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Energy Efficient: GREEN Homes

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***Abstract*– Homes/ buildings that incorporate concepts of solar passive design and utilize energy efficient equipment and devices, which run on renewable energy, are called energy efficient solar homes/ buildings. Such homes/ buildings provide comfortable living and working conditions, both in winter and in summer, with minimal consumption of electricity. Energy efficient homes/ buildings can save over 30% to 40% of electricity used for lighting, cooling or heating.**

Keywords: Green Homes, Energy Efficient Buildings

I. INTRODUCTION

The design of energy efficient solar homes/buildings depends on climate, solar path and intensity, humidity, wind flow, and ambient temperature of a particular place. Design parameters of homes/buildings, therefore, vary with different climatic zones of the country.

The following are the three fundamental strategies that can be adopted to reduce energy consumption in homes/buildings.

- Incorporating solar passive techniques in a building design and enhancing building material specifications for minimizing the load on conventional systems (heating, cooling, ventilation, and lighting). Passive techniques vary with climate, and simple techniques that are useful for new homes/buildings in different climates of India are listed in booklet.
- Designing energy-efficient lighting and HVAC (heating, ventilating, and air conditioning) systems in homes/buildings.
- Integrating renewable energy systems, such as solar photovoltaic systems and solar water heating systems, with buildings to meet part of their load.

II. PASSIVE DESIGN FEATURES

Orientation of Building

We all know that the sun travels daily from the east to the west. Sun movement is from the north to the south and the south to the north results in seasonal changes during the year. The orientation of a building in a particular direction, therefore, can heat or cool the building depending on the climatic zone in which it is constructed. Proper orientation can help increase or decrease the heat load by 5%. For example, if the long sides of the building in the composite climatic zone face north and south and the short sides face east and west, the heat load can be reduced.[1]

Sunshades

These are installed at the top of windows/doors to obstruct sunrays that enter the building during summers but allow them to enter during winters. This helps protect the building from overheating during summers and keeps it warm during winters, thereby reducing electricity consumption which otherwise, would increase due to heavier use of room coolers/heaters.

Window design

Windows in a building allow light, heat, and air to come in. While day light and air are welcome in buildings in all climatic zones, heat may or may not be required, depending on the climatic zone in which the building is constructed. Therefore, decision regarding location of windows should be based on the requirement of heat in the building. The sizes of windows and their shades also depend on the climatic zone.

Double glazed windows

Insulation helps reduce heat gain into and heat loss from, a building. Double glazed windows with air gaps can act as good insulation. The insulating air gap lowers the heat gain of the building. It should be used for air-conditioned spaces.

Building insulation

Insulation can be added to walls or roofs to reduce heat transfer. It also helps in moderating indoor thermal comfort and is effective in reducing temperature fluctuations in non air-conditioned spaces. Some commonly used insulation materials are mineral wool, extruded/ expanded polystyrene, PUF (polyurethane foam), and vermiculite, among others. Since roofs receive maximum solar radiation, it is advisable to insulate them using any of the above materials. Cavity walls are an effective method of insulation. Fly ash-based aerated concrete blocks and cellular concrete blocks have good insulating properties and can be used for wall insulation. Suitable specifications can be provided by an architect depending on the climatic zone where the building is to be constructed.

Roof treatment

Some simple roof treatments, other than roof insulation, for reducing the summer heat gain in buildings, are as follows.

- White washing the roof before the onset of the summer.
- Spraying water on the roof. Sprinkling water at regular intervals can reduce heat gain through roof.
- Using shining and reflecting material for the rooftop.

Evaporative cooling

When water stored in a water body evaporates into the surrounding air, it lowers the ambient temperature. This phenomenon is known as evaporative cooling. The presence of a water body such as a pond, lake or sea near the building or even a fountain in the courtyard can provide the cooling effect. The most commonly used system is a desert cooler, which comprises water, evaporating pads, a fan, and a pump. External cooling through humidification can also be achieved by keeping surfaces of roofs moist using sprays or lawn sprinklers. Evaporative cooling is very effective in the hot and dry climatic zone, where humidity is low.

Landscaping

Landscaping provides a buffer against heat, sun, noise, traffic, and airflow. It is also effective in diverting airflow or exchanging heat in a solar-passive design. Deciduous trees, such as *amaltas*, *champa*, and similar varieties, provide shade in the summer and sunlight in the winter when their leaves fall. So planting such trees to the west and south-west of a building is a natural solar passive strategy. Evergreen trees provide shade and wind control round the year. They are best placed to the north and north-west of a building. Natural cooling, without air-conditioning, can also be enhanced by planting trees to channel south-easterly summer breezes in tropical climates. Hard surfaces and dark coloured pavings such as concrete pavements or cement concrete pathways around a house should be avoided because it may increase the surrounding temperature. Increased temperature would result in thermal discomfort inside the house and increase air-conditioning bills. Instead, soft surfaces such as organic paving or vegetated areas should be used.

