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EFFECTIVE AND PASSIVE UTILIZATION OF SOLAR ENERGY FOR ENERGY EFFICIENT BUILDINGS; AN APPLICATION PERSPECTIVE

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ABSTRACT

We live in a world where exists a serious gap between the demand and supply of energy in various forms. The picture is all the more bleak when one realizes that some of the most reliable non renewable energy source like fossil fuels is slowly being exhausted. Energy demands from functional needs of buildings consume a major chunk of energy produced both in tropical and cold countries. The concept of tapping solar energy for storage and then use is fast developing as a practical idea, with the technology catching up parallel. There are many ways in which the quantum of energy required to ensure comfort in buildings can be reduced if we are aware of what sun can offer, round the year in a given location and the various ways in which this information can be utilized for reduced energy demand in buildings. The paper is precisely attempting this. It briefly introduces the concept of documenting solar energy distribution through the use of a sun path diagram and the multiple ways in which this can be used for energy efficient buildings and also for evolving passive solutions possible in buildings. Subsequently the paper provides an overview of the sun based passive solutions and design approaches possible in the case of buildings especially with reference to tropical countries.

Keywords: Energy efficient buildings, Natural ventilation, Passive design, Solar energy, Sun path diagram.

1 INTRODUCTION

There has been no other time in history when the importance of efficient use of energy being so much overstated for the right kind of political and sustainability reasons. Our most commonly used energy sources; fossil fuels received all this importance for their versatility ease and convenience of extraction and use. However now it is apparent that all stored concentrated energy forms are going to be depleted due to the rapid rate at which they are consumed globally. Unless we catch up with appropriate technology and avenues of alternate energy production and supplementation, it may not be too long before we confront an energy crisis that can bring life to a grinding halt. A major chunk of fossil fuels goes into uses connected with the built environment. The form of energy may vary depending upon whether it is for the proper luminous thermal or entertainment environment but finally it is nothing but drawing another scoop from the available pool of energy to run your buildings.

One of the important objectives of design for the buildings we live and work is the thermal comfort for the occupants. People spend 85-90% of their time indoors, so providing a comfortable and healthy environment is vital [1]. The difficulty is in providing acceptable levels of comfort with as low energy environmental and economic costs as possible.

Of Of all sources of energy, sun is the most regular and dependable source of energy we can bank on for all ranges of uses from making an electric light work to running an automobile. It is high time we look for more efficient and effective tapping of solar energy for all these range of uses. The concept of energy efficient buildings that selectively avoids/receives solar energy gains its pivotal importance in this context. Janssen [2] claims that an improvement in energy efficiency is considered as any action undertaken by a producer or user of energy products, which decreases energy use per unit of output, without affecting the level of service provided.

Thermal comfort is a condition of mind, which expresses satisfaction with the thermal environment, but there can be significant individual variation in responses to the thermal environment. Alternatively, it is the state where the person is entirely unaware of their surroundings neither considering whether the space is too hot or too cold. It is not the same concept as sensation of temperature although this is clearly an important factor. Dissatisfaction with the thermal environment may be caused by the body as a whole being too hot or cold or unwanted heating or cooling of a particular part of the body.

An ideally designed energy efficient building maintains the best environment for human habitation while minimizing the cost of energy.

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Development and Land Use Policy Manual for Australia [3], states the objectives of energy efficient buildings are to improve the comfort levels of the occupants and reduce energy use (electricity, natural gas, etc) for heating, cooling and lighting. United Nations [4] defines energy efficient buildings to have the minimum levels of energy inputs.

