

## **REVIEW ON PASSIVE SOLAR BUILDINGS**

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### **ABSTRACT**

Passive solar design is the first step toward achieving climate responsive and sustainable building design. With the introduction of modern construction technologies in the country, the building sector has adopted uniform design and building techniques which is neglecting local climate. Houses generally refer to a shelter or building that is meant as a dwelling or place for habitation by human beings. “Houses” include many kinds of dwelling ranging from rudimentary huts or nomadic tribes to high-rise apartment buildings. A major constraint in meeting this demand is the spiralling cost of energy and other changes in climate. Passive solar buildings aim to maintain interior thermal comfort throughout the sun's daily and annual cycles whilst reducing the requirement for active heating and cooling system. Passive solar building design is one part of green building design. The scientific basis for passive solar building design has been developed from a combination of climatology, thermodynamics (particularly heat transfer), and human thermal comfort (for buildings to be inhabited by humans). Specific attention is directed to the site and location of the dwelling, the prevailing climate, design and construction, solar orientation, placement of glazing-and-shading elements, and incorporation of thermal mass. While these considerations may be directed to any building, achieving an ideal solution requires careful integration of these principles.

***Keyword- Passive solar design, Solar buildings, green building, solar orientation, glazing-and-shading elements, etc.***

### **1. INTRODUCTION**

New construction offers the greatest opportunity for incorporating passive solar design, Passive solar system make use of natural energy flows as the primary means of harvesting solar energy, Passive solar system can provide space heating, cooling load avoidance, natural ventilation and day lighting. Passive solar design refers to the use of the sun's energy for the heating and cooling of living spaces. In this approach, the building itself or some element of it takes advantage of natural energy characteristics in materials and air created by exposure to the sun. Passive systems are simple, have few moving parts, and require minimal maintenance and require no mechanical systems. Solar energy is a radiant heat source that causes natural processes upon which all life depends. Some of the natural processes can be managed through building design in a manner that helps heat and cool the building. The basic natural processes that are used in passive solar energy are the thermal energy flows associated with radiation, conduction, and natural convection. When sunlight strikes a building, the building materials can reflect, transmit, or absorb the solar radiation. Additionally, 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.

### **2. MOTIVATION**

To get the most from your home - think sun. That's right, the sun can heat and cool your home and reduce its energy use. More importantly, the energy from the sun can make your home comfortable year around. The main concept of passive solar buildings is that the windows, walls and the floors are made able to collect solar energy and store them. This energy is then used in the winter for warmth and used to reject the heat during the summer seasons. The passive solar building system has the advantage of blocking almost 99.9% of the ultraviolet radiation energy. Preventing this would save the interior fabrics as well as decor and make them long lasting.

Summer is made cooler and comfortable – It keeps the interior cool during the hot season. As we are seeing the day by day the earth’s weather condition is changing improperly due to the pollution which we are making on the earth, & global temperature is also raising day by day, this year in India we are observing a Highest temperature of 47° C, in north, so there is a lot of scope for this type of construction which provide us a complete comfort during all seasons and all weathering condition. In the broad area of energy conscious design, we define the various phases of growth as follows.

- (i) Solar architecture uses/excludes solar radiation with the help of devices mechanical, such as evaporative cooling or architectural, like passive integrated water heaters or sun control louvers.
- (ii) Energy-conserving buildings primarily use low-energy materials and reduce possible consumption by proper choice of orientation, urban design, landscaping and building envelope parameters.
- (iii) Passive buildings, even though using some or all of the above, are primarily those which use the temperature difference caused by the sun/wind as the driving potential via natural processes such as convection, evaporation, radiation and conduction to collect, store and distribute or reject energy into internal spaces. Some of the design features are glasswalled rooms, chimneys, fenestration for natural daylight and heat, ponds or water sprays for evaporative and radiant cooling/heating.

