SYSTEM

- Passive cooling systems are least expensive means of cooling a home which maximizes the efficiency of the building envelope without any use of mechanical devices.
- It rely on natural heat-sinks to remove heat from the building.
- They derive cooling directly from **evaporation, convection**, and **radiation** without any intermediate electrical devices.
- All passive cooling strategies rely on daily changes in temperature and relative humidity.
- The applicability of each system depends on the climatic conditions.
- These design strategies reduce heat gains to internal spaces:

NATURAL VENTILATION	COURTYARD EFFECT	PASSIVE DOWN DRAUGHT COOLING
SHADING	EARTH AIR TUNNELS	ROOF SPRAYS
WIND TOWERS	EVAPORATIVE COOLING	

TYPES OF PASSIVE COOLING

COOLING WITH VENTILATION

Comfort Ventilation: Ventilation during the day and night to increase evaporation.

Night Flush Cooling: Ventilation to pre cool the building for the next day.

RADIANT COOLING

Direct Radiant Cooling: A building's roof structure cools by radiation to the night sky.

Indirect Radiant Cooling: Radiation to the night sky cools a heat-transfer fluid, which then cools a heat-transfer fluid, which then cools the building

EVAPORATIVE COOLING

Direct Evaporation: Water is sprayed into the air entering a building

Indirect Evaporative Cooling: Evaporation cools the incoming air or the building without raising the indoor humidity

EARTH COOLING

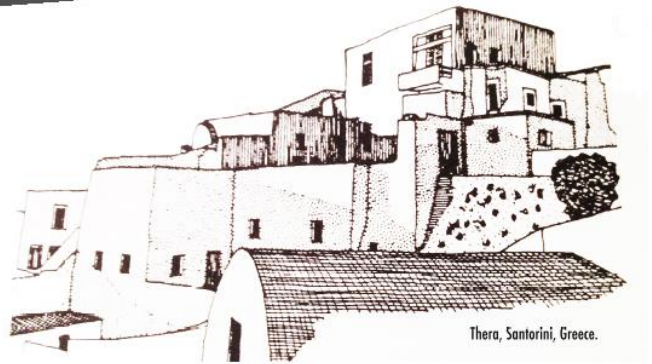
Direct Coupling: An earth-sheltered building loses heat directly to the earth.

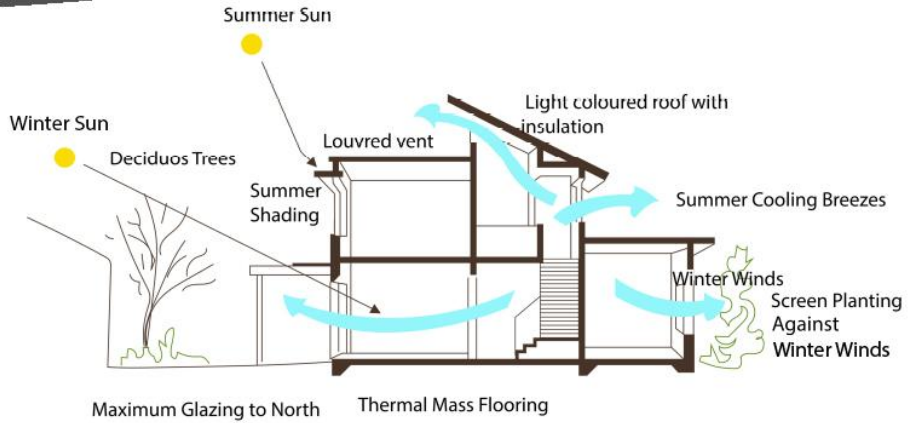
Indirect Coupling: Air enters the building by way of earth tubes. Dehumidification with a desiccant.

DEHUMIFICATION WITH A DESICCANT

Removal of Latent Heat. Example: In the south, the earth might be too warm for cooling unless its temperature is first lowered by evaporation.

PASSIVE COOLING SYSTEM





HYSTORICAL AND INDIGENOUS USE OF PASSIVE COOLING

HOT AND DRY CLIMATE TYPICALLY HAVE BUILDINGS WITH SMALL WINDOWS, LIGHT AND MASSIVE CONSTRUCTION.

