BASIC PRINCIPLES OF PASSIVE SOLAR HEATING

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Abstract: *Buildings are recognized as large energy consumers in modern society. Design of energy efficient buildings today means incorporation of renewable energy resources. Among them, solar energy has a great potential for increasing building energy efficiency and for reducing energy consumption. Solar energy in buildings can be used through implementation of active systems, and also passive systems. Imlementation of Passive Solar Design in buildings can provide fundamental comfort conditions related to heating, cooling, natural lighting for visual comfort or help building's conventional mechanical systems to achieve these conditions with less energy consumption. This paper presents the brief history of passive solar building design and fundamental strategies of passive solar heating.*

Implemantation of passive solar heating significantly reduce energy consumption and thus greenhouse gases emission in buidings.

Keywords: *building; passive solar design; passive solar heating; solar gains.*

1. INTRODUCTION

Building energy consumption at the global level is 20 - 40% of total energy consumption, but in Serbia, buildings are mostly non energy efficient and they consumed about 50% of total energy consumption [1]. According to the data of Serbian Energy Efficiency Agency, the largest consumer in building is heating system (about 60 % of total energy consump–tion), than cooling system, installation for the domestic hot water and electric equipment. Energy inefficient buildings in Serbia have no thermal insulation and their annual energy consumption is about 220 kWh/m^2. There are almost 400 000 of these buildings in Serbia. At the other side, European average energy consumption in buildings is 60 kWh/m^2 [2]. The conclusion is that the various methods of energy efficiency must be implemented in the early stage of building design.

An intention of our country to become a member of EU obliges us to reduce the energy consumption by 20% and to obtain 20% of total energy from renewable energy by 2020 [3]. Renewable energy resources have a significant impact on the energy consumption and environment, so use of renewable energy in buildings is essential.

Energy efficient building design implies the active and passive use of solar energy. Passive solar design is a strategic approach to sustainable construction that utilises the fabric of a building and natural solar effects to create a comfortable environment for occu–pants. Reliance on mechanical methods to satisfy heating, cooling, ventilation and and daylighting needs and their associated energy demands can be reduced through this approach. Passive strategies provide thermal and visual comfort by using natural energy sources.

The difference between a passive solar home and a conventional home is design. Some of the Passive Solar Desgin strategies are seem in traditional architecture from harsh cold to hot humid climate, they have been in harmony with their environment and provide comfort conditions adjusting the outdoor climatic features by climatic design strategies and they are called as climate-responsive buildings. And the key is designing a passive solar home to best take advantage of the local climate. Solar orientation, solar apertures, thermal mass, solar chimneys, wind captures and lattice brise-soleils are the Passive Solar Design elements which have been used in traditional buildings.

Two elements must be present in all passive solar heating designs: a south facing exposure of transparent material (glass, plastic) to allow solar energy to enter; and a material to absorb and store the heat. With these two basic elements, there are a number of approaches to designing a passive solar structure.

2. HISTORY AND EVOLUTION OF PASSIVE SOLAR DESIGN

Traditional architecture has had a lot of passive strategies to create thermal comfort in the buildings.

The ancient Greeks were the first that used solar energy to help heat their homes. They were well interested in benefits of solar design, and built their houses by orienting them towards the South and used the thermal storage property of materials to keep the solar heat gain in the space. Greek cities such as Priene were planned on a grid plan with streets running east-west direction to allow the buildings to face south for accsess to the Sun [4].

The Romans developed the Greece solar architecture inventing the clear material such as mica and glass to cover their openings.

Solar energy strategies have been used for many years as it was observed. Orientation has been the most important criterion in traditional settlements.

First modern applications of Passive Solar Design strategies is Trombe Walls which was put into practice by prof. Trombe the director of solar energy research centre in Odelio in France. This system was then applied in architecture by Jacques Michel. Various solutions have been developed to realize the effective collection, storage and distribution of solar energy in buildings. This variation of solutions have taken effect on building's design so, they have caused forming of solar architecture as not a new concept but as a new option for modern architects and engineers with the new technologies [4].

