

# Passive Cooling Techniques for A Green Building



## Engineering

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### ABSTRACT

Natural or Passive Cooling techniques help in reducing or some cases, Eliminating the mechanical air conditioning requirements in areas where cooling is a major problem. The use of air conditioners and coolers, conventionally, expends a huge sum of money in power and operational requirements. Passive Cooling is an initiative in the direction of reducing the expenditure on cooling and also providing a clean atmosphere to thrive in. In the present scenario of depleting natural resources, energy crisis and the global carbon emissions problem, green buildings provide a healthy escape from the traditional mechanical operations inside the structures. Passive Cooling is one such aspect of green building design. It employs the natural techniques and sources of cooling thereby rendering a building totally energy-efficient. Thus, the paper aims at explaining the various processes that could be used to achieve proper cooling and ventilation and paves way for the development of green buildings.

### Solar Chimneys

Solar chimneys are structure aimed at improving the natural ventilation of buildings by natural convection of air by solar energy. The air warmed by the sun's heat rises up causing the denser cool air to fill up its space flow through the building. This is known as stack ventilation. Air is thus driven in and out of the building as a result of pressure differences across the openings.

A solar chimney is designed in such a way so as to receive maximum heat from the sun. Apart from the proper orientation, painting and use of conducting materials increases the efficiency of the set-up.

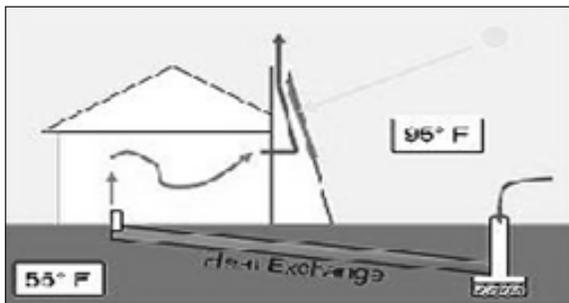


Figure 1: Solar Chimney

Generally, solar chimneys are built along trombe wall, the wall which faces the maximum amount of sunlight and is provided with vents for entry and exit of air. In this way the chimney can actually serve its purpose both in summers and winters.

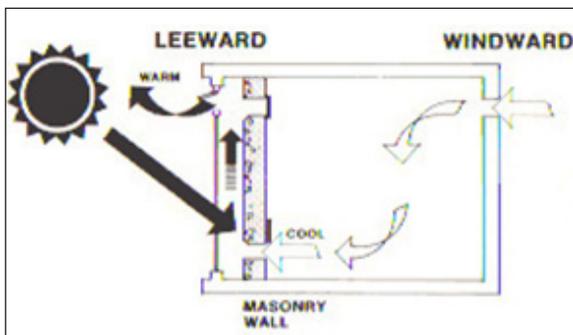


Figure 2: Solar Chimney integrated with a Trombe Wall

In residential units, solar chimneys can prove advantageous in terms of efficient evaporative cooling and also reducing heating of attics. Generally attics of bungalows, directly facing the sun

gets heated very much. To prevent this, solar chimneys can be integrated with the attics solving the purpose of both cooling the attics and also causing proper ventilation.

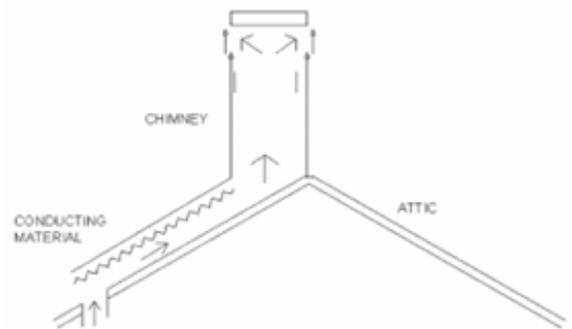


Figure 3: Solar Chimney integrated with the attic

The vents provided in the attic, in such cases, should be mechanically controlled so that the system works in both summers and winters.

Solar collectors or glazing helps in using the sun's energy to heat up the air flowing through the attic.

### Evaporative Cooling for Residential Units

Evaporative cooling as produced in a cooling tower is an energy-efficient way of inducing passive cooling in residential or small-scale industrial unit without consumption of power on fans or blowers. The system can operate on a 12v sprinkler pump.