WINTER VENTILATION

WINTER VENTILATION STRATEGY IS FUCUS ON HEAT RECYCLING WITH LIMITED INCOMING FRESH AIR. IN ADDITION, INDOOR AIR IS BEING PURIFIED AND MUMIFIED BY PLANTS IN A CONSERVATORY.

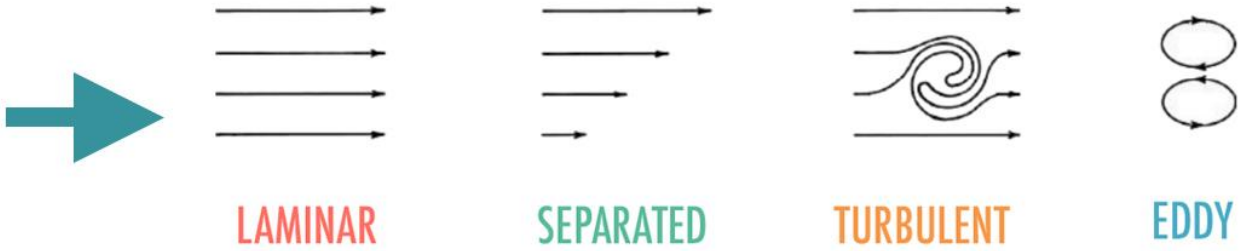
SUMMER VENTILATION

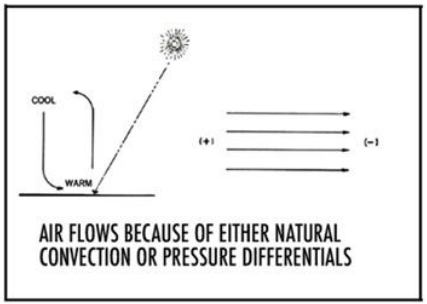
SUMMER VENTILATION STRATEGY IS FOCUS ON CROSS VENTILATION. PRESSURE DIFFERENCES ENCOURAGE CROSS VENTILATION WHICH ALSO COOLS THE BUILDING DOWN.

CLICK HERE TO WATCH VIDEO

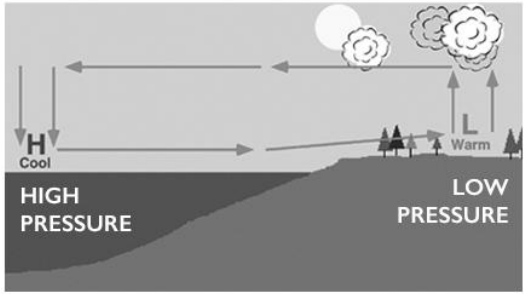
BASIC PRINCIPLES OF AIR FLOW

TYPES OF AIRFLOW





Temperature difference between land and a large body of water. Since land is able to absorb the sun's energy more quickly than water, it warms faster. As a result, air over the ground heats and rises, creating an area of low pressure. Cooler air is then drawn from the zone of higher-pressure above the ocean to fill the void, forming an onshore breeze.



BASIC PRINCIPLES OF AIR FLOW

INERTIA

Air has mass and moves in straight lines, when forced to change directions, it curves but never at 90 degrees.

CONSERVATION OF AIR

Air approaching a building is equal to the air leaving the building

HIGH AND LOW PRESSURE AREA

Air hitting the windward side of the building compresses and creates positive energy. Air is sucked from Leeward side, creating negative pressure. The slope of roof determines the pressure. High and low pressure areas are not calm, but Turbulent and Eddy.

BERNOULLI EFFECT

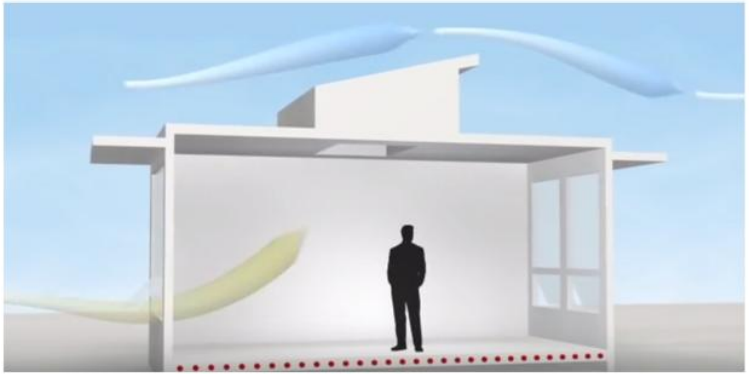
An increase in velocity of a fluid decreases its static pressure. This causes negative pressure at the constriction of a venturi tube. The velocity of the air rapidly increases with the height above the ground. Pressure at roof ridge is lower than windows at ground level

