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# SHADING: 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. Natural cooling can be achieved by 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, external surface finish. 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. 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.

**Keywords:** Shading, Natural Cooling, Energy Conservation, Energy.

## I. INTRODUCTION

Energy consumption of buildings is destroying the planet as we know it. Buildings use about 48 percent of all the energy consumed, with 40% for the operation of buildings and 8 percent for the construction of buildings (Figure 1). This energy is mostly derived from fossil sources that produce the carbon dioxide that is the main cause of global warming. We must replace these polluting sources with clean, renewable energy sources such as wind, solar energy, and biomass, or we must increase the efficiency of our building stock so that it uses less energy, or we must do both. Of course, we need to do both, but decreasing the energy consumption of buildings is both quicker and less expensive.

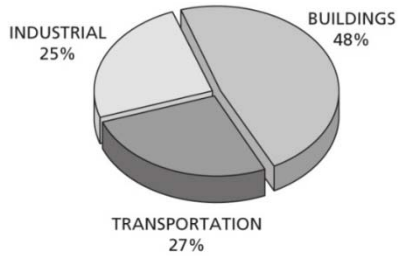


Figure 1. Energy Consumption
(Source: Energy Information Administration, EIA)

Furthermore, the design of energy - responsive buildings will yield a new aesthetic that can replace both the blandness of most modern buildings and the unimaginative copying of previous styles. Is it really possible for architecture to seriously address the problem of global warming? The answer is an unambiguous yes, both because present buildings are so wasteful of energy and because we know how to design and build buildings that use 80 percent less energy than the standard new building. Presently, there are architects around the world designing "zero-energy buildings" [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 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 [1]. 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 10-40%.

Because of global warming, it is now widely recognized that reducing the energy appetite of buildings is the number one green issue. For example, in 2007 the U.S. Green Building Council (USGBC) increased the energy requirements for LEED (Leadership in Energy and Environmental Design) certification. As Figure 2 illustrates, the energy issues are a very large subset of all of the sustainability issues. Figure 2 also demonstrates that the solar issues are a surprisingly large subset of the energy issues. One reason for this is that "solar" refers to many strategies: photovoltaics (solar cells), active solar (hot water), passive solar (space heating), day lighting, and shading. Although shading is the reverse of collecting solar energy, it is one of the most important solar design strategies, because it can save large amounts of air - conditioning energy at low cost.

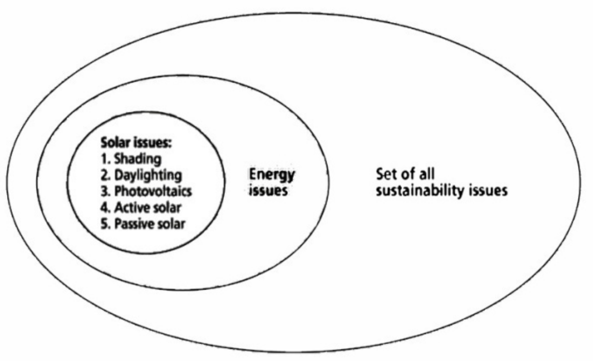


Figure 2. Sustainability issues

## II. SHADING OF BUILDING

The performance of solar passive cooling techniques such as solar shading, insulation of building components and air exchange rate was evaluated. In the study 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 4.4-6.8 °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 [1]. 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, learning about different methods employed to shade a building leading to natural cooling and energy conservation.

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

The different criteria of shading of buildings for various climatic zones have been given by Bansal [2]. They are given in the following Table 1.

Table 1. Criteria of Shading for Various Climatic Zones (Bansal et. al., 1988)

| Climate Zones | Requirements |
|---|---|
| Hot and dry | Complete year round shading |
| Warm and humid | Complete year round shading, but design should be made such that ventilation is not affected |
| Temperate | Complete year round shading but only during major sunshine hours |
| Cold and cloudy | No shading |
| Cold and sunny | Shading during summer months only |
| Composite | Shading during summer months only |

## III. SHADING BY OVERHANGS, LOUVRES AND AWNINGS

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 (Figure 3).

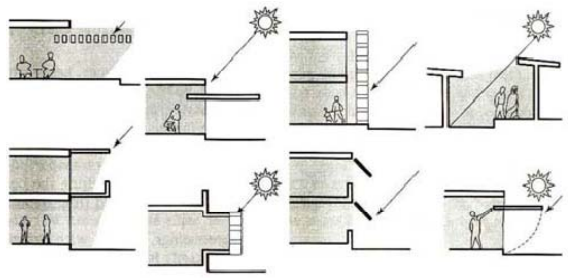

Figure 2. Different types of shading devices

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 (Figure 4):

- Movable opaque: Roller blind curtains, awnings etc. reduce solar gains but impede air movement and block the view.
- Louvres: They are adjustable or can be fixed. To a certain extent impede air movement and provide shade to the building from the solar radiation.
- Fixed: Overhangs of Chajjas provide protection to the wall and openings against sun and rain [3].

