EFFECTS OF LIGHT AND SHADING DEVICES

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ABSTRACT

In addition to building's aesthetics appeal, building's façade plays major role regarding form, shape, color & material which categorize the building as modern, light, bulky or boring. Shading Devices are extensively used on the building surfaces as modern aesthetic materials. The aim of the research is to investigate various types of shading devices (vernacular, traditional & modern) & their thermal performance on the structures. One method used to control the amount of sun coming through a window is the provision of appropriate shading devices. Their efficiency depends on placement and dimensions. In this paper a scientific method is presented that aids in the design of efficient shading devices for windows at any orientation. A computer program has been developed by the authors to address this issue specifically. The computer program is interactive, prompting the user to provide minimal geographic and climatic data. The program processes this information and presents results graphically as well as numerically. The sun path diagram for the locality under investigation along with the overheated period is plotted accurately. Profile angles for the respective shading devices are determined, whereby dimensions and shading efficiency of the devices are calculated accurately for energy-efficient design

KEYWORDS: Vernacular Architecture, Hot & Dry, Thermal Performance on the Structure

To meet human needs for natural light and outside views, buildings are designed with large window openings, making proper orientation and sun control very important. Solar radiation affects airconditioning capacity and solar energy can supplement the heat source in winter. Thus it is increasingly important to know and understand the sun's effect on the design and engineering of a building. Paramount in this is knowledge of the sun's apparent position.

Shading Devices always represent fundamental system to control the incoming natural light with two main purpose:

a) Improving indoor visuals
b) Thermal Comfort
c) Reducing HVAC and artificial lights
d) Energy consumption of the structure

Industries in these last years have developed and produced different types of transparent materials and lighting control systems that take full advantage of energy saving potential coming from daylight.

CLIMATIC FACTORS FOR SHEDING DEVICE

Hot & Dry Climatic Zones

The general characteristics of this climate are as follows:

a) Hot dry weather in summer and cold in winter
b) very little rainfall
c) very low humidity
d) sandy or rocky ground with very low vegetation cover.
e) high temp. difference between night and day.
f) hot winds & frequent dust storms
g) High solar radiations
h) Clear sky most of the times

Building Typology

The Structures at Hot & Dry climatic zones have following typology:

a) Wall is still warm at night because of the high solar radiation during the day.
b) Pitch roof used as buffer to reduce the entry of the heat inside the houses.
c) Walls are plastered in single layer to reduce the heat capture in the house.
d) Window hoods and balcony to reduce the entry of solar radiation and daylight in the house.
e) More windows and openings are kept wider.
f) Aprons to prevent dirt on wall

Thermal Comfort

Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHRAE Standard 55). Maintaining this standard of thermal comfort for occupants of buildings or other enclosures is one of the

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important goals of HVAC (heating ventilation and air conditioning) design engineers. Most people will feel comfortable at room temperature, colloquially a range of temperatures around 20 to 22 °C (68 to 72 °F), but this may vary greatly between individuals and depending on factors such as activity level, clothing, and humidity.

Thermal neutrality is maintained when the heat generated by human metabolism is allowed to dissipate, thus maintaining thermal equilibrium with the surroundings. The main factors that influence thermal comfort are those that determine heat gain and loss, namely metabolic rate, clothing insulation, air temperature, mean radiant temperature, air speed and relative humidity. Psychological parameters, such as individual expectations, also affect thermal comfort.

Factors in human comfort are as follows:

Metabolic Rate: The energy generated from the human body

Clothing insulation: The amount of thermal insulation the person is wearing

Air temperature: Temperature of the air surrounding the occupant

Radiant temperature: The weighted average of all the temperatures from surfaces surrounding an occupant

Air velocity: Rate of air movement given distance over time

Relative humidity: Percentage of water vapor in the air

Value	Sensation
-3	Cold
-2	Cool
-1	Slightly cool
0	Neutral
1	Slightly warm
2	Warm
3	Hot

The recommended acceptable PMV range for thermal comfort from ASHRAE 55 is between -0.5 and +0.5 for an interior space.