Surface to volume ratio

A compact building gains less heat during daytime and loses less heat at night. The compactness of the building is the ratio of its surface area to its volume, that is, Compactness = S/V (surface area/volume). In hot-dry climates the S/V ratio should be as low as possible to minimize heat gain. In warm humid climates the prime concern is creating airy spaces. This would require a higher S/V ratio.

Passive heating

In places in cold climatic zones, for example Shimla, where temperatures outside are lower than they are inside, heat flows away from buildings through their external envelopes and due to air exchange. In such climates, passive heating measures are adopted to provide thermal comfort and also to reduce the demand for conventional heating. Two methods are popular for passive heating of buildings. *Direct gain method* It is the simplest, cheapest, most common, yet effective approach for heating the interiors of a building. Sunlight is permitted into habitable spaces through an opening, which allows it to directly strike and heat the floor, walls or other internal objects. These, in turn, heat the air within the room. Double glazed windows face the south (in the northern hemisphere) to receive maximum sunlight in winter.

During the night, these windows act as insulating curtains and prevent heat loss. In addition, during the day, when areas of the building exposed directly to sunlight tend to over-heat, high thermal mass absorbs and stores heat in bare massive walls or floors and arrests the increase in room temperature. Heat stored in the mass is then released into the interior during the night, when the temperature falls, keeping the room suitably warm. Some examples of thermal storage materials are concrete, bricks, stone, and water, which are usually located in internal or external walls, floors and other built-in structures that receive sunlight directly. *Indirect gain method* In this strategy, a thermal storage wall is placed between the glazing and habitable space. This prevents solar radiation entering the living space. It is absorbed, stored, and then, indirectly transferred to the habitable space. A trombe wall is a thick solid wall with vents at its lower and upper ends. It is usually painted black or a dark colour to increase its heat absorption capacity. This wall is placed directly behind the glazing with an air gap in between. The vents act as inlets of warm air into the room and as outlets for flushing out cool air from the room. The air in the space between the glazings gets heated and enters the habitable room through the upper vents.

Earth air tunnel

At a depth of 4 m below ground, the earth's temperature remains more or less constant throughout the year. This temperature is nearly equal to average temperature of the place. The earth air tunnel takes advantage of this phenomenon. Concrete hume pipes are laid at a depth of 4 m below ground and are surrounded by earth. The earth acts as a heat exchanger for air that is passed through this tunnel. Hot summer air is passed through this buried pipe, and as it passes through, there is an exchange of heat between the air and the surrounding earth. Hence, during the summer, the air gets cooled and during winter it gets heated. It works in a similar manner during the winter, absorbing earth's heat and releasing it into the structure. Tunnel air can be supplied to a house for cooling during summers and heating during winters.

Solar chimney

Solar chimneys are tall, hollow structures that are preferably located on the south/south-west portion of a building. These chimneys can help ventilate rooms and are ideal for hot climatic zones. They should, preferably, be dark in colour with lightweight construction (for instance, Ferro cement). Spaces within a building have vents opening into this chimney. The chimney heats up during summer days and the air inside the chimney rises creating a low-pressure zone. The air from the rooms of the house then replaces the escaping chimney air creating a low-pressure zone inside your home. This makes way for outside air to enter the home naturally and cool it.

Applicable passive features for various climatic zones

As mentioned earlier, buildings in different climatic zones require different passive features to make structures energy-efficient. Some features that can be adopted in particular zones are listed below.

Hot and dry

- Appropriate orientation and shape of building
- Insulation of building envelope
- Massive structure
- Air locks, lobbies, balconies, and verandahs
- Weather stripping and scheduling air changes
- External surfaces protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Windows and exhausts
- Courtyards, wind towers, and arrangement of openings
- Trees, ponds, and evaporative cooling

Warm and humid

- Appropriate orientation and shape of building
- Roof insulation and wall insulation
- Reflective surface of roof
- Balconies and verandahs
- Walls glass surface protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Windows and exhausts
- Ventilated roof construction, courtyards, wind towers, and arrangement of openings
- Dehumidifiers and desiccant cooling

Moderate

- Appropriate orientation and shape of building
- Roof insulation and east and west wall insulation
- Walls facing east and west, glass surface protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Windows and exhausts
- Courtyards and arrangement of openings

Cold

- Appropriate orientation and shape of building
- Use of trees as wind barriers
- Roof insulation, wall insulation, and double glazing
- Thicker walls
- Air locks and lobbies
- Weather stripping
- Darker colours
- Sun spaces, greenhouses and trombe walls

Composite

- Appropriate orientation and shape of building
- Use of trees as wind barriers
- Roof insulation and wall insulation
- Thicker walls
- Air locks and balconies
- Weather stripping
- Walls, glass surfaces protected by overhangs, fins, and trees
- Pale colours and glazed china mosaic tiles
- Exhausts
- Courtyards, wind towers, and arrangement of openings
- Trees and ponds for evaporative cooling
- Dehumidifiers and desiccant cooling

Energy-efficient lighting

Lighting in a home is generally responsible for 20% of the electricity bill. Efficient lighting reduces energy consumption, thereby, saving energy and money, without compromising on the quality of light. Lighting improvements are the surest way of cutting energy bills. Using new lighting technologies can reduce energy use in the house by 50% to 75%. Lighting controls offer further energy savings by reducing the amount of time that lights are on without being used.