### **3. LITERATURE REVIEW**

Serkan et.al (2003) concluded that the energy-efficiency design strategies by passive solar components having the additional cost of about 9% of the total building cost, it is possible to save the total annual energy used in this specific residential building by 18%. It will save three types of energy need for the space conditioning and visual comfort (i.e., heating, cooling and lighting), 61% energy use reduction in heating is the maximum energy saving, lighting energy use is also decreased by 40%. However, in cooling energy need, there is an increase of 34%. [1] Andreas Athienitis et. al (2008) stated that based on the design of the houses, it is expected that homes with low and near net-zero energy use can be designed in a cost effective manner within a period of about 5 years, provided a heat pump-based system is used for heating and heat is recovered from the PV system and efficiently utilized in the house. [3] Tanbiruj et.al (2010) finalized that the solar energy that receive naturally by a building can be used to heat the building without special devices to capture or collect sunlight in direct gain passive solar system. Passive solar heating can be applied by using of large sunfacing windows (south-facing in the Northern Hemisphere) and building materials. A well-insulated building with such construction element can absorb the sun’s energy and reduce heating bills around 50 percent. [2] Javad Sadegh Saberi et.al (2013) observed the different methods which use in passive solar energy building like direct gain, indirect gain, isolated gain etc.[4] Najmeh Najafi et.al (2013) studied the experience in conventional architecture of Shiraz, it is possible to create an environmental and sustainable architecture. [5] Singh et.al (2016) research that the height to width ratio of the built mass with each other and other physical features like trees, streets etc. can help not only in desirable thermal indoor conditions but, can also reduce the use of valuable land for other purposes. [6] According to U.S Department of energy a special builder-friendly computer program has been developed to automate the calculations involved in telling out the four worksheets. The program operates like a spreadsheet: the user fills in values for the building and the computer completes the calculations. The results are the same as if you completed the worksheets manually but it is much faster more convenient and less prone to arithmetic error. Many design variations can be evaluated very quickly. [8] Givoni (1994) found that a roof painted with a gray or dark color records a higher ceiling temperature compared with a roof painted with a lighter color. It was also justified that a dark colored roof has a higher indoor temperature than the outdoor climate. The study concluded that the incidence of solar radiation on the

roof surface depends on the color and thermo-physical properties of the roof (Givoni, 1994). Anil kumar (2013) concluded that concept of appliance of 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 and also provides an overview of the sun based passive solutions and design approaches possible in the case of buildings especially with reference to tropical countries. Abdol Vahid Kahoorzadeh et.al (2014) shows passive solar elements like shading devices. Additional elements would keep the interior space at a more comfortable and stable temperature. Similarly, the indoor humidity can be controlled. Open the building up at night to ventilate and cool interior thermal mass. Close the buildings up during the daytime to keep the heat out. Therefore, with a standard passive solar system, dwellers feel more comfortable in terms of any conditions either cold weather or hot weather. It also has financial benefits. In fact, buildings require relatively small cooling or heating systems.[9]

#### **4. MATERIALS AND METHODS**

All the passive solar buildings have these common elements/components which are shown in the figure below.

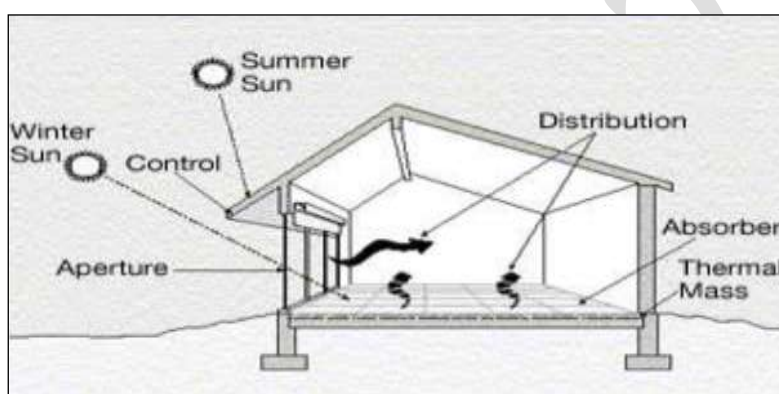
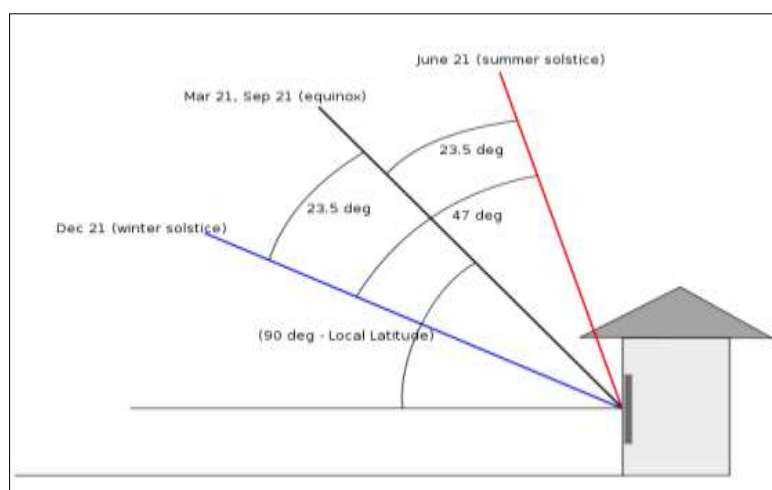