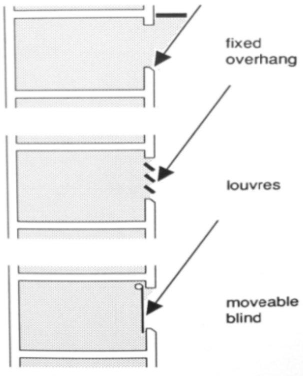


Figure 3. Different types of shading devices

Solar control devices can have two functions (Figure 5):
- They reduce the total amount of radiation entering the room by reflection and absorption.
- They improve the distribution of the light in the room.

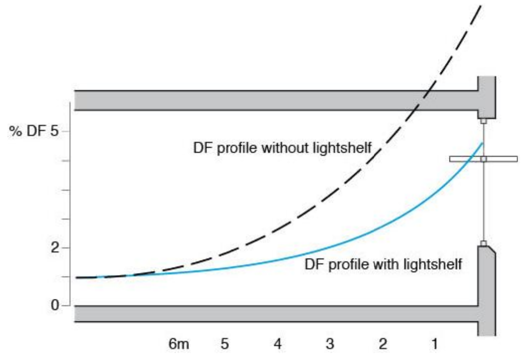


Figure 4. A light shelf obscures sunlight to the front of the room whilst reflecting light to the back of the room

A light shelf obscures sunlight to the front of the room whilst reflecting light to the back of the room. The unwanted energy is represented by the area between the two curves, i.e. the solar gain is reduced by at least a half without compromising the minimum daylight levels.
Three options are possible: external, internal and mid-pane; they all carry advantages and disadvantages.

The term greenhouse effect was coined long before the application of the term to global warming, and refers to the mechanism whereby short wavelength solar radiation (visible and invisible) enters the room through the glass, to which it is transparent. The radiation is then absorbed by the room surfaces warming them up, and re-radiates, but due to the relatively low temperature the radiation is of long wavelength, to which the glass is opaque. Thus the energy gets trapped behind the glass.

External shading devices are the most efficient thermally because they intercept the solar energy before it has entered the room. Thus, even if energy is absorbed by them, it is not trapped behind the glass. They carry the disadvantage of having to be weatherproof and are more difficult to control from inside.

Internal shading is generally much cheaper to install and is easy for users to control, but is less efficient, for reasons outlined above, see figure. It is also vulnerable to damage [3].

Mid-pane shading devices have become more popular as technical problems have been overcome, and now can be installed in sealed, gas-filed double glazing units. Control of the louvres can be achieved through magnetic linkages. Or, they may be installed in much larger non-sealed cavities found in so called double skin buildings. They carry some of the advantages of both (the above), and are particularly effective in double skin buildings where they are protected, but the cavity is large enough to be independently ventilated, to remove any absorbed solar gains (Figure 6).

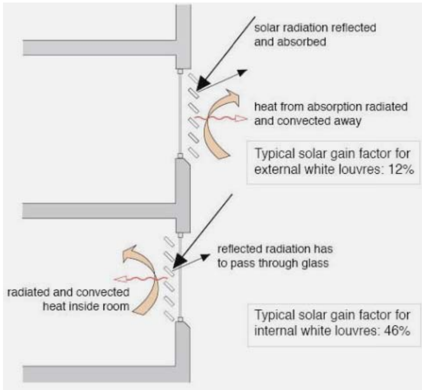


Figure 5. A comparison between external and internal shading

It is important that the design of shading devices is closely linked with the design of the daylighting. The window, shading devices and room system must be seen as a single system for delivering daylight, view, minimizing unwanted heat gains in summer, and (possibly) maximizing them in winter. It is quite likely that the window will also be expected to provide ventilation air, and shading devices may interfere with this as well. Figure 7 shows how different kinds of shading device affect view and ventilation. Figure 8 shows how different blind materials have quite different optical and thermal performance [3].

