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Passive Solar Design for Buildings

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Abstract

"In houses that look toward the south, the sun penetrates the portico in winter, while in summer the path of the sun is right over our heads and above the roof so that there is shade."

—Socrates

Solar energy is among the few renewable sources having higher potential. It is cost effective, easily operable, widely available and safe. With high sunshine in tropical countries like India , sunlight can provide ample heat, light, and shade and induce ventilation into well-designed buildings. A passive building is one which relies less on mechanical heating and cooling systems. Passive solar design can reduce heating and cooling energy bills, increase spatial vitality, and improve human comfort. It can also reduce energy use and environmental impacts such as greenhouse gas emissions. Inherently flexible passive solar design principles usually increase energy benefits with low maintenance risks over the life of the building .By using the basic physical characteristics and layout of a building, natural lighting and indoor comfort can be improved, the need for mechanical cooling and heating can be reduced or even eliminated. Passive solar design can reduce electricity consumption irrespective of the climate zone.

A building's windows, walls, and floors can be designed such that they trap, store, and distribute solar energy in the form of heat in the winter and reject solar heat in the summer. This paper deals with the fundamental approach to designing a building for natural day lighting, through building form, orientation and shading devices.

Keywords: *solar, passive, cooling, design, building*

1. INTRODUCTION

A ‘passive’ solar design involves the use of natural methods for heating or cooling to achieve optimum living conditions. Maintaining a comfortable environment within a building in a hot climate relies on reducing the rate of heat gains into the building and enabling the removal of excess heat from the building. At the same time maintaining a suitable environment in the winter is to allow maximum heat to enter and distribute inside the building. This is called passive solar design because, unlike active solar heating systems, it does not involve the use of mechanical and electrical devices**.** Passive cooling techniques can reduce the peak cooling load in buildings, thus reducing the size of the air conditioning or HVAC in case of larger buildings and the period for which it is generally used.

Sunlight is partly diffused by the atmosphere and locally prevailing atmospheric conditions thus the light reaching inside the building is partial. Light reaches the building in the following ways:

- Diffused light
- Externally reflected light
- Internally reflected light
- Direct sunlight
  It is how this light and the heat is collected and distributed inside the building that plays a major role in 'Passive' Buildings.

2. BUILDING ORIENTATION & FORM

2.1 Orientation

In any building orientation is a major design consideration, mainly with regard to daylight and wind.. When designing for passive features orientation is also important for the incoming solar radiation that needs to be trapped or rejected. Any building , if properly oriented can reduce as much as half the energy used for lighting. Different aspects of a building do not have equal access to the sun. Therefore each orientation should be treated differently to optimize the result. Orientation for solar gain will also depend on other factors such as proximity to neighboring buildings and trees that shade the site .For solar gain, as well as considering location, orientation and window size and placement, it is also important to consider the thermal performance and solar heat gain efficiency of the glazing itself.

For different climatic regions building orientation must be in accordance with the sun height and wind pattern.

- In tropical climate like India long facades of buildings oriented towards North—South are preferred. East and West receive maximum solar radiation during summer.
- In predominantly cold regions, also North South long facades are advisable, as South orientation receives maximum intensity of solar radiation in winter months.
- For composite climate building is orientated with the long axes in the east-west direction so that the longest walls face north and south, and only the short wall face east and west.

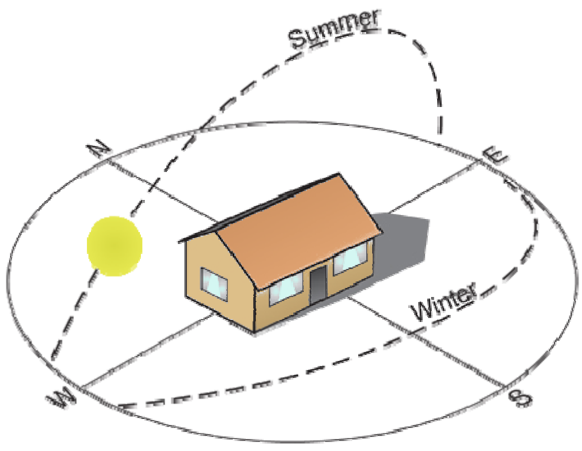

Fig. 1: Building orientation and daylight

2.2 Building Form

Building form can affect solar access and wind exposure as well as the rate of heat loss or heat gain through the external envelope.

- The volume of space inside a building that needs to be heated or cooled and its relationship with the area of the building envelope affects the thermal performance of the building.
- The building form also determines the air flow pattern around the building directly affecting its ventilation.

2.2.1 Surface volume ratio: The compactness of the building is measured using the ratio of surface area to volume (S/V). To minimize the losses and gains through the fabric of a building a compact shape is desirable. The most compact orthogonal building would then be a cube. Contrary to this, a building massing that optimizes day lighting and ventilation would be elongated so that more of the building area is closer to the perimeter.

