Passive Solar Building Designs: An Anticipated Approach towards Energy Efficiency

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Abstract: ***The present society which we are living utilizes the electrical energy for their comfort. This electrical energy is majorly obtained by burning the fossil fuels. These fuels are decreasing in a dramatic rate and it is also contributes to the pollution. Passive solar design for homes helps to reduce the consumption of electrical energy by utilizing the solar energy. Passive solar design is a green concept which is aimed to utilize the maximum solar energy in the form of heat to maintain interior thermal comfort throughout the sun's daily and annual cycles, thereby the reducing the dependence of energy consuming mechanical and electrical systems of heating and cooling. The Windows, walls and floors of the homes are designed to collect the solar heat from the sun in winter and reject it in the summer. While the building sector accounts more than a third of energy. Therefore reduce the amount of energy in Buildings causes toward sustainable development which consistent with the needs of today's generation which put future generation at risk. One of the painters of sustainability in architecture is the use of natural energy and fossil energy consumption and minimum natural environmental conditions and climate so solar building designs which is a step towards its achieving. In this article, has been expressed the important factors in solar buildings design. These factors are included external factors and internal factors. More owner implementation strategies in the design to same energy in buildings also will be presented. This paper deals with the fundamental heat movement principles, passive solar design and design provisions for buildings. This paper also describes a study on the savings achieved by using daylight in passive solar design of buildings. The findings from this study show that at least 10% savings can be produced from simple day lighting strategies.***

Keywords: Passive solar building, Green concept, Insulation, Solar energy, Ventilation, South facing

1. Introduction

In Industrial and technological innovations, population growth and rapid urbanization lead to an increase in energy consumption. Negative effect of energy on environment impact has made this as critical issue. We need to make a quick switch about the use of energy in building and by this I indicate to my topic 'Passive Solar Building'.

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. This is called passive solar design because, unlike active solar heating systems, it does not involve the use of mechanical and electrical devices.

The key to design a passive solar building is to best take advantage of the local climate performing an accurate site analysis. Elements to be considered include window placement and size, and glazing type, thermal insulation, thermal mass, and shading. Passive solar design techniques can be applied most easily to new buildings, but existing buildings can be adapted or "retrofitted".

The scientific basis for passive solar building design has been developed from a combination of climatology, thermodynamics (particularly heat transfer: conduction (heat), convection, and electromagnetic radiation, fluid mechanics/natural convection (passive movement of air and water without the use of electricity, fans or pumps), and human thermal comfort based on heat index, psychometrics and enthalpy control for buildings to be inhabited by humans or animals, sunrooms, solariums, and greenhouses for raising plants.

Specific attention is divided into: the site, location and solar orientation of the building, local sun path, the prevailing level of insulation (latitude/sunshine/clouds/precipitation), design and construction quality/materials, placement/size/type of windows and walls, and incorporation of solar-energy-storing thermal mass with heat capacity.

While these considerations may be directed toward any building, achieving an ideal optimized cost/performance solution requires careful, holistic, system integration engineering of these scientific principles. Modern refinements through computer modeling (such as the comprehensive U.S. Department of Energy "Energy Plus" building energy simulation software), and application of decades of lessons learned (since the 1970s energy crisis) can achieve significant energy savings and reduction of environmental damage, without sacrificing functionality or aesthetics. In fact, passive-solar design features such as a greenhouse/sunroom/solarium can greatly enhance the livability, daylight, views, and value of a home, at a low cost per unit of space.

Passive solar building construction may not be difficult or expensive (using off-the-shelf existing materials and technology), but the scientific passive solar building design is a non-trivial engineering effort that requires significant study of previous counter-intuitive lessons learned, and time to enter, evaluate, and iteratively refine the simulation input and output.

One of the most useful post-construction evaluation tools has been the use of thermograph using digital thermal imaging cameras for a formal quantitative scientific energ audit. Thermal imaging can be used to document areas of poor thermal performance such as the negative thermal impact of roof-angled glass or a skylight on a cold winter night or hot summer day.

