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Passive Design Strategies for Composite Climate

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Abstract- Passive Architecture involves amalgamating conventional architectural principles with solar & wind energy and the inherent properties of building materials to ensure that the interiors remain warm in winter and cool in summer, thus creating a year-round comfortable environment. In passive building designs, the passive system is integrated into the building elements and materials. It should be understood that passive architectural design does not necessarily mean the elimination of standard mechanical systems. In recent designs however, passive systems coupled with high efficiency back-up systems greatly reduce the size of the traditional heating or cooling systems and reduce the amount of non-renewable fuels needed to maintain comfortable indoor temperatures.

Index Terms- climate responsive design, design strategies in hot dry area, traditional architecture

INTRODUCTION

Passive solar heating systems make use of the building components to collect, store, and distribute solar heat gains to reduce the demand for space heating. A passive solar system does not require the use of mechanical equipment because the heat flow is by natural means, such as radiation, convection, and conductance, and the thermal storage is in the structure itself.

Passive Solar Architecture is a way of designing buildings that takes advantage of the local environment (such as sunlight), while minimizing the adverse impacts of the climate (such as cold night time temperatures) on the comfort level of the building. Passive solar design integrates a combination of building features to reduce eliminate the need for mechanical cooling and heating and daytime artificial lighting. The side of the building that is utilized for solar gain needs to be facing the south to take maximum advantage of sun's radiation. A passive solar building passively sit, where it is located and be efficient for its design. Passive design home does collect, store and distribute heat in different ways and convection. Passive solar design is not new. In fact, ancient civilizations used passive solar design. What is new are building materials, methods, and solar positioning considerations. The aim of a passive solar building is to absorb (in winter) the maximum amount of radiation from the sun during the day, and to utilize this heat to warm the interior. The sides of the buildings exposed to the sun gain heat during the day, while the other sides, in the shade, lose heat. This helps to avoid overheating during the summer.

CLIMATE RESPONSIVE DESIGN STRATEGIES IN COMPOSITE CLIMATE

In passive solar energy mechanical means are not employed to utilize solar energy.

Passive solar systems basic rules:-

1. The building should be elongated on an east-west axis.
2. The building's south face should receive sunlight between the hours of 9:00 A.M. and 3:00 P.M during the heating season.
3. Interior spaces requiring the most light, heating and cooling should be along the south face of the building.
4. Less used spaces should be located on the north.
5. An open floor plan optimizes passive system operation.
6. Use shading to prevent summer sun entering the interior.

Difference between Passive and Active Design

Passive Solar Design

Passive solar design refers to the use of the sun's energy for the heating and cooling of living spaces by exposure to the sun. When sunlight strikes a building, the building materials can reflect, transmit, or absorb the solar radiation. In addition, the heat produced by the sun causes air movement that can be predictable in designed spaces. These basic responses to solar heat lead to design elements, material choices and placements that can provide heating and cooling effects in a home.

Unlike active solar heating systems, passive systems are simple and do not involve substantial use of mechanical and electrical devices, such as pumps, fans, or electrical controls to move the solar energy.

Passive Solar Collector

A passive solar system typically relies on south-facing windows as collectors to capture solar energy, although some systems may also use supplemental PV panels. In any case, the goal is to redistribute the energy collected according to a fundamental law of thermodynamics, which states that heat moves from warm to cool areas and surfaces. The simplest method of transferring the heat from passive solar collectors is through convection. To illustrate, think of a sunroom with windows on a southern wall. As the sun's ray's travel through the glass, the heat is directed into the room. It then rises to areas where the air is cooler, including other rooms beyond and above.

Active Solar Design

Active solar systems use external sources of energy to power blowers, pumps and other types of equipment to collect, store and convert solar energy. Once energy from the sun is absorbed, it is stored for later use. Small systems are used to furnish electricity for heating and cooling systems in homes and other buildings, while large systems can furnish power for entire communities.

Active Solar Collector

Active solar collectors are more complex than passive collectors in both design and mechanism. They consist of flat-plate PV panels that are usually mounted and remain stationary, although some are designed to track the sun throughout the course of the day. In some designs, multiple panels are connected together to form modules. Active solar collectors contain either air or a liquid as a conductor. Those that use air is referred to as "air collectors," while liquid-based types are called "hydronic collectors". The advanced design of these collectors makes an active solar heating system the most cost-effective in terms of reducing reliance on traditional energy sources.

A complete passive solar design has five elements:-

1. **Aperture:** The large glass area through which sunlight enters the building. The aperture(s) should face within 30 degrees of true south and should not be shaded by other buildings or trees from 9a.m. to 3p.m. daily during the heating season.

2. **Absorber:** The hard, darkened surface of the storage element. The surface, which could be a masonry wall, floor, or water container, sits in the direct path of sunlight. Sunlight hitting the surface is absorbed as heat.