STACK EFFECT

Exhaust air from a building by natural convection. This only happens if indoor temperature difference between two vertical openings is greater than the outdoor temperature difference between the same openings.

This DOES NOT depend on wind. Weak winds can't move air quickly and causes negative pressure at the bottom of a building and positive pressure at top.

AIR FLOW THROUGH BUILDINGS



Pattern of airflow is affected by:

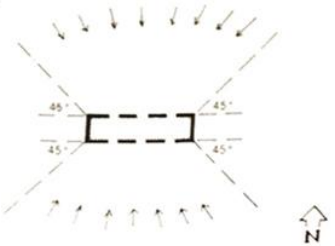
* Pressure distribution around a building
* Direction of air entering windows
* Size, location, details of windows
* Interior partitioning details

Three Purposes of Fans

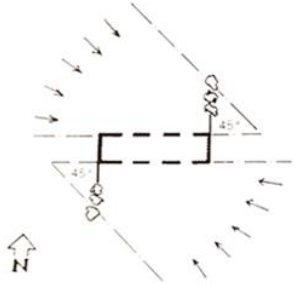
* Exhaust hot, humid and polluted air
* Cool people by bringing in outdoor air
* Circulate indoor air

AIR FLOW THROUGH BUILDINGS

Usually indoor ventilation is better from oblique winds than from head-on winds because the oblique airstream covers more of the room.

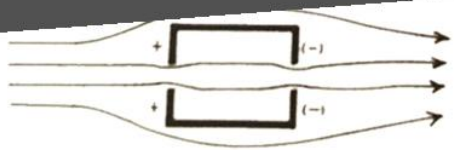


Acceptable wind direction for the orientation that is best for summer shade and winter sun

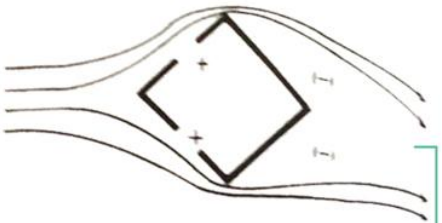


Deflecting walls and vegetation can be used to change airflow direction so that the optimum solar orientation can be maintained.

AIR FLOW THROUGH BUILDINGS



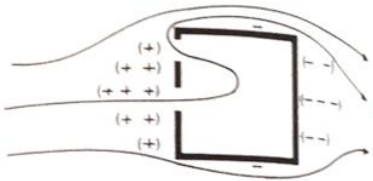
VERY GOOD → CROSS VENTILATION BETWEEN WINDOWS ON OPPOSITE WALLS IS THE IDEAL CONDITION



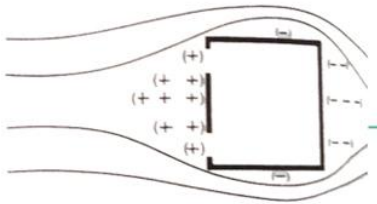
POOR

GOOD

→ VENTILATION FROM WINDOWS ON ADJACENT SIDES CAN BE POOR OR GOOD, DEPENDING ON WIND DIRECTION

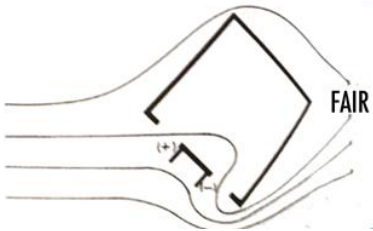


FAIR



POOR

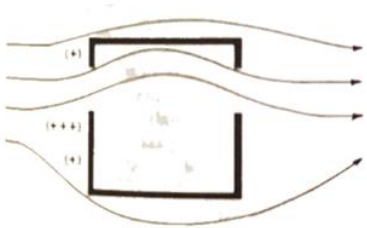
→ SOME VENTILATION IS POSSIBLE IN THE ASYMMETRIC PLACEMENT OF WINDOWS BECAUSE THE RELATIVE PRESSURE IS GREATER AT THE CENTER THAN AT THE SIDES OF THE WINDWARD WALL.