2 ACTIVE AND PASSIVE SOLUTIONS IN SOLAR ARCHITECTURE

A building can effectively try to solve its energy problems by using solar energy through an active or passive design solution. An active solution, involves gadgets and appliances used in a building such as Desert coolers, Air conditioners, Lamps etc. which directly make use of solar energy to generate electricity through photo thermal, photo chemical or photovoltaic processes. Of these, the most popular is photovoltaic (pv) cell based system [5]. A passive design solution intends to bring in comfort or ideal task performance condition into a built environment by making the basic design layout responsive to a number of parameters, which influence the insolation on the building, and by virtue of the design, ill effects of solar heat, is minimized [6]. This will eventually lead to energy savings and it reflects the environmental consciousness of the designer. We may classify passive solar solutions to fall into either of the two categories mentioned below [7].

2.1. Planning aspects:

- Site analysis
- Building form
- Building orientation
- Room orientation
- Landscaping

2.2. Building envelope:

- External wall
- Thermal insulation
- Building material
- Roof
- Windows (Size, Orientation, shading device, natural ventilation and daylight)

Of the listed aspects, those with major bearing on sun's position and its availability are covered in the succeeding sections.

3 AWARENESS AMONG DESIGNERS; A PREREQUISITE

As the first step towards conserving fossil fuel and promoting use of non-conventional energy sources en route to achieving energy efficient buildings, a deliberate campaign has to be made among designers to orient their building designs so as to bank to the maximum on solar energy for their routine energy requirements.

This include; measures to create an awareness among the designer community, the need to build up an extensive solar radiation availability database (which is geographically varying), an exploration on its interpretation possibilities, development of solar charts and their uses and passive solar design solution methodologies etc.

4 SOLAR ENERGY AND BUILT ENVIRONMENT

Invariably any building needs the availability of solar energy either in the light or heat form in order to modulate its environment to contain the required function/task performance. India being in the tropical region has the geographical advantage that most of its parts receive more or less steady sunshine round the year. The available intensity of solar radiation is in fact adequate for all gamut of innovative uses ranging from domestic cooling to operating domestic appliances such as Fridges, TV's and Lamps and can even be used to run vehicles if a dynamic tracking system is coupled with.

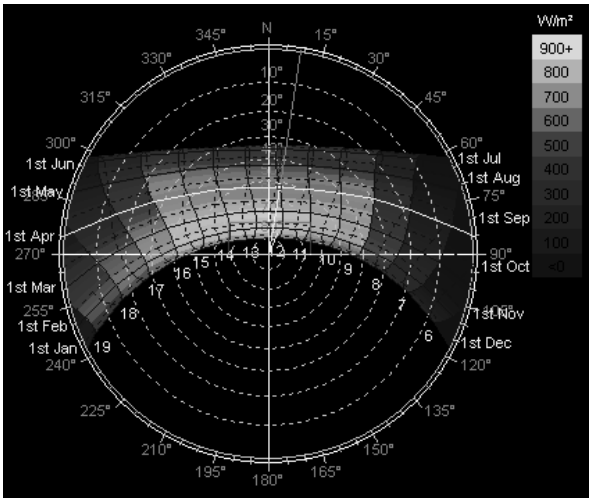

Figure 1 Typical solar chart (sun path diagram)

In the case of buildings in tropics, it is a tricky affair to have the right amount of light without trapping unwanted heat as, it is a combined package. Most of the buildings in the tropics suffer from specific periods of overheating during summer which a prudent designer should try to avoid, yet taking advantage of the sun. This selective exclusion and use of solar energy, normally available in the dual form of light and heat is first of all, a matter of knowing, what sum can provide us with, be it light or heat in form, at a given point of time, over an year, in a given location. Precisely, here Sun path diagrams come for our help. In the simplest sense, they help us to fix the position of sun. Having fixed the sun to locate the building for maximum solar benefits, as well as to avoid sun, wherever wanted, is an easier task.