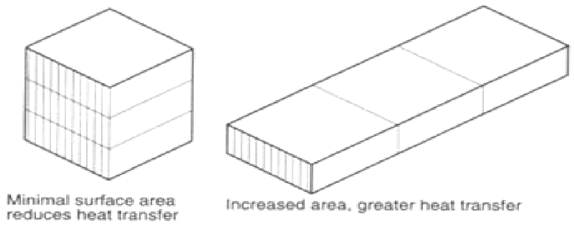

Fig. 2: Surface to volume ratio in buildings

- In hot dry climates S/V ratio should be as low as possible as this would minimize heat gain.
- In cold-dry climates also S/V ratios should be as low as possible to minimize heat losses.
- In warm-humid climates the prime concern is creating airy spaces. This might not minimize the S/V ratio, but the materials of construction should be such that they do not store heat.

2.2.2 Building Depth: The depth of a building also determines the requirement for artificial lighting. The greater the depth, higher is the need for artificial lighting.

2.2.3 Building Form and climate

- Cold climate - A compact form is preferred as it maintains temperate by preventing it from escaping.
- Temperate climate - In this climate building can be elongate having the larger axis which gains heat in winter and rejects heat in summer
- Hot and dry climate - A courtyard type building is preferred as it helps to create a micro-climate within the building as also because it facilitated passive cooling.
- Hot and humid climate - A scattered or clustered form is preferred to allow natural ventilation.

3. LANDSCAPING

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 evapo-transpiration (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 can be selected on the basis of their growth habit to provide the desired degree of shading for various window and fenestration.
- Planting deciduous trees on the southern side of a building is beneficial in a composite climate. Deciduous plants such as champa cut off direct sun during summer, and as these trees shed leaves in winter, they allow the sun to heat the building in winter which is suitable in composite climate.
- The use of dense trees and shrub plantings on the west and northwest sides of a building will block the summer setting sun.

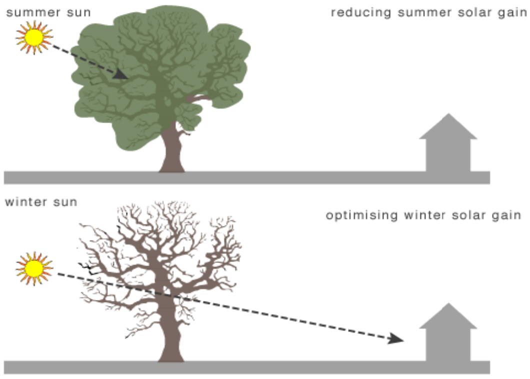

Fig. 3: Shading through deciduous trees

- Natural cooling without air-conditioning can be enhanced by locating trees to channel south-easterly summer breezes in tropical climates like India. Cooling breezes will be able to pass through the trunks of trees placed for shading.
- Shade can also be created by using a combination of landscape features, such as shrubs or trellises.
- Trees, which serve as windbreaks or form shelterbelts, diminish wind.

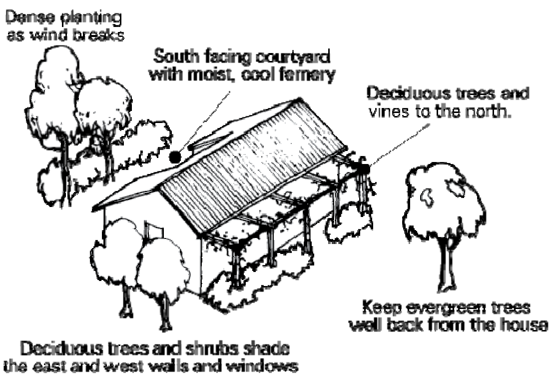

Fig. 4: Shading and windbreak through plantations

- Certain climbers are also useful for shading exposed walls from direct sunlight.
- Trees also provide visual relief and a psychological barrier from traffic and thus reduce pollution on the site.

4. SHADING OF BUILDING

Since buildings are designed to maximize daylight penetration, it becomes important to provide appropriate shading in building for proper heat gain/ loss.

4.1 Shading of Roof

Most of the sun's radiation falls on the roof of a building, thus shading the roof is a very important method of reducing heat gain in summers and increasing heat gain in winter time. 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.

4.1.1 GI sheets: A cover of concrete or galvanized iron sheets, provides protection from direct solar radiation. Disadvantage of this system is that it does not permit escaping of heat to the sky at night-time

4.1.2 Natural cover: A natural cover of deciduous plants and creepers can be a better alternative to the above mentioned GI sheets. Evaporative cooling from the plantation and creepers reduces the temperature of the building lower than the exterior temperature both at day-time and night-time.

