

Solar architecture

The term solar architecture refers to an approach to building design that is sensitive to Nature and takes advantage of climatic conditions to achieve human comfort rather than depending on artificial energy that is both costly and environmentally damaging. Unlike the conventional design approach that treats climate as the enemy which has to be kept out of the built environment, solar architecture endeavours to build as part of the environment using climatic factors to our advantage and utilising the energy of Nature itself to attain required comfort levels. Nature's energies can be utilised in two ways - passive and active and consequently solar architecture is classified as passive solar and active solar architecture.

Passive solar architecture

It relies upon the design or architecture of the building itself to ensure climate control by way of natural thermal conduction, convection and radiation. The rudiments of solar passive design were developed and used through the centuries by many civilisations across the globe; in fact, many of these early civilisations built dwellings that were better suited to their climatic surroundings than those built today in most developed and developing countries. This has been largely due to the advent of cheap fossil fuels that allowed for artificial temperature and light control at the cost of natural light and cooling. A substantial share of world energy resources is therefore being spent in heating, cooling and lighting of such buildings. The use of solar passive measures such as natural cross ventilation, sufficient day-lighting, proper insulation, use of adequate shading devices coupled with auxiliary energy systems that are renewable and environment friendly can considerably bring down the costs as well as the energy needs of the building.

Passive solar systems

The term passive solar refers to systems that absorb, store and distribute the sun's energy without relying on mechanical devices like pumps and fans, which require additional energy. Passive solar design reduces the energy requirements of the building by meeting either part or all of its daily cooling, heating and lighting needs through the use of solar energy.

Passive heating

Heating the building through the use of solar energy involves the absorption and storage of incoming solar radiation, which is then used to meet the heating requirements of the space. Incoming solar radiation is typically stored in thermal mass such as concrete, brick, rock, water or a material that changes phase according to temperature. Incoming sunlight is regulated by the use of overhangs, awnings and shades while insulating materials can help to reduce heat loss during the night or in the cold season. Vents and dampers are typically used to distribute warm or cool air from the system to the areas where it is needed. The three most common solar passive systems are direct gain, indirect gain and isolated gain. A direct gain system allows sunlight to windows into an occupied space where it is absorbed by the floor and walls. In the indirect gain system, a medium of heat storage such as wall, in one part of the building absorbs and stores heat, which is then transferred

to the rest of the building by conduction, convection or radiation. In an isolated gain system, solar energy is absorbed in a separate area such as greenhouse or solarium, and distributed to the living space by ducts. The incorporation of insulation in passive systems can be effective in conserving additional energy.

Passive cooling

Passive solar technology can also be used for cooling purposes. These systems function by either shielding buildings from direct heat gain or by transferring excess heat outside. Carefully designed elements such as overhangs, awnings and eaves shade from high angle summer sun while allowing winter sun to enter the building. Excess heat transfer can be achieved through ventilation or conduction, where heat is lost to the floor and walls. A radiant heat barrier, such as aluminium foil, installed under a roof is able to block up to 95% of radiant heat transfer through the roof. Water evaporation is also an effective method of cooling buildings, since water absorbs a large quantity of heat as it evaporates. Fountains, sprays and ponds provide substantial cooling to the surrounding areas. The use of sprinkler systems to continually wet the roof during the hot season can reduce the cooling requirements by 25%. Trees can induce cooling by transpiration, reducing the surrounding temperature by 4 to 14 degrees F. Active cooling systems of solar cooling such as evaporative cooling through roof spray and roof pond and desiccant cooling systems have been developed along with experimental strategies like earth-cooling tubes and earth-sheltered buildings. Desiccant cooling systems are designed to dehumidify and cool air. These are particularly suited to hot humid climates where air-conditioning accounts for a major portion of the energy costs. Desiccant materials such as silica gels and certain salt compounds naturally absorb moisture from humid air and release the moisture when heated, a feature that makes them re-useable. In a solar desiccant system, the sun provides the energy to recharge the desiccants. Once the air has been dehumidified, it can be chilled by evaporative cooling or other methods to provide relatively cool, dry air. This can greatly reduce cooling requirements

Evaporative cooling

Evaporation occurs whenever the vapour pressure of water is lesser than the water vapour in the surrounding atmosphere. The phase change of water from liquid to the vapour state is accompanied by the release of a large quantity of sensible heat from the air that lowers the temperature of air while its moisture content increases. The provision of shading and the supply of cool, dry air will enhance the process of evaporative cooling. Evaporative cooling techniques can be broadly classified as passive and hybrid.

Passive direct systems include the use of vegetation for evapotranspiration, as well as the use of fountains, pools and ponds where the evaporation of water results in lower temperature in the room. An important technique known as 'Volume cooler' is used in traditional architecture. The system is based on the use of a tower where water contained in a jar or spray is precipitated. External air introduced into the tower is cooled by evaporation and then transferred into the building. A contemporary version of this

technique uses a wet cellulose pad installed at the top of a downdraft tower, which cools the incoming air.