Indoor lighting

Use fluorescent tubelights and energy efficient CFLs (compact fluorescent lights) in fixtures at home for high-quality and high-efficiency lighting. Fluorescent lamps are much more efficient than incandescent (standard) bulbs and last up to six times longer. Although fluorescent and compact fluorescent lamps cost a bit more than incandescent bulbs, they pay for themselves by saving energy over their lifetime.
(A 15 W CFL can replace a 60 W incandescent bulb and a 20 W CFL can replace 100 W bulbs)

Outdoor lighting

Many homeowners use outdoor lighting for decoration or security. Consider PV-powered lights for areas that are not close to an existing power supply line. Solar outdoor lights also come as stand-alone fixtures. An 11 W CFL, with a 74 W photovoltaic module and a 12 V/75 A battery, costs Rs 22 000–24 000. When fully charged, the battery can power a light from dusk to dawn.

Energy-efficient air conditioners

ACs (air conditioners) are used to cool or heat a room and usually consume the highest energy among all home appliances. Window ACs and split ACs are most commonly used. These are available in different sizes— 0.75 tonne, 1 tonne, 1.5 tonne, and 2 tonne. Insulation of the walls, roof, and efficient windows in the room would allow you to pick an AC with lesser tonnage.

- *Selecting the right size*

The energy consumption of an AC depends on the size of the AC. Therefore, select an AC that suits your requirements. A 1-tonne AC is appropriate for a 150 sq ft room, while 2-tonne AC is sufficient for a room, which is 300 sq ft in area.

- *Selecting an efficient AC*

The efficiency of an AC affects energy consumption as much as the size of the AC does. Select an efficient AC, preferably one that has a BEE Star label. The number of stars on the BEE label indicates the efficiency of an AC; the higher the number of stars the more efficient the appliance. For instance, a BEE 4-star rated 1.5-tonne AC would consume 194 units of electricity in a month compared to an inefficient .The additional Rs 1500 invested on the efficient AC will be recovered in less than six months due to savings in the electricity bill. In case of the non-availability of the BEE star label, check the EER (energy efficiency ratio) mentioned on the AC. An EER of 8 is equivalent to a 1-star BEE label and an EER of 10.6 and above is equivalent to 5-star BEE label.

- *Installing an AC*

While installing an AC, ensure that the exterior (or back) of the AC is not exposed to direct sunlight and is away from heat sources such as chimneys. Efficient airflow across the exterior would ensure efficient operation of the AC. Seal doors and windows properly to make sure that air does not escape through them. This would help in reducing energy consumption.

Renewable Energy/devices Systems

Solar water heating system

A solar water heater is a device that uses heat energy of the sun to provide hot water for various applications. In homes, it is useful for bathing, washing, cleaning, and a solar water heater is a device that uses heat energy of the sun to provide hot water for various applications. In homes, it is useful for bathing, washing, cleaning, and other chores. A domestic solar water heater, with a capacity of 100 lpd (litres per day), is sufficient for a family of four or five members. It can easily replace a 2-kW electric geyser and can save up to 1500 units of electricity a year. It pays back the cost in three to five years depending on the electricity tariff and hot water use in a year. After this, hot water is available almost free of cost during remaining lifespan of the system, which is about 15-20 years.

The system is generally installed on the terrace and requires minimum maintenance. It works automatically and one does not have to operate any part of the system. Typically, a surface area of 3 sq m is required to install it. The system can also be installed on a south-facing windowsill if space is not available on the terrace.

Two types of systems are being promoted—one based on FPC (flat plat collectors) and the other on ETC (evacuated tube collectors). The life of FPC-based systems is generally 15–20 years, and they are costlier than ETC-based systems. There are 57 BIS (Bureau of Indian Standards) - approved manufacturers of these systems, and they have had a stable market in the country for the last many years.

ETC-based systems are relatively new and could be more reliable for colder regions and regions that have hard water. The life of these systems is, however, less since their collectors comprise glass tubes, which are fragile.

In addition, some state governments also provide state subsidy.

Building integrated PV system

A PV system can be incorporated in a building as part of the building's structure. In new buildings, PV systems can be built-in at the design and construction stage. They can be retrofitted on existing buildings as well. Photovoltaic's can be integrated in every possible structure—from bus shelters to high-rise buildings. They can also be used as landscaping elements. Incorporating PV in the building results the following value additions.

- Generating electricity at the point of demand without any extra use of land area
- Reducing the cooling load of the building, as it also acts like a shading element
- Replacing building construction material, such as glazing elements, depending on the building design

In building integrated PV systems, PV modules are used as part of the building envelope. PV systems can be incorporated in a building in three basic ways 15–20 years, and they are costlier than ETC-based systems.

III. CONCLUSION

There are various other renewable energy devices/ systems, such as solar cookers, solar lanterns, solar home systems, and solar inverters, which can be used for saving conventional energy after the home/building is constructed.

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