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Passive Solar Building Design

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***Abstract*— In passive solar building design, windows, walls, and floors are made to collect, store, and distribute solar energy in the form of heat in the winter and reject solar heat in the summer. Since mechanical and electrical devices are not used, as they are in active solar heating systems, this is called passive solar design or climatic design.**

The key factor in designing a passive solar building design is the local climate so that the elements to be considered in construction include window placement and glazing type, thermal insulation, thermal mass, and shading can yield maximum benefits.

The levels of application are pragmatic, annualised, minimum machinery and zero-energy building.

The 47-degree difference in the altitude of the sun at solar noon between winter and summer forms the basis of passive solar design. This information is combined with local climatic data (degree day) heating and cooling requirements to determine at what time of the year solar gain will be beneficial for thermal comfort, and when it should be blocked with shading. By strategic placement of items such as glazing and shading devices, the percent of solar gain entering a building can be controlled throughout the year.

With this information available with us, a case study was carried out in Chandigarh and the current implementation of such techniques was studied. As passive solar design techniques can be applied most easily to new buildings, but existing buildings can be adapted or "retrofitted", we would focus on developing methods so that this practice can be used for maximum utilization of the conditions.

***Index Terms*— Passive solar design, zero-energy building, retrofitting**

I. Introduction

Over the last decade, there has been a lot of pressure on energy consumption in domestic households. Also, since the amount of devices that our daily needs have begun to require, the concern is quite reasonable. One of the best ways to help combat this load on urban households is solar passive building. Principally, what passive design achieves is to utilise the site location by responding to the local climate and by doing so, it maximises the comfort of the people inside the building and reducing the energy consumption. It does so by utilising the natural and free factors such as wind, sun and other renewable sources of energy to provide household heating, cooling, ventilation and lighting, thereby reducing or removing the need for mechanical heating or cooling. Temperature fluctuations, improving indoor air quality and making a home drier and more enjoyable to live in is also what the passive design can achieve easily.

Passive solar heating techniques generally fall into one of three categories: direct gain, indirect gain, and isolated gain[1]. Direct gain is solar radiation that directly penetrates and is stored in the living space. Indirect gain collects, stores, and distributes solar radiation using some thermal storage material. Conduction, radiation, or convection then transfers the energy indoors. Isolated gain systems (e.g., sunspace) collect solar radiation in an area that can be selectively closed off or opened to the rest of the house.

II. Features of Passive Solar Buildings

The key features of passive solar building are the solar access, orientation of the building, thermal mass, ventilation, shading and insulation[2]. This list, although, covers majority of the factors, yet, is not exhaustive. A lot of improvisations can be made according to the local climate to maximise the gains that reduce the use of mechanical or electrical temperature control.

The first step is to obtain the solar access in a manner that solar gain and natural lighting can be optimally used. Chandigarh being a planned city and considering that, more or less, the construction of houses has reached its level of saturation, does not experience this freedom. Still, technically, the major axis should lie along the east west boundary and the north light that enters the house is the most beneficial orientation.

Other features, bearing equal importance, such as ventilation for temperature maintenance, thermal mass for heat distribution and shading for admitting adequate light according to the variation in solar position over the seasons also are to be adequately incorporated in the building.

However, it must be kept in mind that these features must be kept in purview of the building holistically. Since these are not exclusive of each other, it cannot be said for sure that the greater implementation of either of them will reinforce the effect of other. The situation may be quite the opposite in certain cases as one may observe. For example, bigger size of the doors and windows makes sure that more ventilation of breeze and air ensures greater ventilation. However, it also allows a greater noise to be allowed inside the house. So, the rooms not sensitive to noise must be positioned in such areas.

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Another example to illustrate this is the use of large windows that allow large amount of natural light may also result in large heat gain. This, if the light falls on thermal mass may not be required in months of high temperatures in regions such as Chandigarh that experience extreme temperature variations.

III. Constructional Discrepancies

Now, the passive building focuses not only on heating the house in cooler temperatures, but also to provide cooler breeze in hotter temperatures. For latitudes that experience such extreme climates where the average temperature minimum during day time in winters can be as low as 2 degree Celsius and the average maximum temperature during summer months is about 40 degree Celsius, it is a challenge to be able to put to use a zero energy building. But it is important to avoid certain discrepancies that are included only to reinforce the effects that we hope to counter.

To get the right answer all we have to do is to ask the correct question, simply. What are the reasons that some houses get too hot? The reasons lying in construction of these houses that include plain slip-ups as heat gain through windows unshaded for summer sun, roofs and clerestory windows; inadequate ventilation and lightweight construction with low thermal mass.

Similar reasons can be cited as to why some houses are very cold i.e. windows shaded from the sun in winters, inadequate insulation in the floor, heat loss from ill-insulated roofs and gaps around the doors and windows that add up to the cooling factors[3]. As we can see that these mistakes are not ones that require elaborate undermining of logic, the solutions are also not very difficult to find. All we need to do is to club all such solutions under one manual what we call as passive solar building.

IV. Effect of Use of Thermal Mass Structure

Thermal mass can be said to be that one factor that can be the key to differentiate a passive solar designed house from an ordinary tract house. The principle of its use is simple. If the heat gain from the solar access needs to be utilised when the sunlight present cannot directly alter the temperature inside the house, the heat gain must be stored. Any solid or liquid material that stores this heat in any form is said to be thermal mass inside the house which may be as simple as masonry or water which has a better capability then air around to store the thermal utilities.