Passive Heating & Cooling

In any structure, the heating and cooling methods can correlate with following terms:

Direct Solar Gains

Direct gain is the heat from the sun being collected and contained in an occupied space. Direct solar gain is important for any site that needs heating, because it is the simplest and least costly way of passively heating a building with the sun. Avoiding direct solar gain is also important in hot sunny climates.

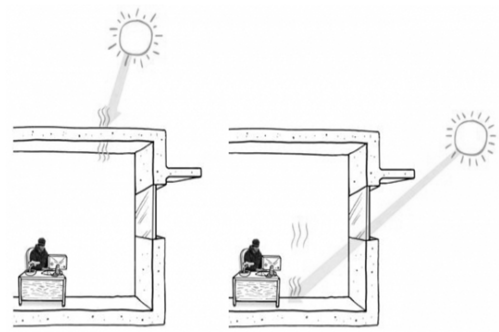


Figure 1: Direct Solar Gain

Massing & Orientation for heating

Massing and orientation are important design factors to consider for passive heating. Consider these factors early in the design so that the surface areas exposed to sun at different times of day, building dimensions, and building orientation can all be optimized for passive comfort.

In hot climates, thin buildings with their biggest face exposed to the sun can cause unwanted solar heat gain. Shading devices and good windows can be used to reduce this while still allowing natural ventilation. Taller buildings can also reduce unwanted gains in hot climates, as the sun's heat strikes more strongly on roofs than on walls in warm latitudes, and tall buildings have less roof area per unit volume.

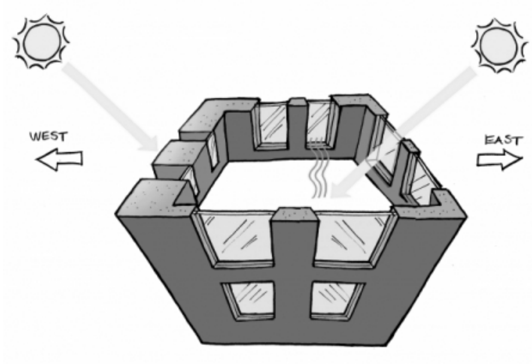


Figure 2: Massing & Orientation For Heating

More glazing to the east and more thermal mass to the west can even out temperature swings from the sun's heat.

Thermal Mass

Thermal mass is a material's resistance to change in temperature. Objects with high thermal mass absorb and retain heat. Thermal mass is crucial to good passive solar heating design, especially in locations that have large swings of temperature from day to night.

Thermal mass is often critical to direct solar gain passive design.

High thermal mass materials conduct a significant proportion of incoming thermal energy deep into the material. This means that instead of the first couple of millimeters of a wall heating up 5–10 degrees, the entire wall heats up only 1–2 degrees. The material then re-radiates heat at a lower temperature, but re-radiates it for a longer period of time.

This helps occupants stay more comfortable, longer. When the internal temperature of the space falls at night, there is more energy still stored within the walls to be re-radiated back out.

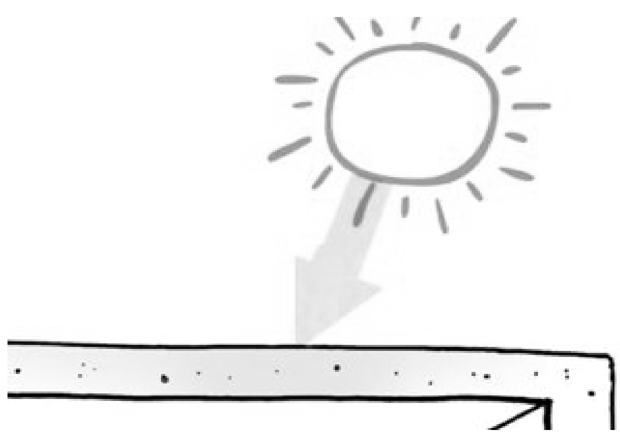


Figure 3: Thermal Mass

Thermal mass can store energy absorbed from the sun and release it over time. Conversely, it can resist heating up too fast from solar radiation.

