Vellore Institute of Technology
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Introduction to Innovative Projects

(PHY-1999)

Project Report on Passive Cooling Techniques

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Introduction: Passive cooling is a building design approach that focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or no energy consumption. This approach works either by preventing heat from entering the interior or by removing heat from the building. Natural cooling utilizes on-site energy, available from the natural environment, combined with the architectural design of building components, rather than mechanical systems to dissipate heat. Therefore, natural cooling depends not only on the architectural design of the building but on how the site's natural resources are used as heat sinks. Examples of on-site heat sinks are the upper atmosphere, the outdoor air, and the earth/soil.

Passive cooling covers all natural processes and techniques of heat dissipation and modulation without the use of energy. Some authors consider that minor and simple mechanical systems can be integrated in passive cooling techniques, as long they are used to enhance the effectiveness of the natural cooling process. Such applications are also called hybrid cooling systems.

Passive Cooling Concepts: Protection from or prevention of heat gains encompasses all the design techniques that minimizes the impact of solar heat gains through the building’s envelope and of internal heat gains that is generated inside the building due occupancy and equipment. It includes the following design techniques:

- Manipulating building form and orientation
- Shading
- Vegetation
- Insulation
- Ventilation
- Evaporative and nocturnal cooling

Manipulating building form and orientation:

• Building should be of optimum shape that loses least heat in winter and accepts least heat in summer

• Maximum solar radiation interrupted by horizontal surface of roof followed by east-west walls and then north-south walls

• Desirable orientation- longest wall facing north-south and short walls facing east-west

• Minimize wall area exposed to intense morning and evening sun

• Volume of building- related to its thermal heat capacity

• Surface area-related to rate of heat gain or loss

• Climate and prevailing local winds of the area should be taken into consideration for orientation.

Ventilation:

• One passive, low-energy method for increasing the effectiveness of ventilation uses fans to flush heat from a building during the night.

• Such nocturnal cooling reduces indoor air and surface temperatures, essentially pre cooling the building for the next day.

• Relatively slow-moving ceiling fans are well-suited for this task.

• Ventilation is typically thought about during the day when it is hot. However, the effectiveness of ventilation for cooling is limited by the temperature of the air supplied. The warmer the air, the less cooling it provides, regardless of how fast it is moved. Stirring air with a temperature of more than 94°F is counterproductive. It actually increases the conduction of heat to a person.

• One passive, low-energy method for increasing the effectiveness of ventilation uses fans to flush heat from a building during the night. Such nocturnal cooling reduces indoor air and surface temperatures, essentially pre cooling the building for the next day. Large, relatively slow-moving ceiling fans are well-suited for this task. These 20-ft fans, typically referred to as high-volume, low-speed (HVLS), circulate air in an area as large as 20,000 sq ft.

Architecture:

• Cool roofs combine high optical reflectance with high infrared emissivity, thereby simultaneously reducing heat transfer from the sun and increasing heat removal through radiation.

• Example, nocturnal ice making In India where the water would lose heat by radiation upwards.

Vegetation:

• Vegetation and trees in particular, very effectively shade and reduce heat gain.

• Trees can be used with an advantage of shading roof, walls and windows.

• Shading can reduce the temperature as much as much as 50°C.

• Different types of plants can be selected on the basis of their growth habit to provide the desired habit (tall, low, dense).

• Vegetation modifies microclimate and the energy use of buildings by lowering the air and surface temperatures.

Shading:

• Shade is an easy way to keep things cool. Shade can be utilized inside and out. An outdoor seating area begs for shade. This can be achieved with trees and shrubs or vines trained over a trellis. A roof structure of some sort can also provide shade for outdoor areas. If you have pets that spend time outside, make sure to provide them with a cool, shady spot for hot summer days.

• The most effective method to cool a building in summer is to keep the heat from building up in the first place. The most important passive cooling strategy, regardless of mass, is shading. Shading is a simple method to block the sun before it can get into the building. The primary source of heat buildup (i.e., gain) is sunlight absorbed by the building through the roof, walls, and windows. Secondary sources are heat-generating appliances in the building and air leakage.