Fig -1: Component Passive Solar Buildings

##### **4.1 Solar Path in Passive Design**

The ability to achieve these goals simultaneously is fundamentally dependent on the seasonal variations in the sun's path throughout the day. This occurs as a result of the inclination of the earth's axis of rotation in relation to its orbit. The sun path is unique for any given latitude. Generally the sun will appear to rise in the east and set in the west, In Northern Hemisphere non-tropical latitudes farther than 23.5 degrees from the equator:

- The sun will reach its highest point toward the South (in the direction of the equator)
- As winter solstice approaches, the angle at which the sun rises and sets progressively. Moves further toward the South and the daylight hours will become shorter.
- The opposite is noted in summer where the sun will rise and set further toward the North and the daylight hours will lengthen.



**Fig -2: Solar Path in Passive Design**

## **5. DESIGN GUIDELINE**

There are several types of passive solar systems that can be used. The most common are direct gain, indirect gain, and isolated gain. Amongst the design guidelines available, three are for heating, one is for heating and cooling, and one is for cooling only. Each of the systems in these categories has specific design limitations and use. Hence, the designer has to choose the one that satisfies the majority of criteria set for a particular building on a given site and the availability of space as well as the fineness of thermal regulation required. The following guidelines can be of help at the initial design stage. These are mainly compiled by Gupta et al (1990).

### **5.1 Solar passive heating**

#### **5.1.1 Direct gain (increased fenestration i.e. glass area)**

- Building form - The building is usually oriented along the east-west axis, with spaces needing heat located along the south wall.
- Glazing - The major glass area must be oriented towards the south and it is essential that windows be carefully designed to eliminate the problem of glare often associated with direct gain systems.
- Material - The system generally implies a heavy building with the interior wall and floors constructed of masonry materials.
- Thermal control - Direct gain systems are characterized by daily indoor fluctuations. To prevent overheating, shading devices are used to reduce solar gain, or excess heat is vented out by opening windows/vents.
- Retrofitting - Retrofitting an existing building with a direct gain system is somewhat difficult, since the building by itself is the system. The system demands skilful and total integration of all architectural elements within each space: windows, walls, floor, roof and interior surface finishes. A direct gain system can usually be built for the same cost as a conventional masonry system

#### **5.1.2 Isolated gain (attached greenhouse)**

- Building form-The greenhouse must extend along the south face of the building adjoining the spaces to be heated. Glazing To heat one square meter of building floor area (excluding the greenhouse) approximately 75% of greenhouse glass area is required in normal constructions.
- Materials-The major construction material in the greenhouse is double glass or transparent plastic and there is a common wall (thermal mass masonry or water) between greenhouse and building.
- Thermal control-Temperature in adjoining spaces is similar to temperatures in thermal wall storage systems.

- Retrofitting - Retrofitting can be carried out easily by adding a sunspace to an existing building on its south side in the northern hemisphere. A useful feature of the system is that it can produce fresh vegetables, apart from the capacity to heat itself and space adjoining it.

### **5.1.3 Indirect gain-(glazed storage wall)**

- Building form - The depth of a space is limited to approximately 5 or 6 metres, since this is considered the maximum distance for effective radiant heating from a solar wall.
- Glazing - The south-facing glass functions only as a collecting surface and admit no natural light into the space except through windows, which may be allowed.
- Materials-Either water or masonry or built-in PCM modules can be used for a thermal mass wall. Double glazing in front of the wall is considered desirable unless insulating shutters are applied over the glazing at night.
- Thermal control- Indoor temperature fluctuations are controlled by wall thickness. The heat output of a masonry wall can be regulated by the addition of thermo-circulation vents with openable dampers or by movable insulating panels or drapes placed over the inside face of the wall.
- System efficiency - For the same area of wall and heat storage capacity, a water wall will be slightly more efficient than a masonry wall.
- Retrofitting - This system can be added without much difficulty to the south wall of a building.