The larger the area of thermal mass receiving direct sunlight, the more heat it receives, so the faster it can heat up, and the more heat it can store.

Trombe Wall & Attached Sun Space

A Trombe wall is a system for indirect solar heat gain and, although not extremely common, is a good example of thermal mass, solar gain, and glazing properties used together to achieve human comfort goals passively.

It consists of a dark colored wall of high thermal mass facing the sun, with glazing spaced in front to leave a small air space. The glazing traps solar radiation like a small greenhouse. An attached sunspace is essentially a Trombe wall where the air space is so big it is habitable.

Trombe walls are a very useful passive heating system. They require little or no effort to operate, and are ideal for spaces where silence and privacy are desirable. Sunspaces are equally simple and silent, and can allow views. Rooms heated by a Trombe wall or sunspace often feel more comfortable than those heated by forced-air systems, even at lower air temperatures, because of the radiantly warm surface of the wall.

A successful Trombe wall or attached sunspace optimizes heat gain and minimizes heat loss during cold times, and avoids excess heat gain in hot times.

BUILDING ENVELOPE

Daylighting

Daylighting is the practice of placing windows, other openings, and reflective surfaces so that sunlight (direct or indirect) can provide effective internal lighting.

Using daylight in your building is a key strategy for passive design. Letting sun into your building impacts visual comfort, as well as thermal comfort. Understanding how light from the sun enters a building as well as how to use the light once it is in a building are important considerations for successful daylighting.

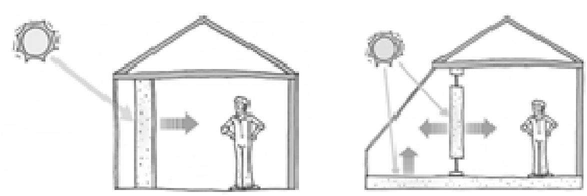


Figure 4: A Trombe wall (left) and attached sunspace (right)

The best way to incorporate daylighting in your home depends on your climate and the openings can be categorized as follows:

- South-facing windows allow most winter sunlight into the home but little direct sun during the summer, especially when properly shaded
- North-facing windows admit relatively even, natural light, producing little glare and almost no unwanted summer heat gain
- East- and west-facing windows provide good daylight penetration in the morning and evening, respectively, but may cause glare, admit a lot of heat during the summer when it is usually not wanted, and contribute little to solar heating during the winter.

U-Value

U-values measure how effective a material is an insulator. We look in detail at terminology and core concepts when it comes to thermal performance.

Note that in the above example, the conductivities (k-values) of building materials are freely available online; in particular, from manufacturers. In fact, using manufacturer data will improve accuracy, where specific products being specified are known at the time of calculation.

Whilst design calculations are theoretical, post-construction measurements can also be undertaken. These have the advantage of being able to account for workmanship. Thermal transmittance calculations for roofs or walls can be carried out using a heat flux meter. This consists of a thermopile sensor that is firmly fixed to the test area, to monitor the heat flow from inside to outside. Thermal transmittance is derived from dividing average heat flux (flow) by average temperature difference (between inside and outside) over a continuous period of about 2 weeks (or over a year in the case of a ground floor slab, due to heat storage in the ground).The accuracy of measurements is dependent on a number of factors:

SHADING DEVICES

Internal Shading Devices

When designing the shading devices, one should take into account the need to control solar gains in summer, as well as the heating and the lighting performance of the building. The exclusive use of internal sun-shading devices such as roller shades, venetian blinds, curtains and drapes, is not recommended. The major disadvantage internal device is that, regardless of how reflective they are made, they trap heat on the interior of the glass so it remains indoors. A combination of internal and external shading devices is recommended; the shading being designed as a whole. Internal shading devices should not block the daylighting or interfere with the natural ventilation, as it can happen when they obstruct the window openings.