3. PASSIVE SOLAR HEATING STRATEGIES

There are three basic types of passive solar design: direct gain, indirect gain, and isolated gain. The purpose of all of them is the passive solar space heating, which can contribute to the significantly reducing of building energy consumption.

3.1 Direct gains

` Direct gain is the simplest passive design technique. Sunlight enters the house through the aperture - usually south-facing windows with a glazing material made of transparent or translucent glass, and virtually all of solar energy can be converted into thermal energy [5]. The sunlight then strikes masonry floors and/or walls, which absorb and store the solar heat. The surfaces of these masonry floors and walls are typically a dark color because dark colors usually absorb more heat than light colors. The walls and floor provide solar collection and thermal storage by absorbing direct, reflected, or reradiated energy. As long as the room temperature remains at normal, the storage mass will conduct heat. At night, when outside temperatures drops and the interior space cools, the heat flow reverses and heat is given up to the interior space until the thermal mass and room reach a temperature equilibrium. This reradiation of collected daytime heat maintains a comfortable temperature during cool/cold nights and has the potential to extend through several cloudy days without "solar recharging" (Fig 1).

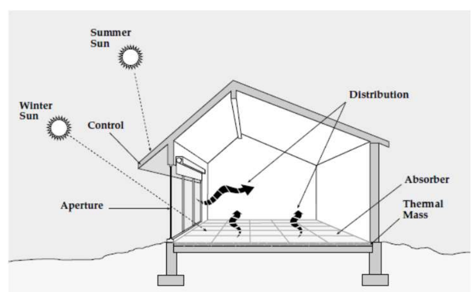

Figure 1 –Direct solar gains in building

The amount of passive solar energy depends on the area of glazing and the amount of thermal mass. The glazing area determines how much solar heat can be collected, and the amount of thermal mass determines how much of that heat can be stored. It is possible to undersize the thermal mass, which results in the house overheating. Another important thing to remember is that the thermal mass must be insulated from the outside temperature. If it's not, the collected solar heat can drain away rapidly, especially when thermal mass is directly connected to the ground, or in contact with outside air whose temperature is lower than the desired temperature of the mass.

When planning the southern facing wall, the amount of window area versus thermal mass and floor space should follow these general guidelines for best performance and minimal daily temperature fluctuations [6]:

- In direct gain houses with no internal mass, the maximum allowable area of south-facing glass should be no more than 7 percent of the floor area.
- Direct gain systems can handle up to 12 percent of the floor area in south-facing windows.
- Every 1 square foot of south-facing glass over the 7 percent should be ccompanied by 5 square feet of 4-inch-thick masonry.

Direct gain design can employ a wide variety of materials and combinations of ideas. Specifics will depend greatly upon the site and topography; building location and orientation; building shape (depth, length, and volume); and space use.

Figure 2 – Building designed with direct solar gains approach

A direct gain design requires that one-half to two thirds of the total interior surface be thermal storage materials. Appropriate materials can include floor, ceiling and wall elements, and can range from masonry (concrete, adobe, brick, etc.) to water. The more advanced design would include a “water wall” due to its unparalleled ability to absorb and reradiate heat. Water stored within a plastic or a metal containment has the advantage of heating more quickly and evenly than masonry walls. Since water can “flow” it creates a convection process that prevents surface temperatures from becoming too extreme as they sometimes do when dark colored masonry surfaces receive direct sunlight. However, the masonry heating problem can be alleviated by using a glazing material that scatters sunlight so that it is more evenly distributed over walls, ceiling, and floor storage. This decreases the intensity of rays reaching any single surface but does not reduce the amount of solar energy entering the space.

Advantages of Direct Gains:

- Low in cost to build, since no special room has to be added.
- Provides direct heating to the living space.
- South-facing windows provide natural daylight and outdoor views.

Disadvantages of Direct Gains:

- It can overheat if you do not properly balance windows and thermal mass.
- Large areas of south-facing glass cause problems with glare and loss of privacy.
- You can not cover thermal mass by carpet or block it by furnishings.
- South-facing windows should have summer shading and night time insulation in winter. In colder climates heat will be lost quickly through even the best double or triple glazed windows.

