Analysis of the Impact of Passive Design Strategies on Energy Consumption of a Building in Composite Climate Zone

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Abstract The demand for buildings that can deal with current challenges such as environmental conservation, climate change, and sustainability etc., has increased as cities have grown more rapidly. Retrofitting of existing buildings utilizing ideas such as sustainability can enhance the energy performance of new and existing infrastructure while taking economic and cultural issues into account. Buildings account for over 40% of global power demand as well as 40% of CO^2 emissions. This paper presents a thorough analysis of thermal performance parameters for composite building walls, including thermal transmittance. Renewable energy sources provide an endless supply of power. Solar energy can be used passively or actively to complement a building's energy demands. It is possible to minimize energy consumption for a building's heating, cooling, and lighting needs by using a climate-sensitive strategy in the design of architectural elements such as static sunshades, walls, and roofs. It has been observed that the base-case consumes 93134.4 kWh, whereas the proposed-case consumes 68317.7 kWh. There is a huge 26.65% reduction in the annual energy consumption by adopting passive design strategies.

Keywords. Energy efficiency, passive solar, HVAC, energy simulation.

1. Introduction

The rapid increase of the world's population has resulted in increased demand for transportation, energy, land, and services like education and security, as well as pollution of air, water, solid waste, and deforestation [1]. To combat the major contributors to global warming, which are our buildings, we must try to make them more energy efficient, particularly older structures.

The use of the sun's energy to heat, chill, and illuminate buildings without the need of mechanical devices is referred to as passive solar. It has become somewhat twisted, as have so many artificial categories, and is now a general word for a design philosophy that attempts to develop low-energy structures that are responsive to the natural environment [2]. A better phrase could be climate sensitive architecture, because buildings designed according to this theory employ their envelope as the primary climate modulator and reduce any mechanical plant to a secondary function. This is in contrast to the trend of constructing buildings with insensitive exterior, resulting in a hostile inside climate that can only be remedied via the employment of costly mechanical systems.

The exact definition of passive solar strategies is debatable, it is undeniable that its core goal is to make low-energy structures using very basic technology. Because the emphasis in such structures is on the envelope, passive solar buildings tend to have complex facades with a variety of characteristics such as external shading, light shelves and opening windows [3].

2. Research Methodology

The stepwise methodology process used in the present study of finding the impact of passive design strategies using simulation software is summarised as:

1. Designing building model in AutoCAD.
2. Choosing location and climate zone.
3. Selecting orientation of building.
4. Creating building block and defining zones.
5. Assigning activity of building.
6. Choosing suitable construction material.
7. Assigning HVAC and W.W.R.
8. Performing thermal analysis on model.
9. Creating a baseline replica (ASHRAE 90.1)
10. Performing thermal analysis on base case.
11. Drawing comparison between proposed and baseline case.

The building which is simulated in this project is a residential building. The floor plan of the building is shown in Fig. 1.