### The basic design of a cooling tower works on two principles :

- Ventilation in the buildings which relies on the movement of air in the building occurring due to the difference in pressure of air. This can be achieved in following ways:
- Buoyant ventilation or stack ventilation, occurring due to difference in air density. Cold air, being heavier than warm air drops down in the building forcing the lighter warm air out, if proper ventilation is provided. The height of drop of cold air determines the velocity or pressure of the exhausted warm air.
- Wind direction which causes pressure difference. Windward side of a building always has a positive pressure while the leeward side has a negative pressure. To equalize pressure fresh air blows in forcing the stale air out.
- Evaporation of water sprinkled over cooling pads through which the hot air from outside blows. The temperature rise causes evaporation of water and the incoming air is cooled.

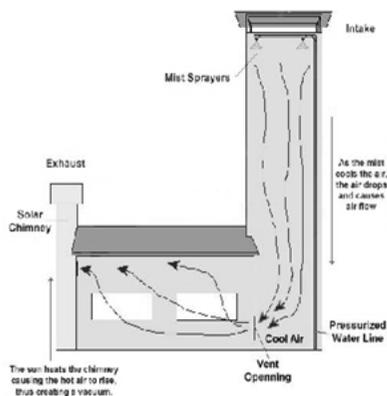


Figure 4: basic design of cooling tower

The figure shows the most basic design of a cooling tower. The design has certain disadvantages when put to practical use which are,

- The height of the cooling tower for efficient air flow needs to be about 30 ft. tall, a height impractical to provide in residential units particularly single storied.
- To maintain proper air flow, a proper exhaust of stale air needs to be provided this is achieved by providing a solar chimney which gets heated by sunlight all through the day and keeps the air inside warm and moving out, thus maintaining the pressure. But this adds to the cost of construction.
- Larger dimension of tower leave the cooled air susceptible to get heated again due to thermal conduction from the outer atmosphere through the outer walls. Therefore, in such design, insulating the walls to a factor of R-15 to R-20 is a must.

Economy and efficiency can be achieved in this scenario by using a simple swivel-scoop assembly which keeps the direction of the inlet always facing the wind, thus increasing the input. The entire input air is forced down through a duct towards the cooling pads. This reduces the wastage of air and improves efficiency. Also the cooling pads are placed inside the tower, so the problems of choking with dust etc. are reduced. The improved wind flow helps in reducing the height of towers and thus the problems of heat conduction from outside.

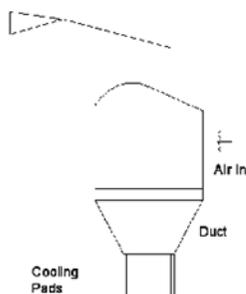


Figure 5: Design Modifications to Improve Efficiency Cooling Tower

A similar swivel-scoop assembly can also be provided at the exhaust end to keep the exhaust vent opposite to the wind direction. This relieves the use of a separate solar chimney.

**Evaporative Cooling using Rainwater Harvesting Tanks**

Rainwater collected on the roofs of building is generally stored in tanks below ground. This stored water is cooler than the ambient temperature. Hot air flowing over the cool rainwater gets cooled due to evaporation. This principle is used in Harvested Rainwater Cooling Technique.

Both this and the cooling tower are evaporative techniques. The difference lies in the direction of flow of air. Contrary to the cooling towers, air in this technique flows in from the bottom of the building.

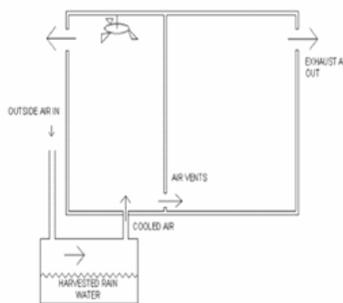


Figure 6: Evaporative Cooling using harvested rainwater

An inlet for the outside air is provided connecting to the harvesting tank. The air outlet from the tank is provided from the bottom in the building through a vent. Vents are also provided at the bottom of walls parting rooms etc. to make the air flow through the building.

Running fan inside a room creates a pressure drop inside which causes air to flow in from windows or doors. In this case, outside air is sucked in the tank due to the pressure drop. This air, while flowing over the stored rainwater gets cooled and still sucked inside the house. Being heavier this air flows through the vents at the bottom to the connecting rooms.

Once utilized, the air gets warm and is forced out through the exhausts and fresh air is sucked in continually.