The scientific lessons learned over the last three decades have been captured in sophisticated comprehensive building energy simulation computer software systems (like U.S. DOE Energy Plus).

Scientific passive solar building design with quantitative cost benefit product optimization is not easy for a novice. The level of complexity has resulted in ongoing bad-architecture, and many intuition-based, unscientific construction experiments that disappoint their designers and waste a significant portion of their construction budget on inappropriate ideas.

The economic motivation for scientific design and engineering is significant. If it had been applied comprehensively to new building construction beginning in 1980 (based on 1970s lessons learned), America could be saving over $250,000,000 per year on expensive energy and related pollution today.

Since 1979, Passive Solar Building Design has been a critical element of achieving zero energy by educational institution experiments, and governments around the world, including the U.S. Department of Energy, and the energy research scientists that they have supported for decades. The cost effective proof of concept was established decades ago, but cultural assimilation into architecture, construction trades, and building-owner decision making has been very slow and difficult to change.

2. Literature Review

Buildings, as they are designed and used today, contribute to serious environmental problems because of excessive consumption of energy and other natural resources. The close connection between energy use in buildings and environmental damage arises because energy-intensive solutions sought to construct a building and meet its demands for heating, cooling, ventilation, and lighting cause severe depletion of invaluable environmental resources. However, buildings can be designed to meet the occupant's need for thermal and visual comfort at reduced levels of energy and resources consumption. Energy resource efficiency in new constructions can be affected by adopting an integrated approach to building design. Thus, in brief, an energy-efficient building balances all aspects of energy use in a building – lighting, space-conditioning, and ventilation – by providing an optimized mix of passive solar design strategies, energy efficient equipment, and renewable sources of energy.

Natural ventilation—uncontrolled air movement into a building through cracks and small holes and through vents such as windows and doors. Nowadays, because of central heating and cooling, as well as the desire for privacy, people tend to make little use of windows for ventilation, so infiltration has become the principal mode of natural ventilation in homes. Unfortunately, a home's natural infiltration rate is unpredictable and uncontrollable because it depends on the home's air tightness, outdoor temperatures, wind, and other factors. During mild weather, some homes may lack sufficient ventilation for pollutant removal. Tightly built homes may have insufficient ventilation at most times. Natural ventilation can save significant amounts of fossil fuel based energy by reducing the need for mechanical ventilation and air conditioning. Air movement within buildings removes foul air and moisture and provides cooling in summer. Take advantage of light summer winds in the design of the site layout and building form. Orient buildings to maximize their exposure to the prevailing summer wind direction. Design buildings with a relatively narrow plan form across the prevailing wind direction, to facilitate the passage of air through the building. Locate wall openings to facilitate the passage of air through the building.
Ventilation provides other benefits besides cooling. Indoor air pollutants tend to accumulate in homes with poor ventilation when homes are closed up for air conditioning or heating. When wind blows against your home, air is forced into your windows. Heat accumulates in your home during the day, and the cool night air can flush it out. For drier climates, this will mean ventilating at night, and closing doors, windows and window coverings during the day. Wind moving along a wall creates a vacuum that pulls air out of the windows. The chimney effect occurs when cool air enters a home on the first floor or basement, absorbs heat in the room, rises, and exits through upstairs windows. This creates a partial vacuum, which pulls more air in through lower-level windows. Natural ventilation works best in climates with cool summers or cool nights and regular breezes. Indoor thermal comfort can be improved significantly by controlling window door opening appropriately in accordance with the temporal variations of indoor and outdoor climates. Results of this study showed that, when outside air velocity is more than inside, hence with opening windows and door, inside air velocity will be increased, then thermal comfort is increased. From this research, it is revealed that when windows-door opening arrangements applied if the outdoor temperature is lower than indoor temperature thermal comfort indices and habitants satisfaction enhance. They prefer to control environment via opening windows-door rather than personal adjustment.