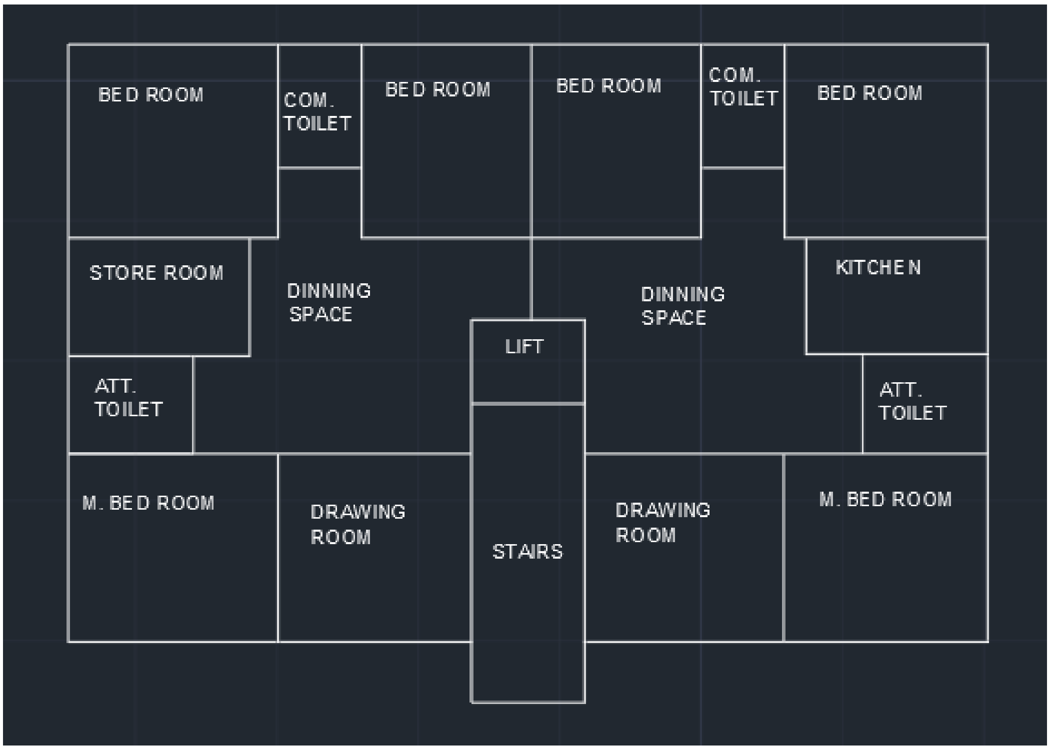

Fig. 1 Floor Plan of Building

The plan is drawn in such a way that only outer perimeter line of the walls is drawn so as required by the Design builder software. The details of the floor plan are provided in Table 1.

Table 1 Floor Plan Details

S. No.	Quantity Per Floor	Zone	Dimensions	Area (sq. ft.)
1.	4	Bed room	13 ft into 11ft 7 inches	143
2.	2	Master bed room	14 ft into 13 ft	182
3.	2	Dining space	15 ft into 8 ft	120
4.	2	Drawing room	14 ft into 13 ft	182
5.	1	Kitchen	12 ft into 8 ft	96
6.	2	Attached toilet	9 ft into 7 ft	63
7.	2	Common toilet	6 ft into 9 ft	54
8.	1	Lift	8 ft into 6 ft	48
9.	1	Stairs	21 ft into 8 ft	168

2.1 Choosing location and climate zone

The plan is imported in Design Builder using the import 2D drawing option. Then the first step in Design Builder is to select the location of the building. The climate zone is selected automatically by the software. The location where the building under consideration is located is selected from the location template as a source of location and weather data for the site. The location defines the geographical location and weather data for the building on this site. The site selected here is Safdarjung, New Delhi, which comes under the climate zone 1B according to ASHRAE climate zone classification.

2.2 Selecting orientation of building

When designing a new building, it is important to understand how the orientation of building will affect the energy profile. Buildings oriented longitudinally require less energy for both heating and cooling, resulting in lower utility bills and increased comfort [4].

2.3 Creating building block and defining zones

2.3.1 Creating zones

The building is then divided into blocks, which can be further subdivided into more than one zone by drawing partitions. In this study, the block is divided into a total of 17 zones which can be classified as 4 zones for bed room, 2 zones for master bed room, 2 zones for dinning spaces, 2 zones for drawing room, 1 zone for kitchen, 2 zones for attached toilet, 2 zones for common toilet, 1 zone for lift and 1 zone for stairs. Then the zones are defined by naming the different zone according to the occupancy of the zone.

2.3.2 Assigning activity of building block

Assigning activity to the building and different zones of the building requires the selection of activity template from the templates stored in the software. The activity schedule of a building or a zone defines the schedule and the intensity of the occupancy of that space. The activity of the any occupied space largely effects the usage of energy for different purposes like fans, lights etc. It also includes the number of days the zone will be occupied. It can be controlled by assigning the number of holidays in the activity template. The details of the activity template assigned to the building level and to the various zones are given in the Table 2.

Table 2 Details of Activity Template

S. No.	Zone	Activity Template	Occupancy (m_2/Person)
1.	Building	Residential – dwelling unit (with kitchen)	46.45
2.	Bed room	Domestic bedroom	43.59
3.	Dinning space	Domestic dining room	59.12
4.	Drawing room	Domestic lounge	53.32
5.	Kitchen	Domestic kitchen	42.19
6.	Stairs	Common circulation area	50.90
7.	Store room	Store room	9.64
8.	Toilet	Domestic toilet	41.12

2.4 Selecting suitable building material

In this study, the building materials chosen in the design of proposed case are listed below:

2.4.1 Walls

The walls are made from Autoclaved Aerated Concrete (AAC) blocks and an insulation layer of Expanded Polystyrene (EPS). It offers high thermal insulation and is therefore suitable for energy efficient design. The thermal conductivity of AAC block varies from 0.1 to 0.7 for density of 400–1700 kg/m^3 [5]. As EPS is lightweight and offers high sound and temperature insulation, it is commonly used as insulation for walls and roofing. Its thermal conductivity is 0.035 W/(m.K).