3. **Thermal mass:** The materials that retain or store the heat produced by sunlight. The difference between the absorber and thermal mass, although they often form the same wall or floor, is that the absorber is an exposed surface whereas thermal mass is the material below or behind that surface.

4. **Distribution:** Method by which solar heat circulates from the collection and storage points to different areas of the house. A strictly passive design will use the three natural heat transfer modes- conduction, convection and radiation exclusively. In some applications, fans, ducts and blowers may be used to distribute the heat through the house.

5. **Control:** Roof overhangs can be used to shade the aperture area during summer months. Other elements that control under and/or overheating include electronic sensing devices, such as a differential thermostat that signals a fan to turn on; operable vents and dampers that allow or restrict heat flow; low-emissivity blinds; and awnings.

Passive Solar Heating

The goal of passive solar heating systems is to capture the sun's heat within the building's elements and to release that heat during periods when the sun is absent, while also maintaining a comfortable room temperature. The two primary elements of passive solar heating are south facing glass and thermal mass to absorb, store, and distribute heat. There are several different approaches to implementing those elements.

- **Direct Gain**

The actual living space is a solar collector, heat absorber and distribution system. South facing glass admits solar energy into the house where it strikes masonry floors and walls, which absorb and store the solar heat, which is radiated back out into the room at night. These thermal mass materials are typically dark in color in order to absorb as much heat as possible. The thermal mass also tempers the intensity of the heat during the day by absorbing energy. Water containers inside the living space can be used to store heat. However, unlike masonry water requires carefully designed structural support, and thus it is more difficult to integrate into the design of the house. The direct gain system utilizes 60-75% of the sun's energy striking the windows. For a direct gain system to work well, thermal mass must be insulated from the outside temperature to prevent collected solar heat from dissipating. Heat loss is especially likely when the thermal mass is in direct contact with the ground or with outside air that is at a lower temperature than the desired temperature of the mass.

- **Indirect Gain**

Thermal mass is located between the sun and the living space. The thermal mass absorbs the sunlight that strikes it and transfers it to the living space by conduction. The indirect gain system will utilize 30-45% of the sun's energy striking the glass adjoining the thermal mass.

The most common indirect gain systems are a Trombe wall. The thermal mass, a 6-18 inch thick masonry wall, is located immediately behind south facing glass of single or double layer, which is mounted about 1 inch or less in front of the wall's surface. Solar heat is absorbed by the walls dark-colored outside surface and stored in the wall's mass, where it radiates into the living space. Solar heat migrates through the wall, reaching its rear surface in the late afternoon or early evening. When the indoor temperature falls below that of the wall's surface, heat is radiated into the room.

Operable vents at the top and bottom of a thermal storage wall permit heat to convect between the wall and the glass into the living space. When the vents are closed at night, radiant heat from the wall heats the living space.

- Isolated Gain

The most common isolated-gain passive solar home design is a sunspace that can be closed off from the house with doors, windows, and other operable openings. Also known as a sunroom, solar room, or solarium, a sunspace can be included in a new home design or added to an existing home.

Sunspaces should not be confused with greenhouses, which are designed to grow plants. Sunspaces serve three main functions -- they provide auxiliary heat, a sunny space to grow plants, and a pleasant living area. The design considerations for these three functions are very different, and accommodating all three functions requires compromises.

Passive Solar Cooling

Passive solar cooling systems work by reducing unwanted heat gain during the day, producing non-mechanical ventilation, exchanging warm interior air for cooler exterior air when possible, and storing the coolness of the night to moderate warm daytime temperatures. At their simplest, passive solar cooling systems include overhangs or shades on south facing windows, shade trees, thermal mass and cross ventilation.

- **Shading**

To reduce unwanted heat gain in the summer, all windows should be shaded by an overhang or other devices such as awnings, shutters and trellises. If an awning on a south facing window protrudes to half of a window's height, the sun's rays will be blocked during the summer, yet will still penetrate into the house during the winter. The sun is low on the horizon during sunrise and sunset, so overhangs on east and west facing windows are not as effective. Try to minimize the number of east and west facing windows if cooling is a major concern. Vegetation can be used to shade such windows. Landscaping in general can be used to reduce unwanted heat gain during the summer.

- **Thermal Mass**

Thermal mass is used in a passive cooling design to absorb heat and moderate internal temperature increases on hot days. During the night, thermal mass can be cooled using ventilation, allowing it to be ready the next day to absorb heat again. It is possible to use the same thermal mass for cooling during the hot season and heating during the cold season.

- **Ventilation**

Natural ventilation maintains an indoor temperature that is close to the outdoor temperature, so it's only an effective cooling technique when the indoor temperature is equal to or higher than the outdoor one. The climate determines the best natural ventilation strategy.

