

A Study on Shading of Buildings as a Preventive Measure for Passive Cooling and Energy Conservation in Buildings

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Abstract— Buildings consume significant large amount of energy for cooling, heating, ventilation and lighting in buildings to create desirable thermal comfort conditions. In warm and tropical climates excess solar gain results in high cooling energy consumption. The depletion of conventional energy and high cost of non-conventional energy enforces a demand for energy conscious designs of buildings. Natural and passive cooling uses non-mechanical methods to maintain a comfortable indoor temperature. Shading is a simple method to block the sun before it can get into the building. Shading minimizes the incident solar radiation and cool the building effectively and hence dramatically affect building energy performance. In this paper an attempt has been made to study different shading strategies that can be employed to shade the building, which provides natural cooling and finally helps in energy conservation in buildings.

Index Term— Shading, Natural Cooling, Energy Conservation

I. INTRODUCTION

The Ministry of Power in India estimate indicates that about 20 to 25 percent of the total electricity consumed in government buildings is wasted because of inefficient design parameters of buildings, which results in an annual energy related financial loss of about 1.5 billion Rupees. (US \$33 million). The residential, commercial and institutional building sector consumed 31 percent of global energy and emitted 1900 mega tons of carbon in 1990. By 2050, its share is expected to rise to 38 percent and 3800 mega tons respectively [IPCC 1996]. In India, estimates suggest that about 20 to 25 percent of the total energy demand is due to manufacturing materials required in the building sector, while another 15 percent goes into the running needs of the building [1].

Energy conservation in buildings can be achieved through proper layout and orientation of building, appropriate shape, insulation, high thermal capacity and resistance of the building materials, good landscape design, proper shading devices, overhangs and external surface finish. The most effective method to save energy and cool the 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 like putting a hat on the building. 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. Shading minimizes the incident solar radiation and cool the building effectively and hence dramatically affect building energy performance. Shading can reduce the peak-cooling load in buildings, thus reducing the size of the air conditioning equipment that will run fewer hours and consume less energy. Energy savings can range anywhere from 10 to 40 percent.

II. SHADING OF BUILDING

Kumar, Garg and Kaushik evaluated the performance of solar passive cooling techniques such as solar shading, insulation of building components and air exchange rate. 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 [2]. Although shading of the whole building is beneficial, shading of the window is crucial. The total solar load consists of three components; direct, diffuse and reflected radiation. To prevent passive solar heating, when it is not wanted, a window must always be shaded from the direct solar component and often so from the diffuse and reflected components.

Decisions on where and when to include shading can greatly affect the comfort level inside a closed space. Shading from the effects of direct solar radiation can be achieved in many ways:

- Shade provided by the effect of recesses in the external envelope of the building
- Shade provided by static or moveable external blinds or louvers
- Transient shading provided by the orientation of the building on one or more of its external walls
- Permanent or transient shading provided by the surrounding buildings, screens or vegetation.

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- Shading of roofs by rolling reflective canvass, earthen pots, vegetation etc.

Shading by Overhangs, Louvers and Awnings etc.

Well-designed sun control and shading devices, either as parts of a building or separately placed from a building facade, can dramatically reduce building peak heat gain and cooling requirements and improve the natural lighting quality of building interiors (Fig. 1). The design of effective shading devices will depend on the solar orientation of a particular building facade. For example, simple fixed overhangs are very effective at shading south-facing windows in the summer when sun angles are high. However, the same horizontal device is ineffective at blocking low afternoon sun from entering west-facing windows during peak heat gain periods in the summer. The shading devices can be classified as given below:

- 1) Movable opaque: Roller blind curtains, awnings etc. reduce solar gains but impede air movement and cut the view.
- 2) Louvers: They are adjustable or can be fixed. To a certain extent impede air movement and provide shade to the building from the solar radiation.
- 3) Fixed: Overhangs of chajjas provide protection to the wall and opening against sun and rain.

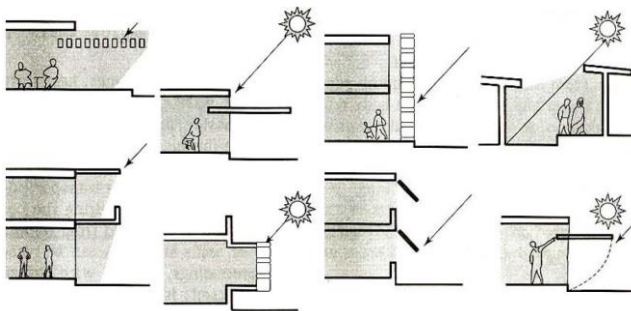


Fig. 1. Different types of shading devices.

In a research conducted at Division of Energy and Building Design at Lund University by Rosencrantz investigated the performance of various internal and external shading devices in offices compared to outdoor measurements by using the simulation software ParaSol version 2.0. ParaSol is a dynamic energy and solar transmittance simulation software for comparison of various solar shading devices. One study showed that both the cooling load and the annual cooling demand could decrease by a factor of two by using external solar shadings. For internal solar shadings the cooling load and the cooling demand decreased only by one third. The general conclusion of this study is that external shadings are much more efficient than internal shadings. This can also affect the design of the HVAC-system, leading to smaller installations. The result of another study showed that the efficiency of the solar shadings increased with decreasing window absorption [3]. Givoni analysed the efficiency of various types of fixed shading devices in different orientations and concluded that in all orientations, horizontal shading is more effective than a

vertical one. Other advantages of horizontal projections over vertical projections are; (i) vertical device is not applicable for shading the whole length of facade (ii) vertical device reduces daylight penetration more than horizontal projection (iii) vertical projections will reduce the extent of external view [4].