Passive indirect evaporative cooling techniques include roof spray and roof pond systems.

Roof spray

The exterior surface of the roof is kept wet using sprayers. The sensible heat of the roof surface is converted into latent heat of vaporisation as the water evaporates. This cools the roof surface and a temperature gradient is created between the inside and outside surfaces causing cooling of the building. A reduction in cooling load of about 25% has been observed. A threshold condition for the system is that the temperature of the roof should be greater than that of air.

There are, however, a number of problems associated with this system, not least of which is the adequate availability of water. Also it might not be cost effective, as a result of high maintenance costs and also problems due to inadequate water proofing of the roof.

Roof pond

The roof pond consists of a shaded water pond over a non-insulated concrete roof. Evaporation of water to the dry atmosphere occurs during day and night time. The temperature within the space falls as the ceiling acts as a radiant cooling panel for the space, without increasing indoor humidity levels. The limitation of this technique is that it is confined only to single storey structure with flat, concrete roof and also the capital cost is quite high.

Earth cooling tubes

These are long pipes buried underground with one end connected to the house and the other end to the outside. Hot exterior air is drawn through these pipes where it gives up some of its heat to the soil, which is at a much lower temperature at a depth of 3m to 4m below the surface. This cool air is then introduced into the house.

Special problems associated with these systems are possible condensation of water within the pipes or evaporation of accumulated water and control of the system. The lack of detailed data about the performance of such systems hinders the large-scale use of such systems.

Earth-sheltered buildings

During the summer, soil temperatures at certain depths are considerably lower than ambient air temperature, thus providing an important source for dissipation of a building's excess heat. Conduction or convection can achieve heat dissipation to the ground. Earth sheltering achieves cooling by conduction where part of the building envelope is in direct contact with the soil. Totally underground buildings offer many additional advantages including protection from noise, dust, radiation and storms, limited air infiltration and potentially safety from fires. They provide benefits under both cooling and heating conditions, however the potential for large scale application of the technology are limited; high cost and poor day-lighting conditions being frequent problems.

On the other hand, buildings in partial contact with earth offer interesting cooling possibilities. Sod roofs can considerably reduce heat gain from the roof. Earth berming can considerably reduce solar heat gain and also increase heat loss to the surrounding soil, resulting in increase in comfort.

Active solar architecture

It involves the use of solar collectors and other renewable energy systems like biomass to support the solar passive features as they allow a greater degree of control over the internal climate and make the whole system more precise. Active solar systems use solar panels for heat collection and electrically driven pumps or fans to transport the heat or cold to the required spaces. Electronic devices are used to regulate the collection, storage and distribution of heat within the system. Hybrid systems using a balanced combination of active and passive features provide the best performance.

Active solar systems

Active heating

In active systems, solar collectors are used to convert sun's energy into useful heat for hot water, space heating or industrial processes. Flat-plate collectors are typically used for this purpose. These most often use light-absorbing plates made of dark coloured material such as metal, rubber or plastic that are covered with glass. The plates transfer the heat to a fluid, usually air or water flowing below them and the fluid is used for immediate heating or stored for later use. There are two basic types of liquid based active systems- open loop and closed loop. An open loop system circulates potable water itself, through the collector. In closed loop systems, the circulating fluid is kept separate from the system used for potable water supply. This system is mainly used to prevent the freezing of water within the collector system. However, there is no need to go in for such a system in India, as freezing of water is not a possibility. Also closed loop systems are less efficient as the heat exchanger used in the system causes a loss of upto 10 degrees in the temperature of water, at the same time, one has to reckon with the extra cost of the heat exchanger as well as the circulating pumps. Compared to these, Thermosiphon systems are more convenient and simple. In Thermosiphon systems, the water circulates from the collector to the storage tank by natural convection and gravity. As long as the absorber keeps collecting heat, water keeps being heated in the collector and rises into the storage tank, placed slightly above (at least 50 cm). The cold water in the tank runs into the collector to replace the water discharged into the tank. The circulation stops when there is no incident radiation. Thermosiphon systems are simple, relatively inexpensive and require little maintenance and can be used for domestic applications. Solar ponds have been developed, which harness the sun's energy that can be used for various purposes including production of electricity. Other devices such as solar cookers, water distillation systems, solar dryers, etc. have been developed which can be used to reduce energy requirements in domestic households and in industrial applications.

Active cooling

Absorption cooling systems transfer a heated liquid from the solar collector to run a generator or a boiler activating the refrigeration loop which cools a storage reservoir from which cool air is drawn into the space. Rankine steam turbine can also be powered by solar energy to run a compressed air-conditioner or water cooler.

Solar refrigeration is independent of electric supply and without any moving parts, for example, Zeolite refrigerator.