4.1.3 Filler roof: Covering of the entire surface area with the closely packed inverted earthen pots, as was being done in traditional buildings, increases the surface area for solar emission. Insulating cover over the roof impedes heat flow into the building. On the contrary, filler roofs are higher in maintenance.

4.2 Shading over windows

When the sun shines through windows, it has a heavy heating effect, which is good in winters but very problematic in summers. An unshaded window can increase room temperatures by 3°C. Openings and their respective shadings must be in accordance with the summer and winter sun angles.

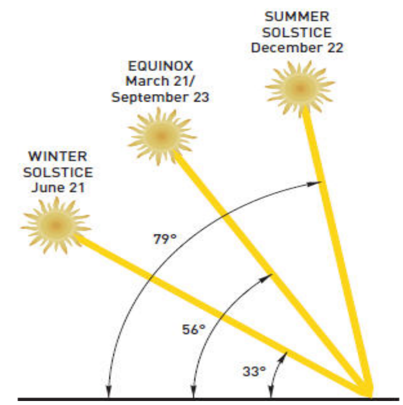

Fig. 5: Position and angle of Sun

External shading devices should be designed according to the orientation of façade.

- For north orientation minimum or no shading is required. The lower winter sun can penetrate inside to warm the house.
- On South orientation external shades should be designed after studying the sun path. Shading devices on South orientation could be permanent in nature, as most part of the day, Sun remains in South orientation.

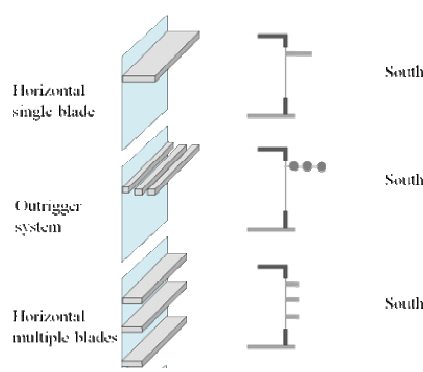

Fig. 6: Shading devices to be used in South facade

- Shading for east or west windows needs to be low over the window & preferable movable, so that the shades could be removed after sun faces opposite orientation.

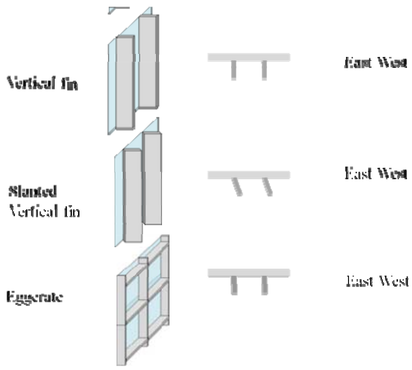

Fig.7: Shading devices to be used in East-West facade

4.3 Surface shading

Highly irregular or textured surfaces create surface shading, which can be provided as an integral part of the building element. The increased surface area of such a wall results in an increased outer surface coefficient. This increases the thermal mass of the building without the use of foreign materials; which permits the sunlit surface to stay cooler as well as to cool down faster at night.

5. DESIGN OF OPENINGS

5.1 Sun Shelves

Sun shelves are constructed over openings to allow maximum daylight inside the building without letting in solar radiation in the form of heat. Light shelves are an effective way to enhance the lighting from windows, this effect being obtained by placing a white or reflective metal light shelf outside the window. The reflected light can contain little heat content and the reflective illumination from the ceiling will typically reduce deep shadows.

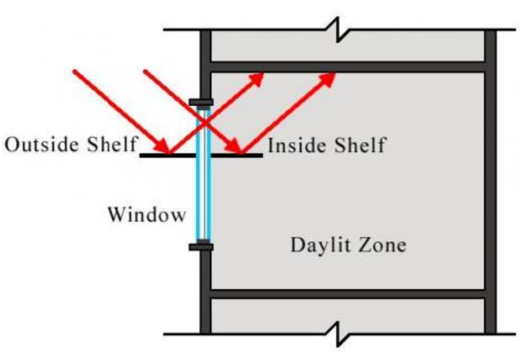

Fig. 8: Window sun-shelf

5.2 Brise-soleil

Brise-soleil or sun baffle outside the windows or extending over the entire surface of a building's facade. Many traditional methods exist for reducing the effects of the sun's glare, such as lattices pierced as used at the Taj Mahal. In the typical form, a horizontal projection extends from the sun side facade of a building. This is most commonly used to prevent facades with a large amount of glass from overheating during the summer. Often louvers are incorporated into the shade to prevent the high-angle summer sun falling on the facade, but also to allow the low-angle winter sun to provide some passive solar heating.

Fig. 9: Brise-soleil in Le Corbusier's Mill owner's Association Building

5.3 Clerestory windows

Clerestory windows are high, vertically placed windows. They can be used to increase direct solar gain and provide a direct light path to polar side.