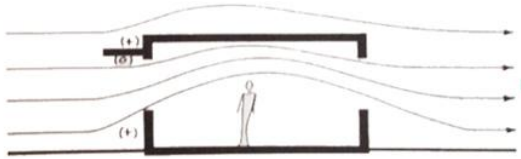


FAIR → FIN WALLS CAN SIGNIFICANTLY INCREASE VENTILATION THROUGH WINDOWS ON THE SAME WALL

AIR FLOW THROUGH BUILDINGS

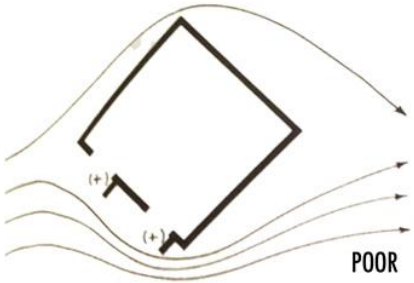
THE GREATER POSITIVE PRESSURE ON ONE SIDE OF THE WINDOW DEFLECTS THE AIRSTREAM IN THE WRONG DIRECTION. MUCH OF THE ROOM REMAINS UNVENTILATED.



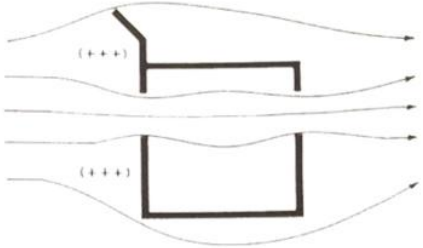


THE SOLID HORIZONTAL OVERHANG CAUSES THE AIR TO DEFLECT UPWARD

POOR VENTILATION RESUTLTS FROM FIN WALLS PLACED ON THE SAME SIDE OF EACH WINDOW OR WHEN TWO FINS ARE USED ON EACH WINDOW



POOR



A FIN WALL CAN BE USED TO DIRECT THE AIRSTREAM THROUGH THE CENTER OF THE ROOM, AS SEEN IN THIS PLAN VIEW.

COMFORT VENTILATION VS. NIGHT FLUSH COOLING

VENTILATION WAS THE MAJOR COOLING TECHNIQUE THROUGHOUT THE WORLD

COMFORT VENTILATION

* Brings in outdoor air in day/night
* Air is passed directly over people

NIGHT FLUSH COOLING

* Cool night air flushes out heat from a building
* During the day, little air comes in
* Mass of building acts as a heatsink

COMFORT VENTILATION

Air passing over the skin creates physiological cooling effect by evaporating moisture from the surface of the skin.

*Best in **Hot/ Humid**
*Can rarely be passive cooling
*Lightweight construction when there is no AC
*Operable window should be 20% of the floor area
*Equally placed between windward and leward walls
*Window should be shaded
*Larger over hangs keep out rain
*Windows need to be open during rain

Mean Radiant Temperature

The lower the incoming air pressure, the more effective comfort ventilation will be.

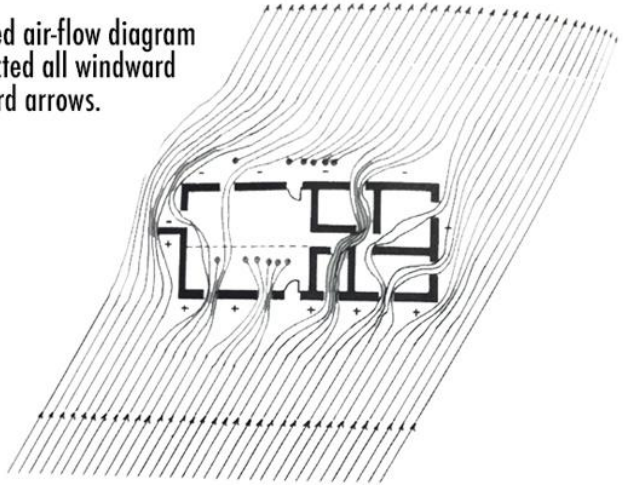
Natural Ventilation is the most common type of passive cooling because:

- Saves energy
- Improves indoor air quality
- Happier occupants

COMFORT VENTILATION

Comfort Ventilation is most appropriate when the indoor temperature and humidity are above the outdoor level. This causes thermal comfort from the resultant air motion

A completed air-flow diagram has connected all windward and leeward arrows.