### **5.2 Solar passive heating and Cooling Roof-top shallow solar pond**

It acts like a panel radiant heater/cooler and is primarily meant only for one-storey buildings with thin horizontal roofs. It is also ineffective during monsoons and roofs need special care with regard to weather proofing.

- Building form - Since the roof itself is a collector, this system is most suitable for heating or cooling one-storey buildings, or the top floor of a multi-storied structure.
- Glazing - For summer cooling, the pond must be exposed to as much of the night sky as possible.
- Materials - Roof ponds are generally 10-20 cm in depth. A structural RCC grid system or metal deck, which also acts as a finished ceiling and radiating surface, is the most commonly used support for the pond itself.
- Thermal control-Roof-pond heating and cooling is characterized by stable indoor temperatures and high levels of comfort due to the large area of radiative surface.
- System efficiency- Roof ponds, which are lined with plastic and have movable insulation, range in efficiency from 30 to 45. It should be noted that the effectiveness of the seal made by the movable insulation will have an impact on the efficiency of the system.
- Retrofitting - The requirements of a large area of radiating surface plus structural and modular considerations make it difficult to apply to existing structures. Solar roof ponds are an inexpensive and effective method of providing both heating and cooling in dry climates with clear night skies.

### **5.3 Solar passive cooling Roof spray on an absorbent fabric**

This system was invented by the Central Building Research Institute (CBRI) (see, for example Jain & Rao 1974). The roof acts like a panel radiant cooler. It was primarily designed for one-storey buildings with thin horizontal roofs but was later extended to normal masonry roofs and multi-storey buildings (e.g. Jain 1989). The principle is to maximize the effective cooling efficiency of the roof deck by making water evaporate in as close a thermal contact with it as possible during the day, and using, in addition, radiant cooling to the sky during the night.

- Building form - No restriction except suitable weather proofing without appreciable increase in thermal resistance or capacity.
- Glazing - With unobstructed exposure to the night sky, it is ideal for hot, dry climates with clear night skies.
- Materials - Gunny bags/coir matting are used in close thermal contact with the roof. A spray of water from sprinklers or wicks in a perforated pipe is obtained to just wet the surface. The roof fabric is necessary to increase the specific surface of evaporation and obtain a thin layer of water so as to need spraying only three to four times in a full day.
- Thermal control-An electrical conducting sensor can operate a relay to shut a solenoid valve or open it for gravity flow. Only a few watts of DC provided by the photo-voltaic (PV) panel is sufficient to automate the system. Usually the water spray is needed at the rate of 10 litres per square metre per day (24h).
- Efficiency - An indoor air temperature depression of upto 8°C has been observed in favourable climates with complete extinction of vertical temperature gradients and asymmetric radiation from the ceiling.
- Retrofitting - Commonly used for factory roofs after checking for weather proofing. The system is very effective in terms of cooling per unit investment and needs very low running costs.

## **6. EFFICIENCY AND ECONOMY**

Technically, PSH is highly efficient. Direct-gain systems can utilize (i.e. convert into "useful" heat) 65-70% of the energy of solar radiation that strikes the aperture or collector. Passive solar fraction (PSF) is the percentage of the required heat load met by PSH and hence represents potential reduction in heating costs. RET Screen International has reported a PSF of 20-50%. Within the field of sustainability, energy conservation even of the order of 15% is considered substantial. Other sources report the following Puffs:

- 5-25% for modest systems
- 40% for "highly optimized" systems
- Up to 75% for "very intense" systems.

In favourable climates such as the southwest United States, highly optimized systems can exceed 75% PSF.

## **7. SUMMARY**

In this paper we mainly focused on the components and design aspects of Passive Solar Building. Passive solar building design is a part of green building design by the providing this type of design; we can able to use solar energy, which offers no cost & our nonrenewable resources can be saved to a larger extent. The design of Passive solar building provides thermal comfort during various seasons, like summer, winter & it is very use full design to provide natural ventilation in the building, passive solar provides natural light by installation of photovoltaic, which didn't require any other source of energy, proper orientation of building can be done by this type of design. The energy-efficiency design strategies by passive solar components having the additional cost of about 9% of the total building cost, it is possible to save the total annual energy used in this specific residential building by 18%. The orientation, shading device, vegetation, concrete vent blocks, natural ventilation, and material act as effective passive design that plays an important role in achieving thermal comfort. The garden plaza and trees planted around the building acts as filtration to cool the heated air. The uses of concrete vent blocks on parts of the building improve the space quality and enhance the ventilation for user's comfort. The concrete vent block also act as shading device that allows air to flow in thus making the building naturally ventilated. In western countries this type of construction is common scenario, and they have codal provisions for Passive solar design, but unfortunately in India we are still lacking behind, this is a very vast study area to deal with. The conceptual idea mentioned in this paper will serve as a model for fully

ubiquitous cities to be implemented in future, and will provide insights into additional challenges in the realization of smart cities. Still, there are numerous challenges to be solved before fully ubiquitous cities become a reality.