3.2 Indirect gains

An indirect gain system uses the basic elements of heat collection and storage in combination with convec–tion. In this approach, Trombe wall is the most common indirect-gain approach, when a dark-colored thermal storage wall is placed behind a south facing windows and in front of the living space (Fig 3). The Trombe wall consists of thick masonry wall on the south side of a house. Asingle or double layer of glass 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. The Trombe wall distributes or releases heat into the home over a period of several hours. 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 begins to radiate and transfer into the room [5].

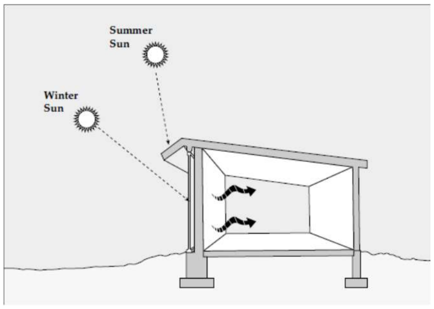

Figure 3 –Trombe wall

Besides direct conduction through a thermal wall, solar heat can be moved to adjacent space by providing a natural convection loop. Heated air flows out through heat-distributing vents at the top of the wall while vents at the bottom of the wall draw in cool air into the heating space. The top and bottom vents continue to circulate air as long as the air entering the bottom vent is cooler than the air leaving the top vent.

Consequently, The storage mass continues to heat the interior space by radiation for six to eight hours. This time lag, as the mass warms and then gives off heat, keeps temperatures in the living space fairly uniform. It also means that the heating of the living area occurs in the evening and at night, when it is most needed.


Figure 4 – Modern construction of the Trombe wall

One problem with an indirect gain is that it will restrict a view and light. Light can be addressed by adding a clerestory above the wall. Conse–quently, a good location for indirect gain in many homes is the southern wall of a garage it has a southern exposure.

A variation of the vented masonry wall design is one that employs a water wall between the sun space and the interior space. Water walls used in this way need not be vented at top and bottom and can be constructed in many ways. As the sun heats the water, the convection process quickly distributes the heat throughout the mass and the interior space is warmed by heat radiated from the wall [6].

Other than building a wall out of water barrels, there are some other alternatives. It can be constructed a south facing "greenhouse space" with water storage in the greenhouse. The water absorbs heat at the same time the sun heats the interior space of the greenhouse. In addition, if a vented design is used, heat can also be released into the living space by convection. The advantage is that a greenhouse condition can be maintained through days of no sun.

A more esthetic design could be to use what is typically referred to as an actual "water wall". In this type of wall, water circulates from a pool to the top of a rock wall, creating a waterfall effect. As water cascades down the wall it heats up. In the "decorative only" design, the small water pool is at the bottom. But if there is a big water pool, it will store large amounts of heat which will be released into the space over a long time period. If duct system is added, then the air can flow from the greenhouse into the house via convection currents. The design also acts as a natural humidifier since it will contain moisture as the water evaporates.

Advantages of Indirect Gain System:

• The storage mass is located closer to the glass or collection area, which allows for efficient collection and storage of solar energy.

• The thermal mass prevents extreme temperature swings.

• The floor and wall area of the living space can be used with more flexibility than in a direct gain system.

• A Trombe wall system provides greater privacy on the south face of the house.

Disadvantages of Indirect Gain System:

• The south-facing view and natural daylight are lost.

• Furniture and objects placed against or on the Trombe wall affect its efficiency in heating the living space.

• The Trombe wall heats only the room to which it is connected, so construction costs maybe high relative to the contribution it makes to the overall heating needs of the house.

• The Trombe wall is a very poorly insulated wall and should be covered with exterior moveable insulation on summer days and winter days without sunshine.