Airflow should also be checked in Section

NIGHT FLUSH COOLING

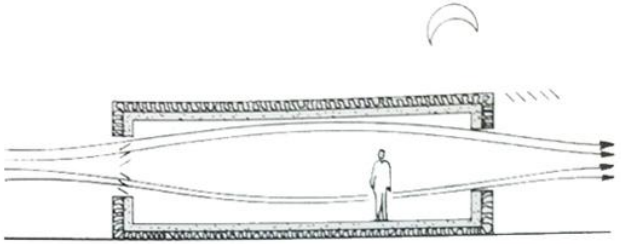
- **Used to flush out hot air and act like a heating sink for the following day**
- **NOT effective in humid regions**
- **Best in Hot/ Dry**
- **Night Flushing works in two stages:**

1. At night, natural ventilation brings in cool outdoor air
2. The next morning, windows are closed to prevent heating. Air keeps house comfortable temperature. Once the temperature exceeds the comfort temperature, fans come on to maintain it.

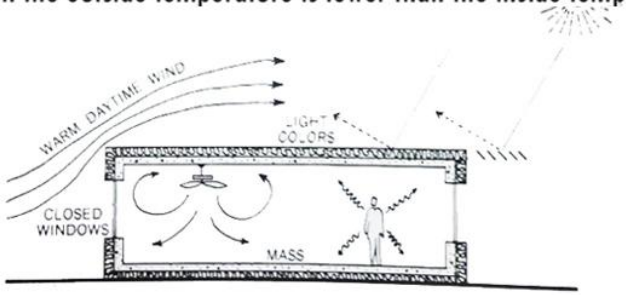
THERMAL MASS IS CRITICAL

NIGHT FLUSH COOLING

Night flush ventilation is a method of "flushing" heat away from the building at night. It is used in conjunction with materials that have a high thermal mass, such as brick or concrete. Night flush ventilation can be as simple as opening a few windows during the night in order to create cross ventilation or you can install fans that switch on when the outside temperature is lower than the inside temperature.



With night-flush cooling, night ventilation cools the mass of the building.



During the day, the night flush cooled mass acts as a heat sink. Light colors, insulation, shading, and closed windows keep the heat gain to a minimum. Interior circulating fans can be for additional comfort

DOUBLE SKIN FACADES & OPERABLE ROOFS

DOUBLE SKIN FACADES
(Smart Facades)

* Increase comfort by integrating:
  1. Passive Solar
2. Shading
3. Daylight
4. Increase Thermal Resistance
5. Natural Ventilation

DOUBLE-SKIN FACADES HAVE:

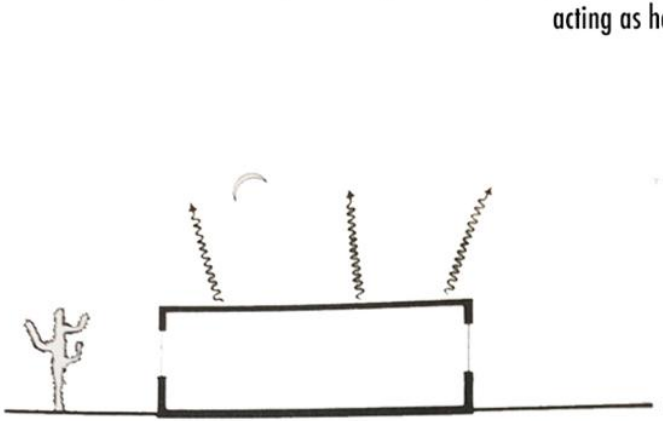
1. Double glazed windows
2. Air space (6-30 in)
3. Safely laminated galss divided into vertical/horizontal components to control the spread of fire and noise.
4. Best in high rises.