Curtains

Roller Blinds

External Shading Devices

Most thermally efficient as it controls the amount of radiation entering the building externally. The external shading devices can be categorized as Horizontal, Vertical or egg-crate devices.

Vegetation and other buildings can also act as shading devices. In the tropical climates, the designer should keep the solar radiation off the opaque solid elements of the building's envelope where possible. Special care should be taken to shade the windows to reduce the incoming heat and the risk of overheating.

Shading Devices Calculation

Rules of the Thumb

Shading devices should be selected according to the orientation of the window. Whilst some orientations are easy to shade, others are much more difficult as the sun can shine almost straight in at times. The table below indicates the most appropriate type of shading device to use for each orientation in the southern hemisphere. These are guidelines and, of course, there are many variations to these basic types.

Orientation	Effective Shading
North (equator-facing)	Fixed horizontal device
East or West	Vertical device/louvres (moveable)
South (pole-facing)	Not required

Design Steps

1) Determine cut-off date. This is the date before which the window is to be completely shaded and after which the window will be only partially shaded.
2) Determine Start and End Times. These represent the times of day between which full shading is required. Keep in mind that the closer to sunrise and sunset these times are, the exponentially larger the required shade. Look up Sun Position. Use solar tables or a sun-path diagram to obtain the azimuth and altitude of the sun at each time on the cut-off date.

Materials Used for Shading Devices

Insulation Materials

Insulation materials run the gamut from bulky fiber materials such as fiberglass, rock and slag wool, cellulose, and natural fibers to rigid foam boards to sleek foils. Bulky materials resist conductive and -- to a lesser degree -- convective heat flow in a building cavity. Rigid foam boards trap air or another gas to resist heat flow. Highly reflective foils in radiant barriers and reflective insulation systems reflect radiant heat away from living spaces, making them particularly useful in cooling climates. Insulation Materials used for shading devices are as follows:

Fiberglass

Fiberglass (or fiber glass) --which consists of extremely fine glass fibers--is one of the most ubiquitous insulation materials. It's commonly used in two different types of insulation: blanket (batts and rolls) and loose-fill and is also available as rigid boards and duct insulation.

Fiberglass loose-fill insulation is made from molten glass that is spun or blown into fibers. Most manufacturer's use 40% to 60% recycled glass content. Loose-fill insulation must be applied using an insulation-blowing machine in either open-blow applications (such as attic spaces) or closed-cavity applications (such as those found inside existing walls or covered attic floors).

Mineral Wool Insulation Materials

The term "mineral wool" typically refers to two types of insulation material:

Rock wool, a man-made material consisting of natural minerals like basalt or diabase. Slag wool, a man-made material from blast furnace slag (the waste matter that forms on the surface of molten metal).Mineral wool contains an average of 75% post-industrial recycled content. It doesn't require additional chemicals to make it fire resistant, and it is commonly available as blanket & loose fill insulation.

Cellulose Insulation Material

Cellulose insulation is made from recycled paper products, primarily newsprint, and has a very high recycled material content, generally 82% to 85%. The paper is first reduced to small pieces and then fiberized, creating a product that packs tightly into building cavities and inhibits airflow. Cellulose insulation is used in both new and existing homes, as loose-fill in open attic installations and dense packed in building cavities such as walls and cathedral ceilings.

Polystyrene Insulation Materials

Polystyrene--a colorless, transparent thermoplastic--is commonly used to make foam board or breadboard insulation, concrete block insulation, and a type of loose-fill insulation consisting of small beads of polystyrene. Molded expanded polystyrene (MEPS), commonly used for foam board insulation, is also available as small foam beads. These beads can be used as a pouring insulation for concrete blocks or other hollow wall cavities, but they are extremely lightweight, take a static electric charge very easily, and are notoriously difficult to control.