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5.0 SUN BASED PASSIVE SOLUTIONS; APPROACHES

5.1 Orientation of Buildings: Watson and Labs [8] suggests that a house can be made more energy efficient if it is planned according to solar orientation and prevailing wind direction. Tropical regions such as India, mostly suffer from problems of excessive heat in the indoors during summer months. At the very outset, if a designer orients the building in such a way that the longer axis of the building is along North-South (so that longer walls face east west and this brings down heat gain through walls). There is more energy available around the equator between latitudes 25 degree north and 25 degree south and most parts of India fall into this region. For a range of orientations broadly based on the above norm, if one wishes to carry out heat load calculations and to choose the alternative of least heat gain (during established overheating periods), a Sun path diagram helps. To select an appropriate solar gain factor in heat gain calculations through windows and for calculating the incident radiation on an opaque surface too, Sun path diagram can help. As a passive solution it brings down the energy spent on the building through various appliances for the maintenance of comfort/ideal task performance conditions.

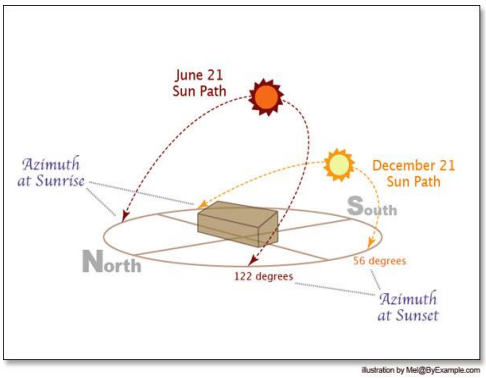

Figure 2 Application of Solar chart

5.2 Designing Shading Devices: Shading devices for openings play a phenomenally vital role in preventing overheating. It is the shortwave fraction of the direct solar radiation entering through an opening that causes overheating. Shading device can help in obstructing sun in the required periods of overheating and in the designs of shading devices; sun path diagrams provide essential design data. A shading device can be a horizontal one, obstructing the vertically incident rays, a vertical one, obstructing the sun rays from sides or a combination of both.

The horizontal shadow angle (HSA) characterizes a vertical shading device. It is the difference between the solar azimuth and wall azimuth angle. The vertical shadow angle (VSA) characterizes a horizontal shading device. Vertical shadow angle is measured on a vertical plane normal to the elevation considered. To calculate the efficiency of a shading device during any period in an year, also one can use a Sun path diagram.

Using a Shadow angle protractor, it is possible to design a horizontal, vertical or a combination shading device which would protect the opening during selected hours of the established overheating period. Hence selective exclusion of sun during typically overheated months is possible. This too equips the building to be more energy efficient.

Cheung *et al*. [9] studied the effects of shading devices (overhangs and wing walls) along with five other passive design strategies on the cooling load for an apartment. The length of the overhang and wing wall were 1.5 metres each. Their results suggest that the longer the shading, the greater the reductions in both annual required cooling energy and peak cooling load. They concluded that the use of such shadings, achieved savings of approximately 5% in annual required cooling energy.

5.3 Devise Suitable Thermal Protection Measures: For a building of which the orientation and placing are already decided for visual and site specification reasons, it is possible to determine the sides which will receive maximum solar radiation, during established months of overheating, say for most of India, this is between April and August. Once it is known which all sides would receive maximum insolation during summer, the designer, can choose appropriate materials, suggest special treatments relocation of functional areas avoiding or reduction in size of openings etc. which all can reduce the heat gain. Gut and Ackerknecht [10] states that the arrangement of rooms depends on their function and according to the time of the day, they are in use. Indirectly this reduces the energy consumption of electric fans, Desert coolers and Air conditioners and again Sun path diagram help us to make our building more energy efficient.

5.4 Design of openings; their size position etc: In the Indian context, openings have the dual purpose of providing day light and facilitating ventilation. While it is essential that the openings should let in sufficient amount of day light for proper natural illumination in the indoors, they should not add to the heat gain of the building's indoor. Direct relationships exist between Sun's position, radiation intensity and its potential to provide daylight. On the building's side, size of its openings the reflective characteristics of internal and external surfaces and the design sky illumination decide the illumination that can be made available from day light. If Sun path diagram is coupled with this illumination estimation methodology, an intermediate solution, which will let in sufficient illumination without the risk of unwanted overheating, can be worked out. Also for the convective cooing in ventilation, in order to induce a thermal gradient, Sun path diagrams can be of use. Here, we may have to let solar radiation fall on certain surfaces, so that the surface and the adjacent layers of air gets heated up and thermal gradient is induced, now ventilation through convective cooling can take place.