The initial studies find that it is possible for natural ventilation to achieve thermal comfort conditions in place of mechanical air-conditioning systems, especially in winter. The experimental research is divided into two parts: environmental arrangement and building opening. By measuring air conditions flowing through different generic types of environment, it is found that the best environment is that covered with large trees. Computational fluid dynamics studies on generic houses discover that cross ventilation is more effective than two side ventilation, and is much more effective than one-side ventilation. In general, increasing the size of openings improves the effectiveness of natural ventilation.

However, the optimum effective opening area in rectangular rooms is found to be 20 percent of functional floor area. The findings from this research lead to the house evaluation method by factors of orientation and size of building openings. The method is successfully tested with different types of houses. It is known that natural ventilation can be generated by two methods: by thermal force or buoyancy effect, and by wind pressure force or wind-driven effect. In general, wind-driven natural ventilation is easier to achieve because it only needs a low wind speed to create adequate indoor air velocities that help people's heat transfer by means of evaporation. Environmental arrangement affects the air temperature and can be regarded as an important factor influencing natural ventilation. The design of the new buildings should be integrated in the compact urban structure that has developed throughout the past centuries. This compact morphology however obstructs the breezes that are an essential component to achieve thermal comfort by passive means in warm and humid climates. New courtyard buildings should be designed in such a way that natural ventilation and thermal comfort are enhanced. Research on natural ventilation and thermal comfort in compact urban environments however is scarce. This is important because natural ventilation by wind is often the only available strategy to achieve thermal comfort or at least to diminish the hot sensation of occupants. The large majority of the population in Cuba and in many other tropical and humid regions cannot afford the use of air-conditioning. In the present global energy crisis, sustainable solutions should be found to reduce energy use while increasing the quality of life of the people.

This paper describes how environmental design considerations in general, and ventilation considerations in particular, shape the architecture of advanced naturally ventilated (ANV) buildings. The attributes of simple and advanced naturally ventilated buildings are described and a taxonomy of ANV buildings presented. Simple equations for use at the preliminary design stage are presented. These produce target structural cross section areas for the key components of ANV systems. The equations have been developed through practice-based research to design three large educational buildings: the Frederick Lanchester Library, Coventry, UK; the School of Slavonic and East European Studies, London, UK; the Harm A. Weber Library, Elgin, near Chicago, USA. The three buildings represent successive evolutionary stages: from advanced natural ventilation, to ANV with passive downdraught cooling, and finally ANV with HVAC support. Hopefully the guidance, simple calculation tools and case study examples will give architects and environmental design consultant's confidence to embark on the design of ANV buildings.

The attributes of two different forms of simple natural ventilation and four generic building types for exploiting advanced natural ventilation (ANV) have been summarized, highlighting, for each one: the architectural implications; the indoor air quality provision; the degree of protection from the surrounding environment; and the likely tolerance to climate change. ANV buildings, with a central air supply and perimeter exhaust stacks, seem to offer benefits in each of these four areas. Such centre-in, edge-out (C-E) buildings can, in principle, be designed so they are essentially wind neutral, that is, wind pressures will not hinder, or assist, the airflow; this gives added reliability to predictions of their likely, as-built, performance. Finally, the as-build structural areas in the case study buildings are compared with the target values. These comparisons illustrate that it is relatively straightforward to design a central supply route (e.g. light well) of sufficient great cross-sectional area but that it can be difficult, particularly with deeper floor plans and densely occupied buildings, to achieve the target structural opening areas for air supply around the perimeter of such light wells. On constrained sites it can also be difficult to achieve the target structural opening areas for the plenum inlets. It is hoped that this paper will give architects and engineers the added confidence necessary to embark on the design of ANV buildings. Their low energy consumption, relative to typical air-conditioned buildings, is valuable in attempts to combat global warming.