Given the wide variety of buildings and the range of climates in which they can be found, it is difficult to make generalize the design of shading devices. However, the following design recommendations generally hold true [5]:

- 1) Study of the sun angles is important for designing the shading devices. An understanding of sun angles is critical to various aspects of design including determining basic building orientation and selecting shading devices.
- 2) Fixed shading devices, using correctly sized overhangs or porches, or design the building to be "self-shading" should be installed. Fixed shading devices, which are designed into a building, will shade windows throughout the solar cycle. Permanent sun shades may be built into the building form and this is often given the French terminology of - brise soleil (Fig. 2). They are most effective on the south-facing windows. Awnings that can be extended or removed can also be considered for shading the windows. The depth and position of fixed shading devices must be carefully engineered to allow the sun to penetrate only during predetermined times of the year. In the winter, overhangs allow the low winter sun to enter south-facing windows. In the summer, the overhangs block the higher sun.

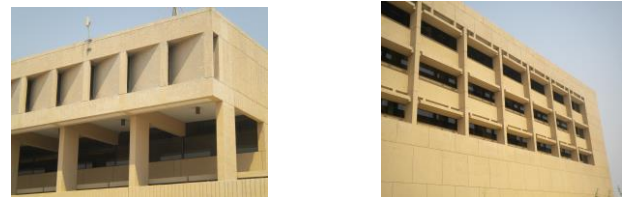


Fig. 2. Brise soleil – shading devices integrated with the building facade.

- 3) Limit east/west glass. Glass on these exposures is harder to shade from the eastern morning sun or western evening sun. Vertical or egg-crate fixed shading works well if the shading projections are fairly deep or close together; however, these may limit views. The use of landscaping can also be considered to shade east and west exposures. North-facing glass receives little direct solar gain, but does provide diffuse daylight.
- 4) In hot and dry climates, the movable blinds help to reduce the convective heat gain caused by the hot ambient air. In warm and humid climates where the airflow is desirable, they impede ventilation. In composite climates, the light colored/ reflective blinds block the solar radiation effectively.
- 5) Internal shading, in the form of blinds or curtains, is

often used to block the unwanted solar gains coming through a window. The effectiveness of any shading device located inside the window is a function of how well it reflects short wave radiation back out through the glass. Darker blinds or curtains may reduce solar penetration into the space and may be helpful, but not as effective as exterior shading because it still convert most of the sunlight into heat within the building envelope since heat has already penetrated the building [6].

- 6) Any shading device will affect the view out of a window and this maybe a crucial factor in favoring one form of shading over another form. If shading devices are employed they will have a major, if not an overwhelming affect upon the external appearance of a building, and therefore they need to be considered at the outset if they are to be used [7].

Shading of Roofs⁸

Shading the roof is a very important method of reducing heat gain. Roofs can be shaded by providing roof cover of concrete or sheet or plants or canvas or earthen pots etc. Shading provided by external means, particularly a roof, should not interfere with nighttime 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 nighttime.

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.

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 radiative emission. Insulating cover over the roof impedes heat flow into the building. However, it renders the roof unusable and maintenance difficult.

Another inexpensive and effective device is a removable canvas cover mounted close to the roof. During daytime it prevents entry of heat and its removal at night, radiative cooling. Painting of the canvas white minimizes the radiative and conductive heat gain.

Shading by Trees and Vegetation⁹

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 of shading for various window orientations

and situations. The following points should be considered for summer shading:

- 1) Deciduous trees and shrubs provide summer shade yet allow winter access. The best locations for deciduous trees are on the south and southwest side of the building. When these trees drop their leaves in the winter, sunlight can reach inside to heat the interiors.
- 2) Trees with heavy foliage are very effective in obstructing the sun's rays and casting a dense shadow. Dense shade is cooler than filtered sunlight. High branching canopy trees can be used to shade the roof, walls and windows.
- 3) Evergreen trees on the south and west sides afford the best protection from the setting summer sun and cold winter winds.
- 4) Vertical shading is best for east and west walls and windows in summer, to protect from intense sun at low angles, e.g. screening by dense shrubs, trees, deciduous vines supported on a frame, shrubs used in combination with trees.
- 5) Shading and insulation for walls can be provided by plants that adhere to the wall, such as English ivy, or by plants supported by the wall, such as jasmine.
- 6) Horizontal shading is best for south-facing windows, e.g. deciduous vines (which lose foliage in the winter) such as ornamental grape or wisteria can be grown over a pergola for summer shading.

Shading by 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 as shown in Figure 5. 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.

III. CONCLUSION

Different shading techniques can be employed to shade the building, which minimize the incident solar radiation and cool the building effectively and hence affect building energy performance. Using any or all of these strategies will help to keep the building cool. Sometimes we need to supplement natural cooling with mechanical devices. Fans and evaporative coolers can supplement our cooling strategies and cost less to install and run the air conditioners. Shading reduces the peak-cooling load in buildings, thus reducing the size of the air conditioning equipment that will run fewer hours and consume less energy. Incorporation of such 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. A study of energy characteristics and savings potentials in office buildings in Greece by Santamouris et al. showed that an appropriate shading of buildings could provide a significant

reduction of cooling loads. According to this study it is possible to reduce the total cooling load of the air conditioned buildings by approximately 7% by employing a more efficient shading strategy [10]. Hence it is essential for architects and building engineers to incorporate these shading techniques in buildings, which will improve thermal comfort and thereby conserves energy.

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