Some of the techniques are listed below:

Earth–Air Tunnel:

• Ground temperatures at a depth of about 4-5 m below the surface remain constant throughout the year.

• A tunnel of suitable length in which ambient air enters at one end would provide heated/cooled air at the other end.

The Sky-Therm System:

• Makes use of roof ponds with movable insulation for collection, storage, and dissipation of heat.

• Black plastic bags filled with water are placed on a metallic roof.

• In winter, the black plastic bags are exposed to sunlight and they act as collection-cum-storage devices of solar energy.

• In summer, the black plastic bags are exposed to night sky and they lose heat by nocturnal radiation to sky.

Environmental Effects and Aftermath:

• The use of the A/C is really common is today’s world.

• People cannot manage without air conditioners.

• Generation of electricity for the A/C to function includes the burning of fossil fuels.

• The cooling agents such as hydro-chloro-fluro-carbons (HFC'S) deplete the ozone layer. These agents might also pollute the soil/land where the A/C's are disposed off.

• Dirty filters of A/C's may be a threat to indoor air quality.

• After implementation, there would be no need of an A/C.

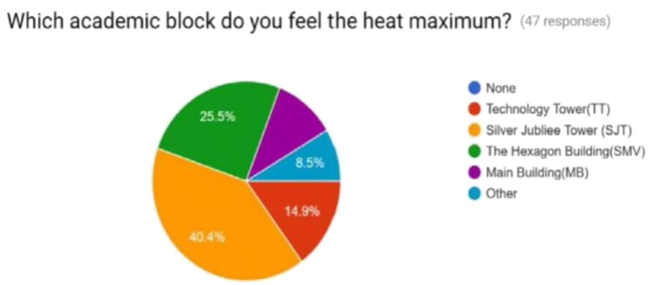
• People will be able to manage without air conditioners.

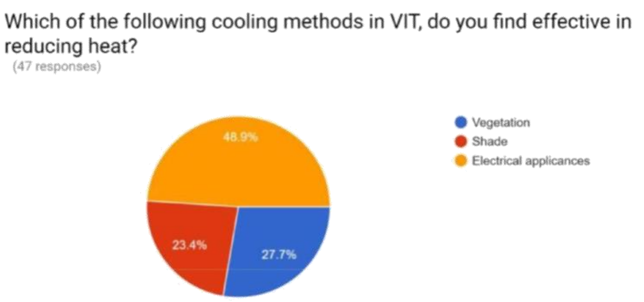
• The consumption of electricity will be much less.

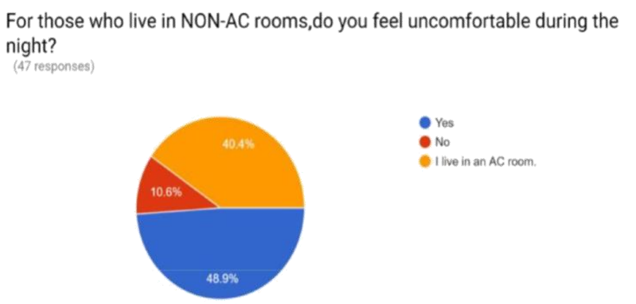
• No need of cooling agents, no ozone layer depletion.