Polyisocyanurate Insulation Materials

Polyisocyanurate insulation is available as a liquid, sprayed foam, and rigid foam board. It can also be made into laminated insulation panels with a variety of facings. Foamed-in-place applications of polyisocyanurate insulation are usually cheaper than installing foam boards, and perform better because the liquid foam molds itself to all of the surfaces.

Liquid foam can be injected between two wood skins under considerable pressure, and, when hardened, the foam produces a strong bond between the foam and the skins. Wall panels made of polyisocyanurate are typically 3.5 inches (89 mm) thick. Ceiling panels are up to 7.5 inches (190 mm) thick. These panels, although more expensive, are more fire and water vapor-diffusion resistant than EPS. They also insulate 30% to 40% better for given thickness.

Thermal Mass Materials

Thermal mass is the ability of a material to absorb and store heat energy. A lot of heat energy is required to change the temperature of high density materials like concrete, bricks and tiles. They are therefore said to have high thermal mass. Lightweight materials such as timber have low thermal mass. During summer it absorbs heat during the day and releases it by night to cooling breezes or clear night skies, keeping the house comfortable. In winter the same thermal mass can store the heat from the sun or heaters to release it at night, helping the home stay warm. Thermal mass is not a substitute for insulation. Thermal mass stores and re-releases heat; insulation stops heat flowing into or out of the building. A high thermal mass material is not generally a good thermal insulator.

Winter

Allow thermal mass to absorb heat during the day from direct sunlight or from radiant heaters. It re-radiates this warmth back into the home throughout the night.

Summer

Allow cool night breezes and/or convection currents to pass over the thermal mass, drawing out all the stored energy. During the day protect the thermal mass from excess summer sun with shading and insulation if required.

CLASSIFICATION OF SHADING DEVICES

Vernacular Shading Devices of Rajasthan

Rajasthan, one of the most vibrant and largest state of our country, was earlier called the Rajputana and historically well known, presently comprises of erstwhile Rajputs, Jat and also Mughal kingdoms.

Rajasthani Architecture is an outstanding arrangement of colonial, Islamic and Hindu architecture. Jain and Muslim architecture had greatly influenced the places and forts of Rajasthan. Rajasthan's architecture maybe broadly classified as secular and religious. The secular buildings are of various scales, which includes towns, village, wells, gardens, houses and palaces as well as forts.

Various Important Architecture elements of Rajasthan Includes:

a) Jharokha: is a kind of suspended or overhanging enfolded balcony generally characteristic of Rajasthani architecture. The jharokha balcony is basically stone window which projects from wall plane and are generally employed for additional architecture beauty of the mansions and also as sight-seeing platform.
b) Chhatris: are elevated pavilions or porches in dome shape and are the best illustrastion of the architecture of Rajasthan. The chattris stands as a symbol of honour and pride used to portray the fundamentals of administration in Rajasthani's Rajput architecture. In Hindi, the term chhatri refers to canopy or an umbrella.
c) Jaali: is normally perforated stone or latticed screen, usually with an ornamental pattern, mainly came into existence on account of the pardah system, which did not allow women to be seen in public, but enabled women to observe the outside world by remaining out of sight.

Modern Shading Devices

The use of sun control and shading devices is an important aspect of many energy-efficient building design strategies. In particular, buildings that employ passive solar heating or daylighting often depend on well-designed sun control and shading devices.

During cooling seasons, external window shading is an excellent way to prevent unwanted solar heat gain from entering a conditioned space. Shading can be provided by natural landscaping or by building elements such as awnings, overhangs, and trellises. Some shading devices can also function as reflectors, called light shelves, which bounce natural light for daylighting deep into building interiors.