CLICK HERE TO WATCH VIDEIO

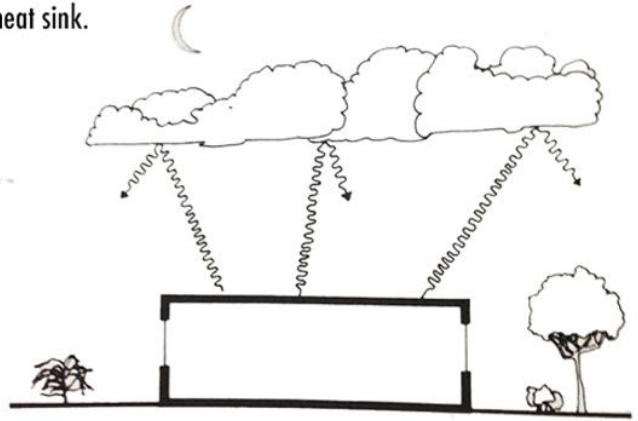
- *All objects emit and absorb radiant energy*
- *The roof is the best place for a long-wave radiator*
- *Painted metal (any color) is best for conducting heat*
- *Clouds block effect*

RADIANT COOLING

Potentially the most effective approach to radiant cooling is to make the roof itself the radiator. For example, an exposed-concrete roof will rapidly lose heat by radiating to the night sky. The next day, the cool mass of concrete can effectively cool a building by acting as heat sink.



On clear nights with little humidity, there is strong ant cooling to the cold night sky (outer space)



Humidity reduces radiant cooling, and clouds practically stop it.

DIRECT RADIANT COOLING

- Most effective is to make the roof the radiator

- Roof Pond- using plastic bags filled with water as a heating sink
- Expensive

INDIRECT RADIANT COOLING

- Metal is cooled at night, which then blows cool air into the building to cool indoor mass

- Building is sealed during the day

- Should be painted white

- **DOES NOT** work in a overcast region

- Applies to only single story buildings

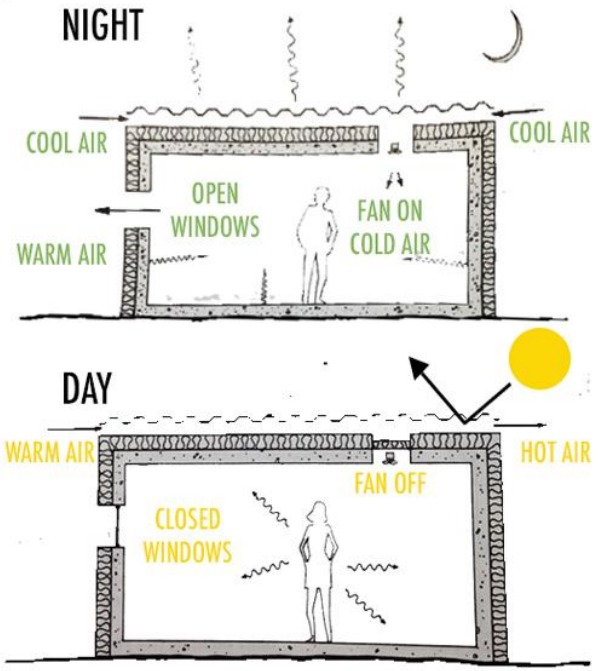
- Whole roof area should be used

- Thermal mass is **NECESSARY** during the day

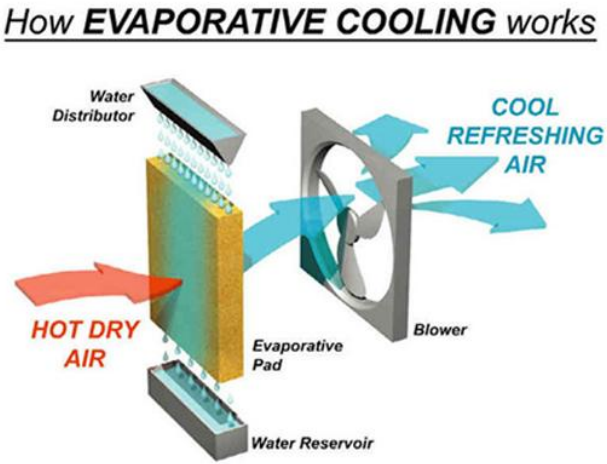
RADIANT COOLING

THE SPECIALIZED RADIATOR COOLS AIR, WHICH IS THEN BLOWN INTO THE BUILDING TO COOL THE THERMAL MASS. THIS IS AN EXAMPLE OF INDIRECT RADIANT COOLING