The wall is designed with 30cm AAC blocks and 60mm EPS and two layers of cement plaster of thickness 1.25cm each. This composition has a very low U-Value of 0.25 W/m^2K.

2.4.2 Roof

The roof is designed with 150 mm Reinforced Cement Concrete and insulation of 60mm Expanded Polystyrene and 60mm Mineral Wool. Mineral wool offers excellent thermal resistance. Its thermal conductivity is 0.03 W/(m·K). The overall U-Value of the roof is 0.252 W/m^2K.

2.4.3 Windows

The proposed building is in a composite climate zone, the goal is to reduce heat flow in and out of the building and to optimize the amount of solar gain for heating and daylighting. This can be achieved by installing efficient windows and utilizing bulk insulation. UPVC (Unplasticized Polyvinyl Chloride) framed, Triple glazed windows with a U-value of 0.049 W/m^2K, and VLT = 0.59 and SHGC = 0.32 are used. The various input data for construction materials are given in Table 3.

Table 3 Construction Input Data

	Units	**Base Case**	**Proposed Case**
Roof – U value	W/sq.m.K	0.273	0.25
Wall – U value	W/sq.m.K	0.704	0.25
Openings			
U value	W/sq.m.K	6.810	0.049
SHGC		0.250	0.32
Vlt		0.56	0.59
Shading		No	0.6 m overhang

2.5 Assigning HVAC and window wall ratio

2.5.1 HVAC System

The HVAC system is defined as the Heating Ventilation and Air Conditioning system and the selection of the HVAC system depends on the climate zone of the site at which the building is constructed. In this project the HVAC system used is System No. 2 PTHP and the template used is "VAV, Water cooled chiller, Air side HR, Outdoor air reset".

2.5.2 Window Wall Ratio

The window wall ratio in a building is defined as the total surface area acquired by windows divided by total surface area of the wall. It is represented in the percentage unit. The details of openings are as follows:

- The window wall ratio (W.W.R.) used in this project is 20%.

- The type of window used is Triple glazing Low emission Argon filled.
- Window height is 1.5m.
- Window spacing is 5m.
- Sill height 0.8m.
- Overhang provided 0.6m.

2.6 Performing thermal analysis on model

2.6.1 Energy simulation

- To perform the thermal analysis on the model, simulation tab given in the bottom bar of the interface of design builder has been used. The simulation provides the energy consumption of the building for the whole year.
- The result after the simulation comes in tabular format or can be converted to graphical format.
- The data is represented as monthly consumption for different loads like room electricity, lighting, fans, heating, cooling, air temperature, miscellaneous etc.
- The data is studied and can be minimized by changing the values of different construction material properties used in the project.
- After the repeated cycle of assigning properties and simulation best result is considered for the model.

3. Results

3.1 Baseline building

The baseline building is the building that perfectly follows the code and does any kind of changes in the prescribed parameters. The code used for the baseline building in this project is ASHRAE 90.1. The building is autogenerated by clicking on the "Generate baseline building" option given in the ribbon of design builder. Then the simulation can be done as done before in the proposed model.

Now, the result of both the cases are compared to check the energy savings percentage of the proposed case as compared to the base case. This helps the builder or architect to decide whether the passive strategies used in the proposed case should be adopted or not. Fig. 2 shows the simulation result in tabular form for the building.