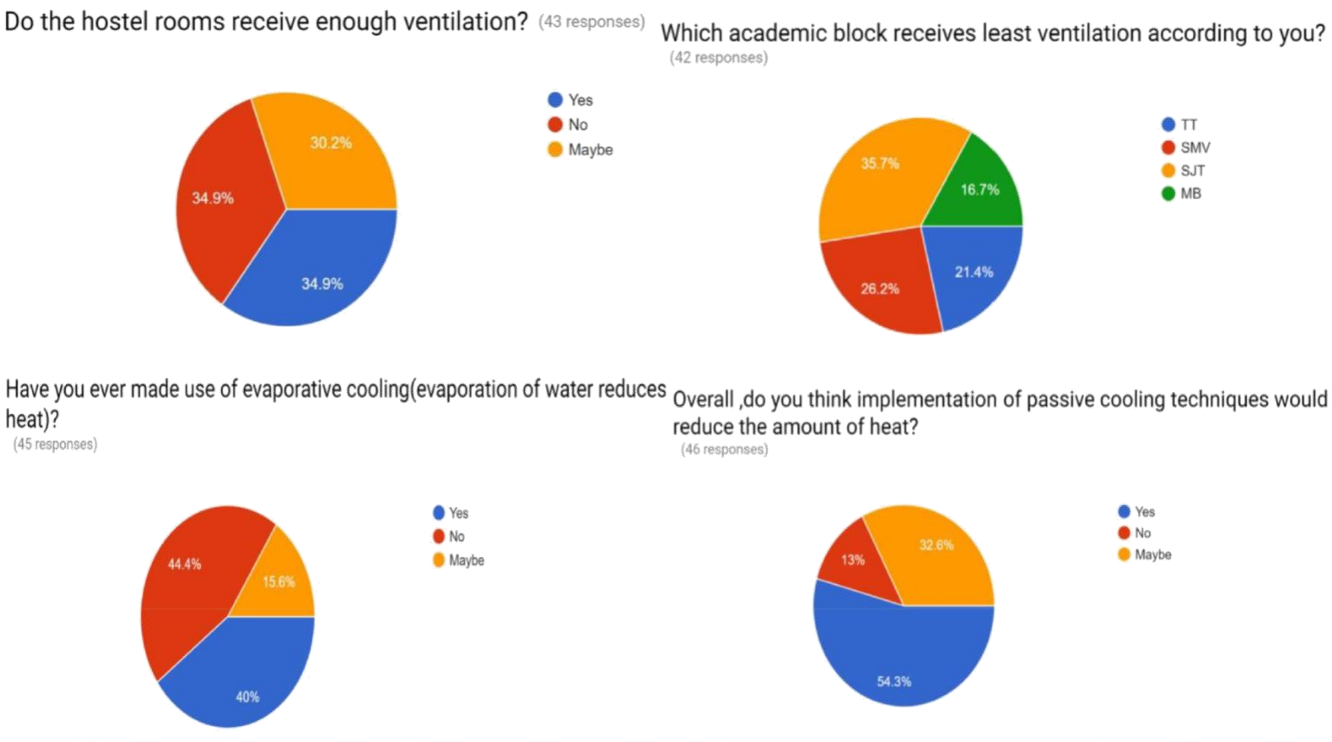
• No need of disposing agents, no soil pollution.

<u>Survey:</u> Following are the results of a survey conducted in VIT Vellore campus.









Survey Conclusion:

• Maximum heat is felt in VIT during the afternoon hours, i.e. 12pm to 4pm on an approx.

• According to students, the most heated up building is SJT followed by SMV and then TT. The reasons for this could be lack of cooling techniques, orientation of the building and more population.

• According to students, most effective passive cooling technique is use of electrical appliances, followed by vegetation and shade.

• Majority students live in non-A/C rooms and follow ventilation techniques to feel comfortable at night (e.g.: keeping doors and windows open).

• An equal number of students say that their hostel rooms are properly ventilated and not properly ventilated.

• Majority students have not made use of evaporative cooling techniques for cooling methods, while many also have.

• Many believe that proper implementation of passive cooling techniques will lead to better cooling in buildings.

Cooling Techniques used in Technology Tower, VIT Vellore:

Solar Shading:

• Among all other solar passive cooling techniques solar shading is relevant to thermal cooling of buildings especially in a developing country owing to their cost effectiveness and easy to implement. Rural India and developing countries in Middle-east region has witnessed a steep rise masonry houses with RCC roofs. However the availability of electric power in the villages especially during summer is limited. These RCC roofs tend to make the indoor temperature very high around 41°C. This is due to high roof top temperature of around 65°C in arid regions. Solar shading with locally available materials like terracotta tiles, hay, inverted earthen pots, date palm branches etc. can reduce this temperature significantly.