In areas where there are daytime breezes and a desire for ventilation during the day, open windows on the side of the building facing the breeze and the opposite one to create cross ventilation. When designing, place windows in the walls facing the prevailing breeze and opposite walls. Wing walls can also be used to create ventilation through windows in walls perpendicular to prevailing breezes. A solid vertical panel is placed perpendicular to the wall, between two windows. It accelerates natural wind speed due to pressure differences created by the wing wall.

In a climate like England where night time temperatures are generally lower than daytime ones, focus on bringing in cool nighttime air and then closing the house to hot outside air during the day. Mechanical ventilation is one way of bringing in cool air at night, but convective cooling is another option.

- **Convective cooling**

The oldest and simplest form of convective cooling is designed to bring in cool night air from the outside and push out hot interior air. If there are prevailing nighttime breezes, then high vent or open on the leeward side (the side away from the wind) will let the hot air near the ceiling escape. Low vents on the opposite side (the side towards the wind) will let cool night air sweep in to replace the hot air.

At sites where there are not prevailing breezes, it's still possible to use convective cooling by creating thermal chimneys. Thermal chimneys are designed around the fact that warm air rises; they create a warm or hot zone of air (often through solar gain) and have a high exterior exhaust outlet. The hot air exits the building at the high vent, and cooler air is drawn in through a low vent.

There are many different approaches to creating the thermal chimney effect. One is an attached south facing sunroom that is vented at the top. Air is drawn from the living space through connecting lower vents to be exhausted through the sunroom upper vents (the upper vents from the sunroom to the living space and any operable windows must be closed and the thermal mass wall of the sunroom must be shaded).

Cost Effectiveness of Passive Solar Design

Passive solar design is one of the most attractive strategies available for energy-efficient construction and green building. The sun provides free heat, day lighting, and a better connection to our outdoor environment. It does this for the life of the structure.

Following these principles, the house will offer passive survivability, meaning it will remain livable through winter power outages. The passive elements of a particular home design will have no moving parts, and the only maintenance need is occasional window cleaning.

The best part is passive solar design can be done with zero extra upfront costs.
One of the ways that passive solar design can add zero extra upfront costs is by refining the window sizes and placement. By decreasing the windows on the non-south sides of the home, one can achieve balance in costs and can decrease year-round thermal losses while increasing needed solar gain.

Other tricks for achieving cost savings and improved performance:

Increase the number of large fixed windows:

Specify as many fixed windows as possible; the costs per square foot of window drop dramatically and there will be an increase in energy performance because there is less thermal bridging and more solar gain. Fixed windows are easier and cheaper to equip with blinds and movable insulated curtains than operable windows. For the most part, fixed windows are easier to clean. However, there is a legitimate concern about the difficulty of cleaning fixed windows on upper levels. One good strategy is to place an operable casement nearby to facilitate cleaning from the inside. But sure it opens the right way.

Decrease the number of operable windows:

It's common to see designs with too many operable windows. They are expensive, have more air infiltration, require maintenance, decrease solar gain, and increase thermal bridging. One operable window per room is usually plenty for ventilation, especially if you are choosing casements. A single bedroom window is already plenty big. Locating windows opposite doors helps with ventilation and makes rooms feel bigger.

Avoid extra engineering:

Another good reason for keeping the glass ratio in the 9% to 12% range is that one can create large areas of wall that are uninterrupted by window openings, increasing shear resistance. This can eliminate the extra expenses of engineering, materials, labor, and energy costs of needing structural members where your insulation should be. Solid wall area can help with interior furniture placement and is a good location for stairwells. This strategy also helps you avoid the use of pricier tempered glass.

Avoid muntins and dividers:

They cost more, decrease solar gain, interrupt views from inside, and make it harder to clean the window if they are not between the panes.

Passive solar building is environmentally friendly and economical and should prove cheap to run all year round. It doesn't have to be hugely expensive; the basic principles are simple and in an ideal passive solar building, there are no noisy, expensive, and even potentially dangerous furnaces or pumps requiring maintenance or refueling.
Having large areas of glazing makes a home light and bright, while open-plan interior which are designed to improve air and heat movement, give a feeling of spaciousness.
Passive solar design works anywhere on Earth even at the poles, where there is sunlight for at least half the year and can be applied to new or existing buildings.

Conclusions:

1. The best part about Passive Solar applications is that they have no moving parts.
2. They can perform effortlessly and quietly without mechanical or electrical assistance.
3. Most design consideration can be made and implemented using standard building materials and basic construction skills.
4. Reductions can be made to heating bills by as much as 40% annually, and also improve the comfort of living spaces.
5. Simple techniques can make a huge difference in the comfort and energy consumption through the years.
6. Passive solar buildings are very rarely used in developing countries like India, Sri lanka, Pakistan etc. and these buildings are having a great potential to be used in future.
7. Passive green building has a bright future and feasibility ahead since it is one of the vital elements of green technology and sustainable development.

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