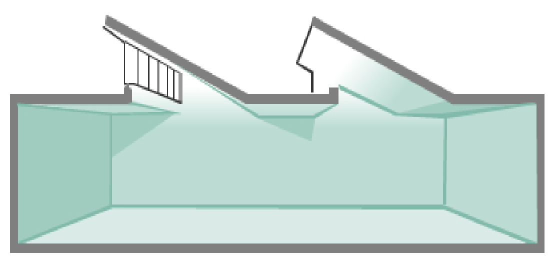

Fig. 10: Natural lighting through clerestory windows

6. PASSIVE COOLING

6.1 Solar Chimney

A thermal/ solar chimney employs convective currents to draw air out of a building. The solar chimney consists of a black-painted chimney. During the day solar energy heats the chimney and the air within it, creating an updraft of air in the chimney. The suction created can be used to ventilate and cool the building below.

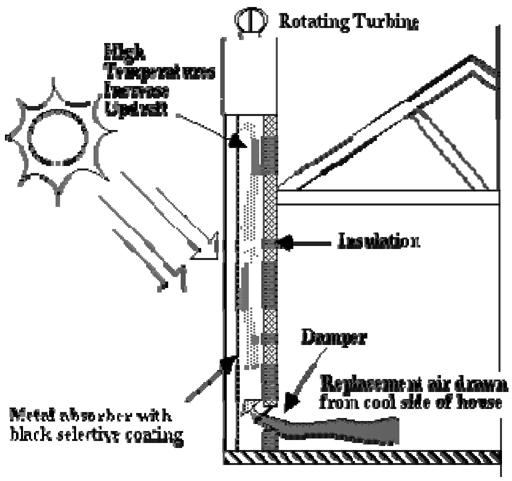

Fig. 11: Working of a thermal chimney

6.2 Earth tunnel cooling

In earth tunnel cooling the air passing through a tunnel or a buried pipe at a depth of few meters gets cooled in summers and heated in winters. Parameters like surface area of pipe, length and depth of the tunnel below ground, dampness of the earth, humidity of inlet air velocity, affect the exchange of heat between air and the surrounding soil.

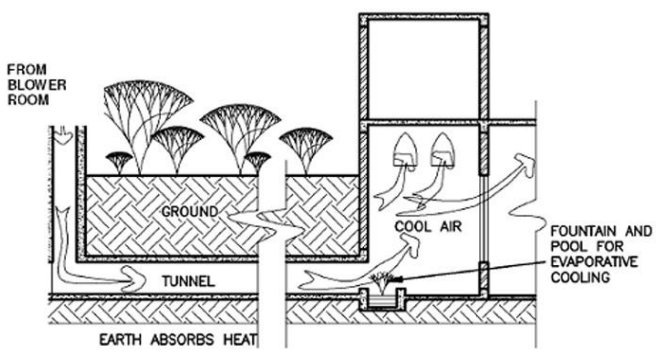

Fig. 12: Earth air cooling system

7. CONCLUSION

Through this paper various passive design techniques were discussed and reviewed. Passive Solar buildings are feasible in all aspects; hence more research and work must be done in this field to adopt it universally.

Theoretical studies have shown that the application of all the above techniques in buildings may decrease their heating and cooling load up to 58%. The subject of energy consumption and zero-energy housing is relatively new to the field of architecture and design but this should now be the aim of any designer, because, in most cases, it is a relatively low-cost exercise that will lead to savings in the operating costs. In today's scenario, it is essential for we as architects to incorporate passive design techniques in buildings as an inherent part of design.

REFRENCES

[1] Passive solar home design , IS 121, February 2001

[2] Mohammad Arif Kamal, An Overview of Passive Cooling Techniques in Buildings: Design Concepts and Architectural Interventions, September 2012

[3] Solar passive design for new buildings, TERI, 2011

[4] Kamal, M. A. Energy Conservation with Passive Solar Landscaping, Proceedings on National Convention on Planning for Sustainable Built Environment, M.A.N.I.T., Bhopal, pp. 92-99, 2003.

[5] Viraj Parekh, Passive Solar Building, International Journal of Applied Engineering Research, Number 3 (2014)

[6] Patrycja Kochaniu, Passive solar design, January 2012

[7] Manual of tropical housing and building , Koenigsberger

[8] M Majumdar, Energy efficient buildings of India, Tata Energy Research Institute, New Delhi, 2001

[9] J.K. Nayak and J.A. Prajapati Handbook on energy conscious buildings, Project Report, IIT Mumbai, 2006

[10] Vinod Gupta, INDIGENOUS ARCHITECTURE AND NATURAL COOLING

[11] Passive Architecture Design Systems,USAID August 2009