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In both these cases, the direction of insolation with respect to the building has a critical say on the quantum of heat gained by the building.

5.5 Effective Planning of Landscape Schemes: While planning landscaping also, we can incorporate heat gain prevention considerations. Plant barriers made as part of landscaping scheme can be shrubs, ground covers, bushes or trees. Each of them has its characteristic way of preventing heat gain [11]. Placed at the right distance from walls and openings, a row of shrubs or trees can be effective in obstructing solar radiation and here too, to decide on the type of plant barrier, most effective in obstructing solar radiation during summer and the distance from building can be worked out with the help of a Sun path diagram. Only thing to be ascertained is that the plant has thick foliage during summer which helps it to screen insolation efficiently.

5.6 Choose suitable Architectural massing Alternatives: Massing of the various components of a building can't solely depend on aesthetic considerations, if it is to be energy efficient too. According to Givoni [12] form of the building should be worked out based on whether the building is planned to be air-conditioned or if it is intended to rely on natural ventilation largely. Often, heat gain is maximum when, the sides, with maximum surface area face solar incidence direction during summer peaks. One solution is to design the 3D massing in such a way that the peak summer sun faces, sides of least surface area, and that reduces consequent heat gain too. Sun path diagrams can help in deciding solar incidence angles and the building ends up, gaining less heat.

6 A CASE FROM THE COMPOSITE CLIMATE CONTEXT

The residence building for Sudha and Atamkumar at New Delhi done as an EASE(Environmentally appealing and Saving energy) house[13] is a good case to manifest how passive design solutions can make a building considerably energy efficient. The house is a duplex structure with a living room, kitchen, three bed rooms and a study and an outhouse. The building area is around $160m^2$ on a site of $450m^2$ and the contractor is Asian townsville farm limited and the building is designed for composite climate. The longer side of the plot faces south and the building is planned in the far north, thereby ensuring a large south open area. Considering sun's movement in the location concerned, the house was oriented in such a way that, every habitable room has a liberal south exposure. Only entries, toilets and staircase are deprived of south orientation. The three bed rooms and the living room have large south glazing for winter heat gain with proper overhang protection for prevention of summer heat gain. The south overhang soffit level is higher than the lintel level in order to ensure that the window is not shaded in winter.

Through this, the entire winter heating is done through south glazing. Also south facing thin-wall and dark colored shafts help in air exhaust during summer days through attic ventilation. With such passive design solutions incorporated, the combined load of appliances including fans, lights, refrigerator and water circulation pump was around 400W, and even when a medium energy appliances such as TV/computer is added, the running load was about 800W. With even a heavy appliance in use, the peak load is seldom exceeding 2000W. With prudent use of sun, there is no need to use electricity for space heating/cooling and also for water heating. 15A circuits are totally avoided in this case. To sum up, the case explained gives a brief but clear idea on the multifarious advantages of adopting passive solutions from an energy efficiency perspective.

7 CONCLUSION

The paper attempted to give a set of practical considerations a designer can exercise as part of creating energy efficient buildings. For most parts of India, much of the energy demand by the built environment is to abate the negative effects of excess heat. Any measure that helps in the building's receiving less heat and yet sufficient light has a major role in bringing down the functional energy requirements. As energy savings from gadgets like Desert coolers, Air conditioners, Electrical fans, Lamps and as improved efficiency of people working inside, a building designed with concern for energy, pays back you during its entire life span. Sun path diagrams have a critical role in accomplishing energy efficient buildings as has been explained in the paper. In this era, when even medium scale towns have many a heat islands slowly building up, and ACs becoming an order of the day, although individually the quantum saved may be meager but together, it can make a substantial change.

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