The investigation of natural ventilation efficiency in traditional architecture in Indonesia, investigation was carried out with comparative method of architectural opus in Java Island. It is selected on historical basis, started from Islam proselytization period until the presence of architectural performance that has been developing up to now. Environment for human in the ancient time constitutes sources of life; this regulation has been prevailing. Traditional society gave us data about the relation between building physical performance and climate condition. Researches about constituent component of climate in tropical-humid area (such as air temperature, wind, sun radiation and humidity) are needed to harmonize building and its surrounding nature. The objective of this paper is to give explanation and description of tropical humid traditional architecture history in tropical-humid region in Indonesia and the influence of technology progress on residential building design to solve environment problems. It is the architects' job to cooperate with urban climatologists and related experts to bear a comprehension about microclimate of immediate surrounding before applying it on their design. To face climate problem, architectural parameters such as building orientation, window opening, roof shape, building performance and vegetation planning must be considered seriously. Climate modification is also effective to obtain optimal temperature in building.

Nowadays, most of the buildings are ventilated with mechanical systems, despite the increased awareness regarding the cost and environmental impacts of energy use. In this context, the energy consumption related to the operation of heating, ventilation and air-conditioning systems (HVAC) is considerable, since according to recent studies, nearly 70% of the total energy consumption in service and residential buildings can be attributed to HVAC systems. On the other hand, natural ventilation replaces indoor air with fresh outdoor air without using mechanical systems. Hence, natural ventilation can save the energy consumed for the building's ventilation, provided that it ensures both acceptable indoor air quality and satisfactory thermal comfort levels. Besides, it is interesting to note that natural ventilation, potentially appearing to be a cost-effective alternative to the respective mechanically driven, has during the last years attracted the interest of numerous building designers. The correct design of a naturally ventilated building is a challenging task, due to the complexity of the physical mechanisms involved. In the present work, emphasis is given on the pressure differences due to the wind driven flow. Therefore, in order to optimize such a design, it is necessary to both take into account the pressure distribution around and inside a naturally ventilated building and also configures the induced airflow patterns in detail. The magnitude of the wind velocity plays an important role on the air change rate of a building, due to its proportionality to the inlet volume flow rate. In addition, despite the fact that inner geometry of the building is not altering the aerating volume flow rate, it seems that it is a very important parameter for the refreshing rate of all the inner regions of building's envelope.

Environmental Conditions for Human Occupancy include a new adaptive comfort standard (ACS) that allows warmer indoor temperatures for naturally ventilated buildings during summer. The ACS is based on the analysis of 21,000 sets of raw data compiled from field studies in 160 buildings, both air conditioned and naturally ventilated, located on four continents in varied climatic zones. This paper summarizes this earlier research, presents some of its findings for naturally ventilated buildings, and discusses the process of getting the ACS incorporated into Std. 55. We suggest ways the ACS could be used for the design, operation, or evaluation of buildings, and for research applications. We also use GIS mapping technology to examine the energy-savings potential of the ACS on a regional scale. Finally, new directions for researchers and practitioners involved in the design of buildings and their environmental control systems. Researchers need to take a more integrative view of the indoor environment. With few exceptions, most studies look at one outcome at a time, and try to assess what the ideal environmental conditions would be for optimizing thermal comfort, indoor air quality, energy consumption, or productivity. Research findings often suggest conflicting goals for the indoor environment. For example, recent work has shown that perceptions of indoor air quality are improved when temperatures are cooler, and you can therefore decrease ventilation rates. Although decreased ventilation rates would reduce energy consumption, cooler temperatures would either decrease or increase energy use, depending on whether you're in a heating or cooling situation. Many practitioners report that the stillness of air within the occupied zone of most air-conditioned spaces (as mandated by current standards like ASHRAE Std 55) is associated with complaints of poor quality "dead" air. Perhaps elevated air speeds within the occupied zone cannot only permit thermal comfort to be achieved at higher temperatures (thereby saving on refrigerated energy inputs), but also improve perceived air quality, or at least offset the enthalpy effect. Many important thermal comfort questions still need answers, and a new generation of researchers needs to be trained to provide them. In thinking beyond just thermal comfort, many people can easily agree on some of the more obvious recommendations for improved environmental control – reduce indoor pollution sources, deliver the air closer to the occupants, provide personal control where feasible. As examples, this could range from a workplace culture that allows a flexible dress code and policy for taking breaks, to providing means for control of the local physical environment (windows, local controls, etc.), or providing areas within the building that have different thermal conditions. One clear conclusion seems to emerge - the "one-size-fits-all" and "uniform conditioning" approach to indoor climate management is fast becoming a curious but misguided fad of the last century.