## REFERENCES

1. Serkan Bilgic (2003), “A case study on improvement of an existing residential building’s thermal performance by passive solar design”, Izmir Institute of Technology Izmir, Turkey September, 2003
2. Md. Tanbirujjaman, Md. Masudurrahman and A.N.M. MizanurRahman(2010), “ Design of a direct gain passive solar heating system”, Proceedings of the 2010 international conference on industrial engineering and operational management Dhaka, Bangladesh, January 9-10 2010
3. Andreas anthienities (2008), “Design of advanced solar homes aimed at net zero annual energy consumption in Canada” ISES-AP -3rd international solar energy society conference-Asia pacific region(ISES-AP-08)Incorporating the 46th ANZES conference 25-28 November 2008
4. Javed Sadegh Saberi, Sanazarei, Shahab-o-din Hemmati, Mohsen. Kameli,(2013), “Passive solar building design”, Journal of Novel Applied Sciences ©2013 JNAS Journal2013-2-S4/1178-1188 ISSN 2322-5149-2013 JNAS
5. Najmeh Najafi(2013), “Iranian Traditional Architecture And Energy Saving (Case Study: Shiraz Ghajar Houses)” International Journal Of Energy And Environment Volume 4, Issue 5, 2013 Pp.871-878
6. Ritu Singh and Madhura Yadav,(2016), “ Study Of Energy Efficient Design Strategies For Building Clusters In Hot & Dry Climate: An Overview”, Emerging trends in Engineering & Management for Sustainable Development 2016 International conference, Feb 2016
7. Abdolvahid Kahoorzadeh, Sahelshah Vazari, Elnazfarzami, Sinaosivand, (2014), “Investigation of Usage of Passive Solar Energy in Salamis Road's Buildings, Famagusta”, International Journal of Environmental Science and Development, Vol. 5, No. 2, April 2014
8. Asian Architecture [ARC 2213/2234](2016), “The Effectiveness of Passive Design Strategies as Natural Cooling Devices in Achieving Thermal Comfort at PJ Trade Centre”,Taylor’s university(JUNE 2016)
9. B. Givoni,(1994) “Passive Low Energy Cooling of Buildings”, John Wiley & Sons, New York (1994)
10. Wolfert and Hinrichs, C.K. Wolfert, H.S. Hinrichs (1974), “Fundamentals of Residential Attic Ventilation: A Basic Reference Handbook Covering Attic Ventilation Requirements, Available Equipment, Research Data, and Recommendations”, HC Products Company, Princeville (1974)
11. Aziah, N.M.A., (1994). “Climate sensitive house for Malaysia. ISI-UTM International Convention”, Kuala Lumpur, Malaysia
12. The Passive Solar Construction Handbook. Steven Winter Associates, Rodale Press: Emmaus, PA, 1983.
13. Passive Solar Energy: The Homeowners Guide to Natural Heating and Cooling (2nd Ed.). B. Anderson and M. Wells. Brick House Publishing Co., Andover, MA, 1993.
14. The Passive Solar Design Handbook. Los Alamos Scientific Laboratory; Total Environmental Action; US Department of Energy, March, 1980.
15. The Passive Solar Energy Book. Edward Mazria, Rodale Press, Emmaus, PA, 1979.

16. Regional Guidelines for Building Passive Solar Energy Conservation Homes. Department of Housing and Urban Development, Washington, DC, 1978.
17. Solar Control and Shading Devices; and Design with Climate. Aladar Olgyay, Victor Olgyay, Princeton, NJ, Princeton University Press, 1976.
18. The Solar Home-How to Design and Build a House you Heat with the Sun. Mark Freeman, Stackpole Books, Mechanicsburg, PA, 1994. (Available from NC Solar Center.)
19. Bozen Bolzano —Building simulation applications BSA-2013| ISBN9788860460585, Published on 2013 1ST Edition.
20. Subratochandra and phillip w. fairey —passive solar design stratagies

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