Thus, solar control and shading can be provided by a wide range of building components including:

- Landscape features such as mature trees or hedge rows;
- Exterior elements such as overhangs or vertical fins;
- Horizontal reflecting surfaces called light shelves;

Low shading coefficient (SC) glass; and, Interior glare control devices such as Venetian blinds or adjustable louvers.

COST AND ENERGY FACTOR

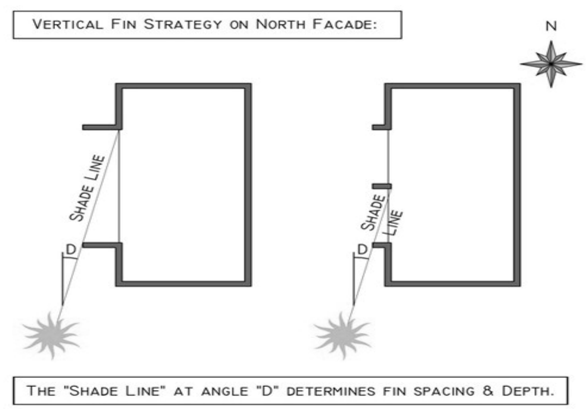
Reduction of Energy

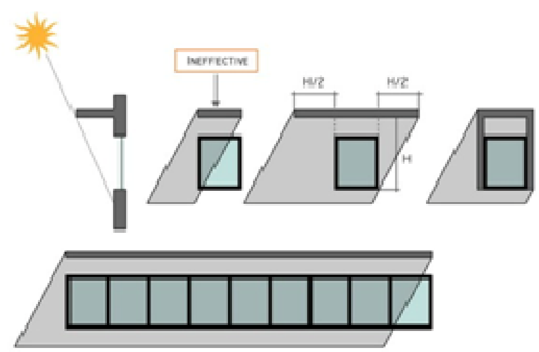
The north elevation (in the northern hemisphere) essentially does not require shading because except in the summer months in the early morning and late evening, no sun penetration occurs. At this time of day, the sun angle is so low that horizontal projections would be useless as shading devices. It is best to limit as much as possible fenestration on the north elevation as there will be very little solar heat gain and much direct heat loss from this side. If fenestration is required for daylighting, then it is important to select a highly efficient glazing assembly to reduce energy transfer.

The south elevation (in the northern hemisphere) allows for the easiest control of solar energy. Shading devices are normally designed as horizontal projections above the windows — the length of the projection is determined as a geometric function of the height of the window and the angle of elevation of the sun at solar noon. Such shading devices can be designed to completely eliminate sun penetration in the summer and allow for complete sun penetration during the winter when such is desired for passive heat gain.

Light & Shadow Factors

Shading devices for heat avoidance need to be designed to be effective beyond the geometry of summer solstice when the sun is highest in the sky. Depending on the local climate conditions, cooling may be a priority from the mid spring to early fall seasons. The length of the south facing shading device should be sized for this extended season.





CONCLUSION

This study aimed to quantify potential energy savings achievable by adding shading devices to an institutional building in Niwai.

Computer simulation was used – IES VE simulation tool- to calculate potential energy savings achieved by the use of four fixed external shading devices; horizontal overhangs, vertical fins, horizontal louvers and vertical louvers.

The most basic application of these shading devices was applied where the shading devices were of common sizes as per existing literature and were fixed at 90 degrees angles with no tilts.

The shading devices were simulated on the South, West and East facades. The results show that all the shading devices perform effectively on the South facade.

The most effective shading device on all the facades was found to be the horizontal louvers, where they resulted in 14.58% savings on the South and 10.3% on both the West and East facades.

The optimum scenario simulated is the application of horizontal louvers on all facades which resulted in energy savings of 33%. The louvers, both vertical and horizontal, caused higher savings which can be due to the fact that they covered a larger part of the window area in comparison to the other two shading devices. It is expected that higher energy savings can be achieved by variant configurations within each shading device, such as title angle and length of protrusion.

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