**Ground Heat Exchange**

This system works on the basis of earth's ability to store heat in thermal masses like shallow ground or ground-water. There are much better reservoirs of heat than air, as used in air-to-air pumps (eg. Air conditioners).

These system operate based on the stability of underground temperatures in the shallow ground (upper 10 ft. of Earth's surface), has a very stable temperature throughout the year- between 10 and 16 °C, depending upon location's annual climate. The shallow ground temperature is warmer than the air above during the winter and cooler than the air in the summer. A geothermal heat pump uses that available heat in the winter (heating) and puts heat back into the ground in the summer (cooling).

Thus this system uses the earth as a source and sink for heating and cooling respectively. Like in an air-to-air pump, the refrigerant is made to flow throughout the loops. This refrigerant exchanges heat with the ground to heat or cool the required built-up environment.

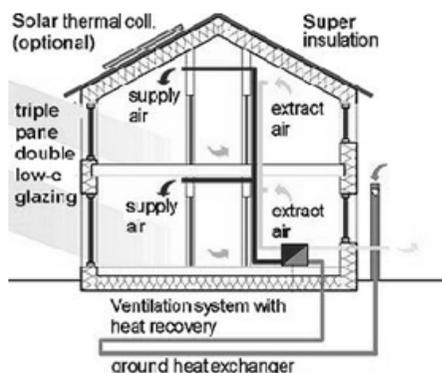


Figure 8: Passive Cooling using Ground Heat Exchange

The figure 8 shows a passive-cooling system based upon this process. Here, air plays the role of the refrigerant.

In summers, the outside air is warm. This is pumped in the system by a two-way heat pump. The air is sent under the ground (about 2-3 m depth) to exchange heat with the shallow ground or ground-water. The air running through a loop inside the ground is cooled to a great extent owing to a large surface area in contact with the ground. This cooled air is then sent in the building and is ejected at the top of the floors. Also hot air floating at the top is collected from the opposite areas simultaneously and is pumped outside the building. The cool air, being denser drops to the bottom and the hot air rises, thus completing the cycle inside the building, while pumping and cooling of air from outside and in the ground keeps taking place continually.

Using geothermal systems, consumers save about 30 to 70% of the cost when air conditioners are employed. Though the initial cost of setting up the system is high, the payback period is relatively short, typically between three and five years. They are also very less stressed in great extremes of temperatures. The base temperature, i.e. the earth is nearly constant throughout the year, thus the system works with far more efficiency than ACs. Geothermal systems are recognised as one of the most efficient heating and cooling systems on the market.

Apart from being economic, this system also cuts down the emission of millions of metric tons of CO<sub>2</sub> and carbon equivalents annually.

#### Glazed Windows

Windows with glazing, if used in a building careful of considering all the requisite factors, could bring down the energy consumption for climatic control by 10-50% below acceptable limits

in most climates.

To counter heat gain and losses the following regarding glazed window should be kept in mind:

#### U- Value

U-value determines the rate of heat flow through conduction, convection and radiation as a result of pressure difference between inside and outside temperatures. U-factors usually range from a high of 1.3 (for a typical aluminium frame single glazed window) to a low of around 0.2 (for a multi-paned, high-performance window with low-emissivity coatings and insulated frames). A window with a U-factor of 0.6 will lose twice as much heat under the same conditions as one with a U-factor of 0.3. total (or net) window U-factors can be considerably higher than the center of glass U-factors.

#### Solar Heat Gain Coefficient (SHGC)

SHGC indicates how much the sun's energy striking the window is transmitted through the window as heat. As the SHGC increases, the solar gain potential through a given window increases. The SHGC is a ratio between 0 and 1. SHGC=0 means none of the incident solar gain is transmitted through the window as heat and SHGC=1 means all the incident solar energy is transmitted through the window as heat. A window with a SHGC of 0.6 will admit twice as much solar heat gain as one with the SHGC of 0.3. Typically, windows with low SHGC values are desirable in buildings with high air-conditioning loads while windows with high SHGC values are desirable in buildings where passive solar heating is needed. The term "SHGC" is relatively new and is intended to replace the term "shading coefficient (SC)" while the terms are related, the shading coefficient of glass is defined as the ratio of the solar heat gain through a given glazing as compared to that of clear, 1/8 inch single pane glass.

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