• Shading with tree reduces ambient temperature near outer wall by 2°C to 2.5°C. In their study they found that a decrease in the indoor temperature by about 2.5°C to 4.5°C is noticed for solar shading. Results modified with insulation and controlled air exchange rate showed a further decrease of 4.4°C to 6.8°C in room temperature. The analysis suggested that solar shading is quite useful to development of passive cooling system to maintain indoor room air temperature lower than the conventional building without shade.

Roof Shading:

• Shading the roof is a very important method of reducing heat gain. Roofs can be shaded by providing roof cover of concrete or plants or canvas or earthen pots etc. Shading provided by external means should not interfere with night-time cooling. A cover over the roof, made of concrete or galvanized iron sheets, provides protection from direct radiation. Disadvantage of this system is that it does not permit escaping of heat to the sky at night-time. A cover of deciduous plants and creepers is a better alternative. Evaporation from the leaf surfaces brings down the temperature of the roof to a level than that of the daytime air temperature. At night, it is even lower than the sky temperature.

Shading due to trees and vegetation:

• Proper Landscaping can be one of the important factors for energy conservation in buildings. Vegetation and trees in particular, very effectively shade and reduce heat gain. Trees can be used with advantage to shade roof, walls and windows. Shading and evapotranspiration (the process by which a plant actively release water vapor) from trees can reduce surrounding air temperatures as much as 5°C. Different types of plants (trees, shrubs, vines) can be selected on the basis of their growth habit (tall, low, dense, light, permeable) to provide the desired degree.

Shading due to textured surfaces:

• Surface shading can be provided as an integral part of the building element also. Highly textured walls have a portion of their surface in shade. The increased surface area of such a wall results in an increased outer surface coefficient, which permits the sunlit surface to stay cooler as well as to cool down faster at night.

Insulation:

• The effect of insulation is to reduce heat gain and heat loss. The more insulation in a building exterior envelope, the less heat transferred into or out of the building due to temperature difference between the interior and exterior. Insulation also controls the interior mean radiant temperature (MRT) by isolating the interior surfaces from the influence of the exterior conditions, and also reduces draughts, produced by temperature differences between walls and air.

• Insulation is of great value when a building requires mechanical heating or cooling and helps reduce the space-conditioning loads. Location of insulation and its optimum thickness are very important. In hot climates, insulation is placed on the outer face (facing exterior) of the wall or roof so that thermal mass of the wall is weakly coupled with the external source and strongly coupled with the interior.

• Use of 40 mm thick expanded polystyrene insulation on walls and vermiculite concrete insulation on the roof has brought down space-conditioning loads of the RETREAT building in Gurgaon by about 15%. Air cavities within walls or an attic space in the roof ceiling combination reduce the solar heat gain factor, thereby reducing space-conditioning loads.

Some existing techniques in India:

• Solar Air Conditioning - Turbo Energy Limited, Chennai.

• Earth Air Tunnels and Passive Cooling: Aquamall water solutions, Dehradun and Police Bhavan, IGP office, Gulbarga.

• Thermal Storage: TCS Techno park and Grundfos Pumps, Chennai.

• District Cooling System – RMZ Ecospace, Kolkata.

• Radiant cooling technology – Infosys, Pocharam Campus.

Conclusion:

Passive solar energy-efficient building design should be the first aim of any building designer, because, in most cases, it is a relatively low-cost exercise that will lead to savings in the capital and operating costs of the air-conditioning plant. In today's architecture, it is now essential for architects and building engineers to incorporate passive cooling techniques in buildings as an inherent part of design and architectural expression and they should be included conceptually from the outset. Incorporation of these passive cooling techniques would certainly reduce our dependency on artificial means for thermal comfort and minimize the environmental problems due to excessive consumption of energy and other natural resources and hence will evolve a built form, which will be more climate responsive, more sustainable and more environmental friendly of tomorrow.