To understand how this thermal mass works, one may observe that during the day hours when sunlight is directly incident on the thermal mass, it stores this heat assn solar gain. However, the temperature maintenance is brought about directly by the radiations. During the time when the sun has set and the temperatures tend to drop, this thermal mass starts to release heat stored and maintains the comfort level. It is only during the early morning hours that the thermal mass may require a supplement heating to provide for the temperature drop that has set in.

Thermal mass can take numerous forms inside a house depending upon the ease of access of incorporation. In the form of brick, tile or concrete floors, it is Solar Slab. Masonry or concrete wall, called Trombe Wall, or water filled containers, called a Tube Wall, may be used to absorb heat and cool. This, however, requires southern exposure and direct sunlight so that it is exposed for the maximum time to direct sunlight for maximum solar gain.

V. Incorporating Passive Design Principles in Existing Buildings

Once a building has been completed, some principles may be added during the later upgrades, but only to an extent. That is, it may not be possible to achieve full benefits from it for obvious reasons such as it is not possible to alter the orientation of an entire house after construction. But, smaller changes such as improving insulation, altering layout of a room or introducing eaves to shade the summer sun can lead to great results in the energy efficiency of the house.

Existing building can largely benefit from improving insulation using retrofits. Even though it is easier and cheaper to include insulation in new homes, retrofits do prove to be useful. Considering our focus on the urban Chandigarh region where construction is largely dominated by concrete and masonry, to say that Concrete Slab flooring and in-situ concrete walls already exist may not be entirely incorrect. Better still, other methods of insulation can be put to use in structures to improve the existing scenario and reduce the overuse of electrical temperature control that we have seen in the region. These include application of EIFS cladding system externally or pumping loose fill or foam through holes into the wall space in the lining so far as the walls are considered as walls account for a majority of heat loss.

Improving the thermal resistance of an existing concrete slab on the ground is not usually a practical option. If renovations are to be carried out (provided there is sufficient ceiling height within the space), one option is to cover the existing slab with a polythene membrane, 25 mm thick polystyrene board and a 75 mm (minimum) thick topping slab. The new concrete must be isolated by a damp-proof membrane from existing timber framing to prevent moisture from the concrete being absorbed by the timber. Alternatively, installing carpet and underlay will reduce the heat loss through an existing floor.

Also, minor constructional amendments such as introduction of eaves on windows of appropriate depth so as to be able to shade the summer sun and admit the sunlight from winter sun can make changes visibly in the temperature control that we manage. For a 2 meter high window in the latitude of Chandigarh, all we need is a 0.9m length of eave to make sure that the 40 degree difference between the solar path of summer sun and winter sun is brought to effect[4]. Simple techniques such as enlarging the size of windows may improve the quality of natural light that is admitted during the day to reduce the use of artificial lighting. However, it may also require insulation to a greater effect as heat loss through windows is a major factor.

It takes more thought to design with the sun; however, passive solar features such as additional glazing, added thermal mass, larger roof overhangs, or other shading features can pay for themselves. Since passive solar designs require substantially less mechanical heating and cooling capacity, savings can accrue from reduced unit size, installation, operation, and maintenance costs. Passive solar design techniques may therefore have a higher first cost but are often less expensive when the lower annual energy and maintenance costs are factored in over the life of the building.

VI. Case Study

The Department of Renewable Energy/ HAREDA has constructed its office in Panchkula that covers an area of 55,000 sq.ft. This building is the first one to achieve Energy Autonomy by using techniques that incorporate all concepts of passive building design. It shall be the first building in the Government sector which is being constructed in Compliance with the Energy Conservation Building Codes (ECBC). Moreover this building shall also comply with the 5 star rating, which is the highest rating of GRIHA rating systems for Green buildings of Govt. of India.

This building is being constructed based on solar passive design techniques having Building Integrated Photovoltaic (BIPV) system of 42.50 KW capacity, Solar Chimney, evaporative cooling, cavity walls, Use of Fly ash based bricks water recycling and Energy Efficient Lighting etc. The incorporation of these features will result in achieving an internal temperature of about 28 deg. Centigrade without Air Conditioning. The energy consumption in this building is estimated to be about 30 kWhr/m2/year in comparison to the consumption of about 200 kWhr/m2/year for the existing air conditioned buildings.

No municipal water supply is required after the first monsoon with the 6.5 lacs litre underground tank that has been optimized for rainwater harvesting and consumption pattern of the building. Optimization of installed load shall be about 55 kW only. This will be the one of its own kind of building with 25% reduced lighting energy need and Annual Energy Consumption at 3.48 units per sq, ft. against 18.5 units per sq. ft. of a conventional building[5].

VII. Conclusion

As we can see that a building with staggering energy efficiency statistics can be conceptualised in the same region as that of the Chandigarh region, passive solar design is a concept that holds the key to energy efficient homes. Considering the unnecessary use of electrical lighting, heating and temperature control that we put to use owing to the extreme climatic conditions in the region, all structural discrepancies may be handles using simple techniques. If on one hand, we have the knowledge and resources to put it to use in the newly developing areas in our neighbourhood, we also have the choice to improve upon the existing homes

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