DURING THE DAY, THE RADIATOR IS VENTED OUTDOORS, WHILE THE BUILDING IS SEALED AND THE COOLED MASS ACTS AS A HEAT SINK.



EVAPORATIVE COOLING



Latent heat in the form of water vapor cools buildings two ways

1. Direct Evaporative Cooling

   Water evaporating inside or in cool air intake will cool air and humidify

2. Indirect Evaporative Cooling

   When the air is cooled without humidifying

PROS:

- Much less energy intensive
- When the air is cooled without humidifying
- Energy savings 30-90%
- No CFO's used
- 3-11 gallons pf water used daily (not a lot)

However, this is only limited to dry areas

COOL TOWERS

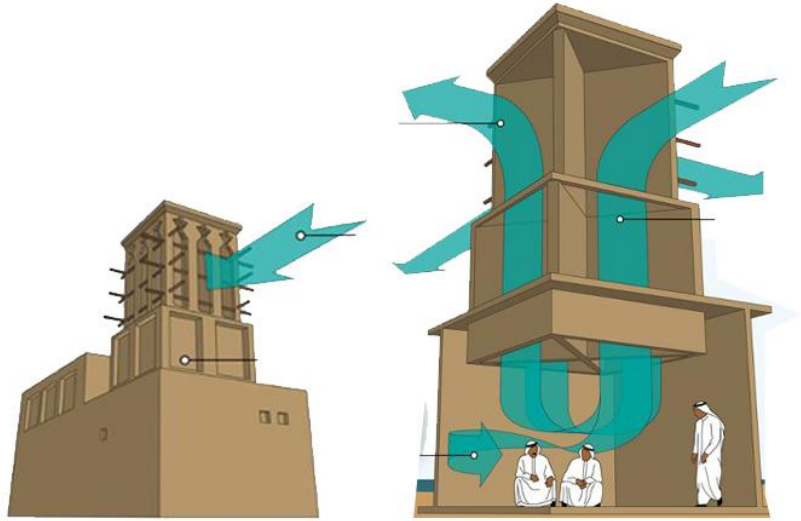
PASSIVE EVAPORATIVE COOLERS THAT ACT AS REVERSES COOLERS

HOW IT WORKS:

- Uses as much natural ventilation as possible

- Achieves 70% annual energy savings

- Works better paired with solar chimney

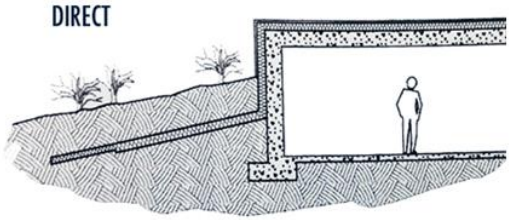


EARTH COOLING

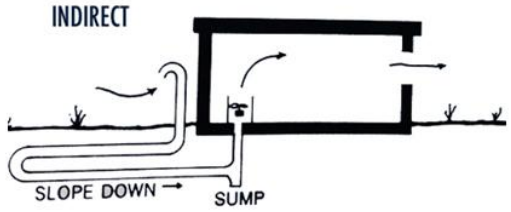
THERMAL PROPERTEIS MUST BE CONSIDERED

- Wet earth= Good heat storer and conductor
-20 ft underground, the temperature is constant.

1. Direct Earth Coupling
2. Indirect Earth Coupling



INSULATING THE SOIL AROUND AN EARTH-SHELTERED BUILDING CREATES A MORE DESIRABLE EARTH TEMPERATURE FOR THE BUILDING IN BOTH SUMMER AND WINTER. THE SOIL WILL BE WARMER IN THE WINTER AND COOLER IN THE SUMMER.