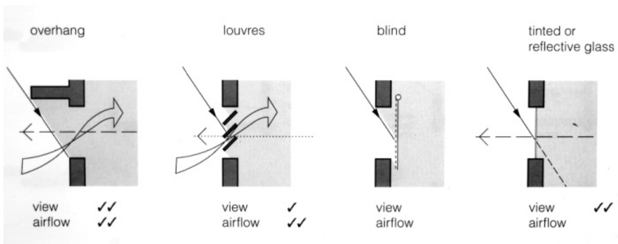


Figure 6. The impact of shading types on vision and ventilation

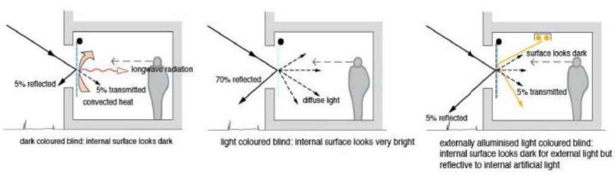


Figure 7. The optical and thermal performance of different types of blind material

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;

(a) vertical device is not applicable for shading the whole length of facade

(b) vertical device reduces daylight penetration more than horizontal projection

(c) 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 (Figure 9). An understanding of sun angles is critical to various aspects of design including determining basic building orientation and selecting shading devices.

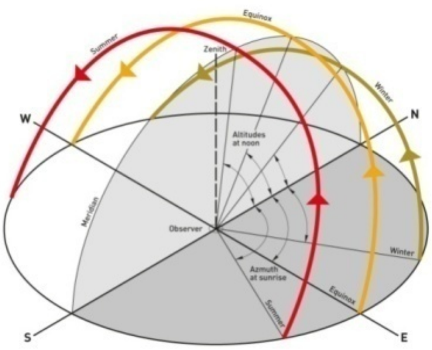


Figure 8. Pattern of sun's seasonal movement

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 (Figure 10). 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.

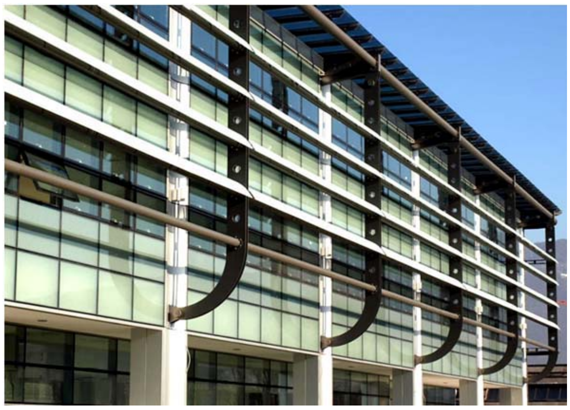

Figure 10. Brise soleil - shading devices integrated with the building facade

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 [5].

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].

## IV. SHADING OF ROOFS

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 (Figure 11).

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 [6].

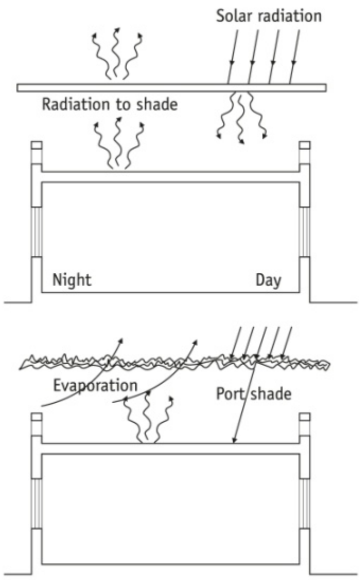


Figure 9. Some methods of shading the roof

## V. SHADING BY 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 vapor-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 (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 (Figures 12 and 13) [8].

Figure 10. Shading by trees and vegetation (green roof)

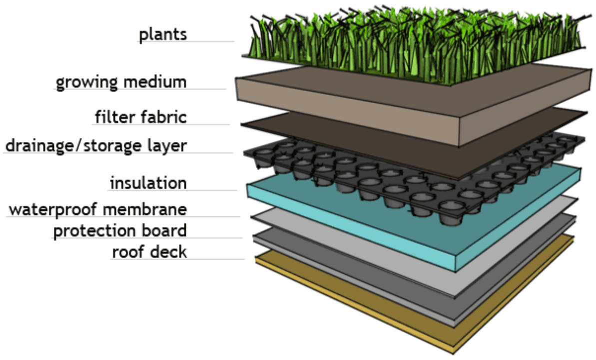


Figure 11. Green roof detail

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 [9].

## VI. SHADING BY URBAN MORPHOLOGY

In regions experiencing hot summers, the built urban environment is often compact in layout. Streets are narrow and sometimes covered, partially or wholly, by fabric awnings and overhangs during the peak summer season, and shaded by neighbouring buildings at critical times. Sloping ground is also exploited to enhance mutual shading of buildings. The main purpose of such measures is to provide a comfortable outdoor and indoor environment. Such design, however, may lead to poor ventilation and so, like daylighting, ventilation should be considered together with shading [11].