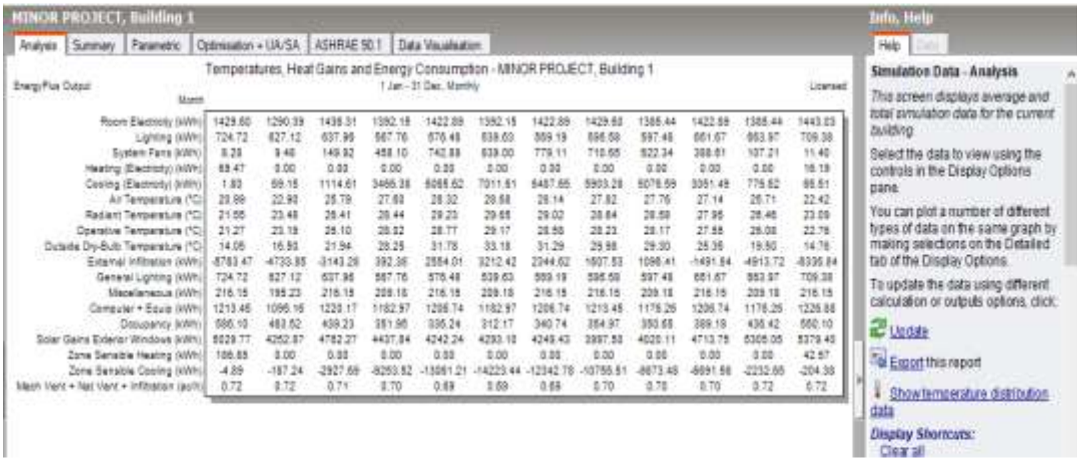

Fig. 2 Simulation Result Screen

3.2 Energy analysis

Design Builder software simulated the energy performance of the designed building. The output was a combination of lighting energy, heating energy and air conditioning energy. The output was analyzed and compared for the base-case and the proposed-case by using monthly and annual energy consumption. The overall energy consumption is measured in kWh.

Fig. 3 is a graphical representation of the monthly variation of energy requirements, temperature, heat balance and fresh air. From Fig. 3, it is observed that the energy requirement for cooling increases in the summer season from the month of March and reaches peak in June and then decreases gradually.