3.3 Isoated gains

A sunspace - also known as a solar room or solarium is a versatile approach to passive solar heating. It can project from the house or be partially enclosed within the house. Typically, the sunspace is a separate room on the south side of the house with a large glass area and thermal storage mass. A sunspace can be built as part of a new home or as an addition to an existing one. The simplest and most reliable sunspace design is to install vertical windows with no overhead glazing. Sunspaces may experience high heat gain and high heat loss through their abundance of glazing (Fig. 5)

The temperature variations caused by the heat losses and gains can be moderated by thermal mass and low-emissivity windows. The thermal mass that can be used include a masonry floor, a masonry wall bordering the house, or water containers. The distribution of heat to the house can be accomplished through ceiling and floor level vents, windows, doors, or fans. Most homeowners and builders also separate the sunspace from the home with doors and/or windows so that home comfort isn't overly affected by the sunspace's temperature variations. Sunspaces may often be called and look a lot like "greenhouses." However, a greenhouse is designed to grow plants while a sunspace is designed to provide heat and aesthetics to a home. Many elements of a greenhouse design, such as overhead and sloped glazing, which are optimized for growing plants, are counterproductive to an efficient sunspace. Moisture-related mold and mildew, insects, and dust inherent to gardening in a greenhouse are not especially compatible with a comfortable and healthy living space. Also, to avoid overheating, it is difficult to shade sloped glass, while vertical glass can be shaded by a properly sized overhang.

If the sunspace serves as the primary heating system, than it have to be thermally isolated from the living area. This means that the sunspace is closed off from the rest of the house by doors and windows. When sunspace is designed with a sufficient mass, it can provide thermal performance better than that of Trombe walls and direct gain systems.

The isolated gain design approach also uses a fluid (liquid or air) to collect heat in a solar collector such as a solar thermal panel. Although not explicitly a "passive solar design", it is simple enough to classify as such. With a hot-air solar panel, heat is distributed immediately through air ducts to interior rooms. Alternatively, the forced air can be directed into a rock (or other thermal mass such as a concrete slab) where heat is adsorbed.

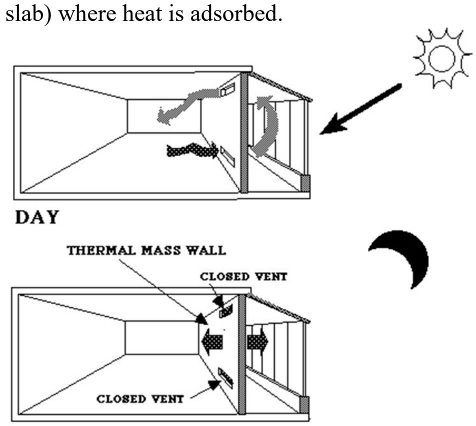

Figure 5 – Isolated gains in building

Advantages of Isolated Gain System:

• It can be physically separated from the living space, so temperature fluctuations within the sunspace do not adversely affect the comfort of the living area.

• Solar thermal panels can be easily incorporated into any architectural style.

Disadvantages of an Isolated Gain System:

• Heavy furnishings and rugs must be avoided to prevent shading of the thermal storage mass.

• Shading and venting are important to avoid summertime overheating. They may require a forced convection system for best performance.

6. CONCLUSION

Passive solar heating is the most cost effective method to heat buildings. In most locations, the amount of solar energy that falls on the roof of a house is more than the total energy consumed within the house. In passive solar architecture, much of this wasted heat can be captured without adding substantially to the cost of the structure. A passive solar and energy efficient design can reduce the monthly operational costs of any home. Because heating and cooling require the most energy in most homes, reducing heating and cooling requirements via a passive design can generate large monthly savings, typically from 50 to 70%.

Most buildings are designed with a HVAC system using forced air or water (furnace, boiler, radiant floor, etc.). In passive building designs, the HVAC system is integrated into the building design elements and materials: the windows, walls, floors, and roof are all used as the heat collecting, storing, releasing, and distributing system. Passive solar does not necessarily mean the elimination of standard mechanical systems, although high efficiency back-up heating systems greatly reduce the size of the traditional heating systems and reduce the amount of non-renewable fuels needed to maintain comfortable indoor temperatures, even in the coldest climates.

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