This paper presents an overview of the most popular methods for predicting ventilation performance, including the analytical models, empirical models, small-scale experimental models, full-scale experimental models, multi zone models, zonal models, and CFD models. Reviewing the publications found in major journals, this paper revealed that the contributions from analytical and empirical models were around 5%, although they may be the bread and butter tools in practical design. Most of the studies conducted in the small-scale and full-scale experimental models were used for validation purpose. The multi zone models were widely used for predicting ventilation performance in entire buildings. Serious effort has been made to improve the multi zone models. Zonal models have yet to gain their popularity in predicting ventilation performance and may be replaced by coarse-grid CFD models in the future. The use of CFD with other building simulation tools to enhance its ability and to reduce computing costs seems attractive.

The method for controlling air quality and ventilation in naturally ventilated poultry buildings consist of placing in controller parameters such as humidity and temperature in a building. Humidity and temperature sensors in the building are mounted above the floors with temperature sensors located directly above each animal or poultry. These sensors are connected to the controller to feed through controller actual conditions of temperature and humidity within the building. The automated controller for naturally ventilated poultry building is in communication with livestock compartment having closable openings such as ridge vents and closable windows in side walls.

3. Results and Discussion

Passive solar heating is something which is becoming more frequently used in modern buildings and homes. It considerably reduces the amount of heating required from other sources and also reduces carbon emissions and that is the most important factor to think about.

Passive solar energy makes more of the efficiency within the heating system of your home. It is not the main source of heating, hence the term 'passive', but it acts as a subsidiary or auxiliary form of heating which can be engaged as and when needed.

Having a glass conservatory is a great form of passive solar heating. The sun's heat will enhance the warmth in the conservatory and this will bring extra heat to nearby areas of the house. This will result in the need to use less gas or electric heating in those areas.

Designers of new buildings now try to optimize the amount of energy they can derive from the sun. Careful planning helps to collect as much of the sun's heat as possible to reduce much of the need for gas or electric heating.

New home construction must be dealt with serious consideration to materials and fabrics that offer great insulation.

South facing garden or home gets direct benefit from passive solar heating without doing much at all. The sun will shed light and warmth on that side of your home all year round. If the house has large patio doors, less money is spend for heating that part of it. It is noticed that even in winter, that side of house still requires less heat than the rest of the house.

Everyone is searching for the ultimate in renewable and sustainable sources these days and the sun is the best answer to getting free renewable solar heating. It creates no carbon footprint whatsoever and we can take reasonably cheap steps to alter home sufficiently enough to reduce household bills by employing passive solar heating.

Having passive solar heating around the house also eliminates the constant use of noisy heating systems and furnaces, which will fire up during quiet times and disturb the peace. Reducing the need for noisy furnaces offers a peaceful time at home.

Not only we benefit from passive solar heating to heat home efficiently, but also can rely on it to cool home during hotter periods. If building a new home, plant trees on the south side of house so that during the summer, they will offer a shade from the heat. During the winter, when they have dropped their leaves, will still get warmth coming in, too.

4. Conclusions

- Passive solar building design is a part of green building design by the providing this type of design; we are able to use solar energy, which offers no cost & our non-renewable resources can be saved to a larger extent.
- Passive solar building design provides thermal comfort during various seasons, like summer, winter & it is very useful 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.
- After doing the cost analysis of the case study, it was found out that Passive Solar Houses indeed provide a return on investment in monetary terms. The reduction in electricity bills cover up the initial additional costs within 14 years.
- As we witness day by day that the earth's weather condition is changing improperly due to the pollution of the earth & global temperature is also raising day by day, This year in India we observed a highest temperature 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 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.

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