Shading can be achieved not only by optimizing street width, but also through the use of courtyards. These can be designed to give both sunlight and shade in harmony with the seasons. Courtyards are a common feature of Mediterranean architecture and can be used to create an entire urban form (Figure 14).

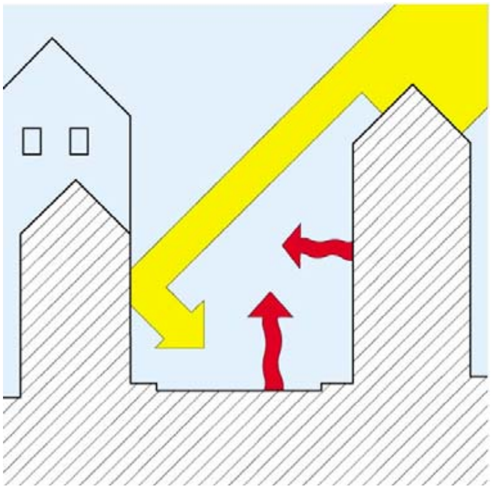

Figure 12. Shading by neighbouring buildings

In the Mediterranean climate, there are two main climatic effects to be considered in building and urban design. First, high ambient air temperature and intense solar radiation during summer produces high heat stress. Second, direct and reflected solar radiation produces very high glare. Well conceived urban design can counter these negative influences to a large extent. The setback distance between buildings, generally represented by the public street, is of chief importance in such design, and may be calculated to provide overshadowing during the cooling season.

## VII. SHADING AND ENERGY

### A. Cooling

Shading systems perform a number of roles, the most apparent of which is protection from direct solar radiation and the resultant unwanted build up of heat inside the building. This protection is best achieved by shading the building's windows and other apertures. Shading the building facades and roof can also significantly reduce unwanted heat build-up, particularly when these elements are uninsulated. Shading the building envelope and apertures directly reduces the need for cooling: the potential of shading systems to reduce building cooling loads should not be under-estimated.

Apart from commercial buildings that experience high internal heat gains from office equipment and occupants, solar radiation represents the major influence on cooling loads in buildings. The direct component is more influential than the diffuse, and exerts its most immediate impact on cooling load when it reaches windows and other apertures because it is transmitted directly to the building interior. As the direct component of solar radiation is of predictable direction, it can be effectively blocked by external shading devices. The diffuse and reflected components, due to their wider angles of incidence, are more difficult to control and are thus more effectively controlled by internal or mid-pane devices. The effectiveness of most internal shades in preventing heat gain to the internal space, however, is limited.

Both direct solar radiation and high external air temperatures will produce conduction heat flow through the building facade and into the building. The rate of conduction heat flow is determined mainly by the thermal insulation and mass properties of the facade elements. A shaded facade will still be subject to the influence of external air temperature and diffuse and reflected solar radiation, but will be free of the influence of the direct radiation. A shaded wall, therefore, conducts less heat to the building interior than an unshaded wall, and so will lead to a lower cooling load [8].

While the cooling load may be reduced by shading, any associated reduction in daylight levels in the space may lead to a higher artificial lighting load. This may lead to a partial negation of the benefits derived from a reduced cooling load. A system that is able to distribute light evenly throughout the space. Reduce glare at the window area and increase illuminance at the rear – is therefore preferable.

Solar heat gains should be reduced without compromising illuminance or ventilation. Moveable external devices usually best achieve this: ideally, moveable external light shelves with a reflective upper surface finish. However, describes a mathematical model for designing fixed shading devices in which the load on the artificial lighting system is not significantly increased, and both thermal and visual comfort requirements are met. This is achieved by ensuring that glare is within allowable limits.

### B. Lighting

Although overall illuminance in a space is important, it is the distribution of light in the field of vision that determines the quality of the lighting environment. Shading devices that are able to redirect and redistribute light throughout a space are thus especially useful. Such devices range from the light shelf to advanced glazing systems, and include blinds, reflective louvres, external fins and glass coatings. Their main function is to improve the uniformity of lighting levels. This may involve reducing excessive levels near the window, redistributing light to the rear of the space, or both [11].

The various systems perform differently but they have one objective in common: they improve lighting uniformity throughout the space, typically by redistributing light from the window area to the rear of the space. Potential glare spots are avoided by redirecting the light. Tests have shown that people will tolerate lower overall light levels providing unduly bright and comparatively dark areas are avoided. When light is evenly distributed throughout the space, people are less inclined to switch on the lights, even when the actual light levels are lower than ideal. When the human eye has to adapt to a higher illuminance gradient, the temptation to turn on the lights is greater.