INDIRECT EARTH COOLING IS POSSIBLE BY MEANS OF TUBES BURIED IN THE GROUND. SLOPED TUBES AND A SUMP ARE REQUIRED TO CATCH CONSENSATION. AN OPEN-LOOP SYSTEM IS SHOWN WHILE A CLOSED-LOOP SYSTEM WOULD RETURN TTHE AIR FROM INDOORS.

DIRECT EARTH COUPLING

INDIRECT EARTH COUPLING

THERMAL PROPERTIES MUST BE CONSIDERED

Wet earth= Good heat storer and conductor
20 ft underground, the temperature is constant

- When earth sheltered buildings have their walls in direct contact with the ground

- Works best in areas with a mean average temperature below 60 degrees

- Bad in winter

- Solution- insulate earth around building (horizontally) bringing heat closer to the building.

-Coupled to the earth by/ with tubes

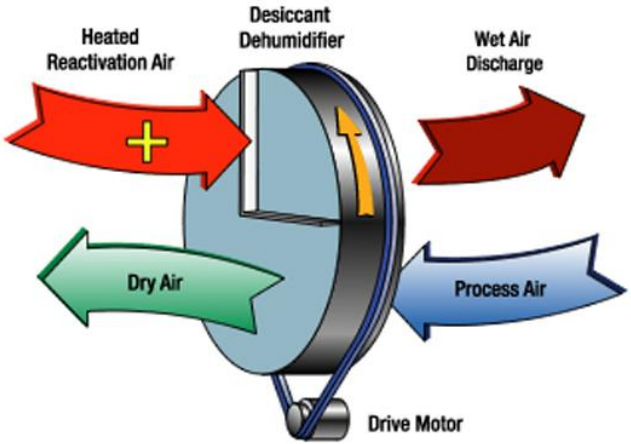
-Air is drawn into buildings by tubes

-Best Results
Tubes should be buried as deep as possible

-Bad in humid areas where condensation occurs
Tubes are sloped to prevent this

-Sizes vary

DEHUMIFICATION WITH A DESICCANT



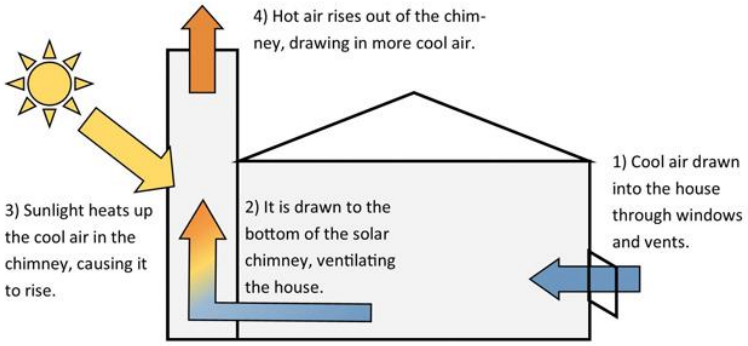
Two methods:

1. Air is cooled, below dew point. Water will then condense out of air (conventional A/C system or dehumidifier)

2. Chemicals such silca gel, natural zeolite, activated alumina and calcium chloride absorb large amounts of water vapor from air (Desiccant, Drying agent)

- Problem with desiccant, it converts latent heat into sensi ble heat, which requires another cooling stage to reduce heat.
- Another problem, the material becomes saturated with water and stops dehumidifying. Desiccant must be regenerat- ed by boiling off water

SOLAR CHIMNEY



Increases ventilation with stack effect

Best with shining sun and no wind

Can be used in wide variety of buildings spanning anywhere from a house to a high rise.

Must be exposed to summer sun at all times (roof, black vertical pipe)

Must be located outside thermal envelope to prevent heating

EARTH COOLING

PROVIDE AND ESSAY (200 WORD MINIMUM) FOR THE QUESTION BELOW

PICK A CLIMATE AND DISCUSS WHICH TECHNIQUE YOU WOULD INTEGRATE IN A BUILDING TO ACHIEVE PASSIVE COOLING USING THE SUN, WIND AND THE GROUND