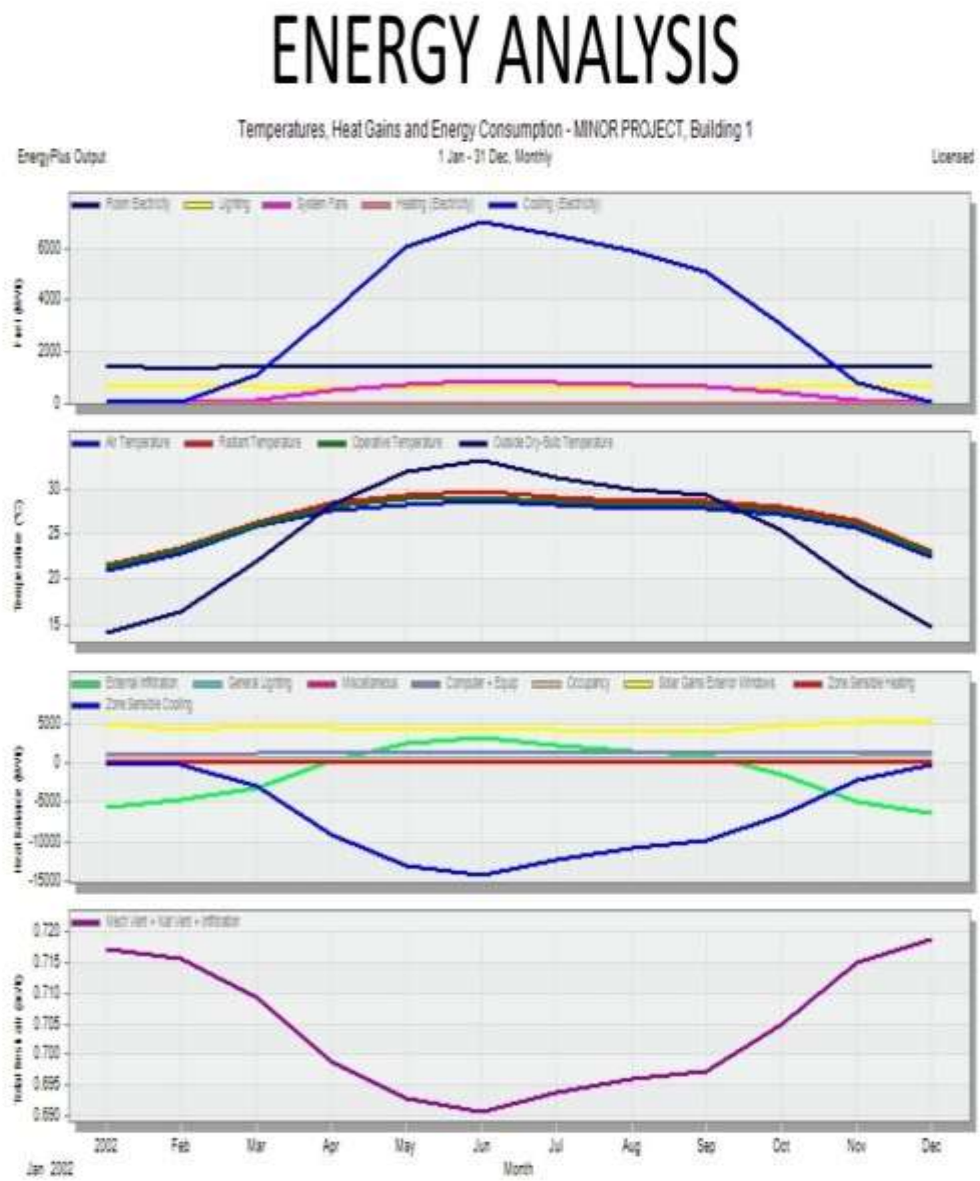

Fig. 3 Energy Analysis

3.3 Comparative analysis

As shown in Fig. 4, the proposed-case, which uses energy conservation measures such as efficient building envelope (walls and roof), energy efficient fenestration, shadings, optimal WWR etc. performs better than the base-case through the twelve months of the year. Moreover, the annual energy consumption as shown in Fig. 4, the base-case consumes 93134.4 kWh, whereas the proposed-case consumes 68317.7 kWh. There is a huge 26.65% reduction in the annual energy consumption.

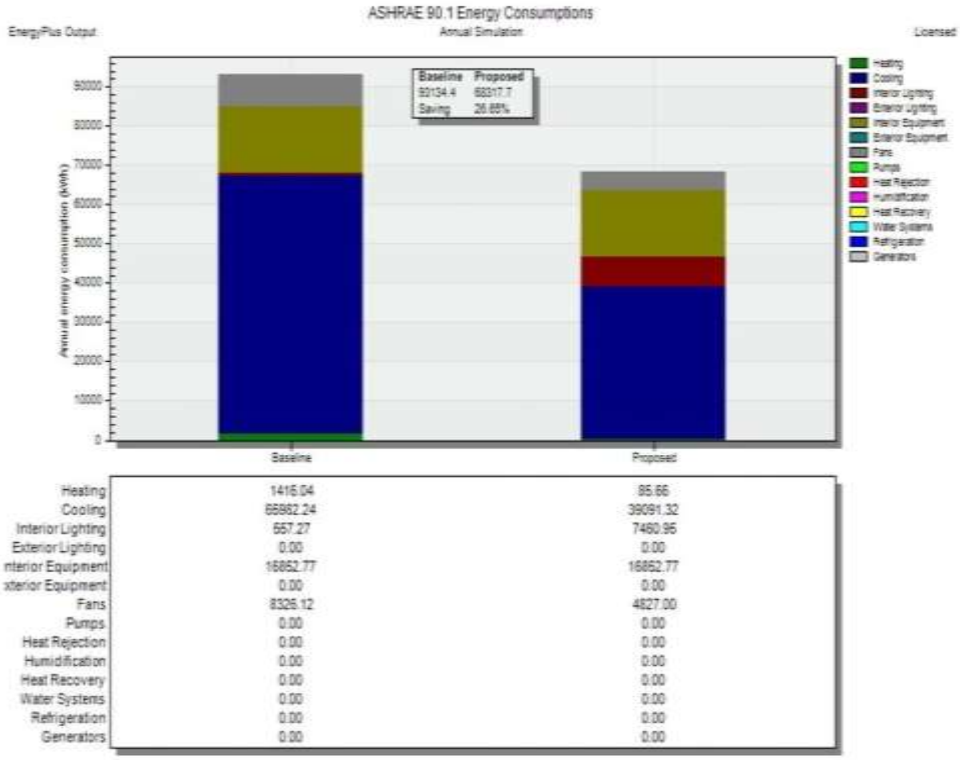

Fig. 4 Comparative Analysis

4. Conclusions

Points concluded by the study of the project are as follows:

- The change in window wall ratio has a significant effect in decreasing the cooling load. As the cooling load will decrease in the building it will thus require a comparatively less energy to have the building under comfortable temperature. This could be made possible by using the passive design techniques in our project which reduced the energy from the building through heating and cooling.
- It has been observed that the climate control accounted for 70% of the total energy use.
- It was further observed that the change in the U-value of wall material also helps in decreasing the energy load.

- By using the energy conservation measures given in this study a total of 26.65% energy is conserved as compared to the base model. This is considered to be a significant.

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