Shading devices that perform the double role of protection against solar radiation and redistribution of available daylight, therefore, have the potential to minimize overall energy consumption in two ways. Firstly, by reducing cooling loads through their shad ing function, and secondly, because of the better luminous efficacy of daylight, by reducing the use of artificial lighting through their light distribution function [10].

## VIII. CONCLUSIONS

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.

Solar shading can help to reduce cooling energy consumption and improve indoor thermal environment.

Appropriate shading design not only achieves higher energy efficiency, but also reduces incremental costs. This paper provides suggestions for solar shading designs for both residential and commercial buildings by comparison of the incremental costs. These results help architects optimize the building design with suitable solar shading devices.

So it is necessary:

- Shading devices should be able to moderate or control direct, diffuse and reflected solar radiation, and glare, whilst ensuring that day lighting and natural ventilation are not excessively reduced.
- Shading devices may be designed to protect opaque as well as transparent surfaces.
- Shading devices that both protect against solar radiation and redistribute daylight can reduce cooling loads and the use of artificial lighting.
- For visual comfort, good daylight distribution is important.
- Fixed shading devices are effective in excluding summer sun but admit low angled winter sun. They can reduce internal luminance in cloudy conditions. They give minimal control of diffuse and reflected light.
- Internal devices should be considered in terms of day lighting and glare control, since they can control diffuse and reflected light.
- External adjustable shading can provide shading without reducing internal light levels, and is effective in controlling low angled direct sunlight, diffuse and reflected light, and glare. It must be robust enough to resist wind damage.
- Retractable shading devices may reduce ventilation when deployed to provide full shading during the cooling season.
- Mid-pane shading devices provide effective glare control, and are protected from weathering.
- Vegetation can shade whole facades and roofs, reducing conductive as well as radiative heat gains. Evergreen species can be used to reduce reflection from water bodies, roads, paved areas and buildings.
- The shading effect of vegetation depends strongly on the type, the species, and the age of the plant.
- Advanced glazing should not normally be considered as a complete shading solution, but can improve a building’s shading performance when used in conjunction with other devices. Window films are highly applicable in a retrofit situation.
- Simple devices, correctly designed, are often as effective as hi-tech systems.
- A wide range of devices will meet similar performance requirements.

## REFERENCES

[1] A. Mahyari, “Wind Catchers”, Ph.D. Thesis, Sydney University, No. 62, 1997.

[2] M. Mahmoudi, S.M. Mofidi, “Analysis on Typology and Architecture of Wind Catcher and Finding the Best Type”, Honarhaye Ziba Journal, Vol. 36, No. 8, p. 29, pp. 22-23, 2008.

[3] M. Mahmoudi, “Wind Tower as a Natural Cooling System in Iranian Architecture”, Passive and Low Energy Cooling in Buildings Conference, Greece, pp. 11-12, 2005.

[4] M.N. Bahadori, “An Improved Design of Wind Towers for Natural Ventilation and Passive Cooling”, Solar Energy, Vol. 35, No. 2, pp. 30, 41, 2005.

[5] K.A. Chauhan, N.C. Shah, “A Study on Sustainable Urban Environment with Climatic Consideration in Housing Planning”, Global Journal of Environmental Research, Vol. 2, Issue 1, pp. 12-17, 2008.

[6] R. Kumar, S.N. Garg, S.C. Kaushik, “Performance Evaluation of Multi-Passive Solar Applications of a Non Air-Conditioned Building”, International Journal of Environmental Technology and Management, Vol. 5, No. 1, pp. 60-75, 2005.

[7] T. Rosencrantz, “Performance of Energy Efficient Windows and Solar Shading Devices”, Lund University, pp. 3, 2005.

[8] M.A. Kamal, Najamuddin, “Energy Conservation with Passive Solar Landscaping”, National Convention on Planning for Sustainable Built Environment, Bhopal, pp. 92-99, 2003.
[9] M. Santamouris, A. Argiriou, E. Daskalaki, C. Balaras, A. Gaglia, “Energy Characteristics and Saving Potential in Office Building”, Solar Energy, Vol. 52, No. 1, pp. 59-66, 1994.
[10] B. Ahmadkhani Maleki, “Traditional Sustainable Solutions in Iranian Desert Architecture to Solve the Energy Problem”, International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 6, Vol. 3, No. 1, pp. 84-91, March 2011.
[11] B. Ahmadkhani Maleki, “Wind Catcher: Passive and Low Energy Cooling System in Iranian Vernacular Architecture”, International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 8, Vol. 8, No. 3, pp. 84-91, September 2011.

## BIOGRAPHY

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