Assessment and Remodelling of a Conventional Building Into a Green Building Using BIM

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Abstract-The demand for sustainable buildings has been highly increasing over the past few years. To meet the sustainability requirements of a building, changes or decisions must be made to a building during the design and preconstruction stages. This can be possible using Building Information Modelling (BIM). To demonstrate the use of BIM in sustainable design, a villa is taken for model study. The conventional building performance is analysed using Autodesk Revit which included various parameters like energy use intensity, lifecycle energy use/cost, annual carbon emissions, monthly heating and cooling loads, monthly peak demand and monthly electricity and fuel consumption. By employing the use of green materials in the conventional building model, the conventional building model is modified into a green building model. Using BIM, the use of artificial resources can be greatly reduced by replacing them with the use of renewable energy resources thereby saving energy. To show how efficient BIM is, the results of the performance of the conventional and green building models are compared. BIM has proved to be efficient in achieving sustainability with earlier decision making and rectification of errors.

Keywords Building information modelling, building performance analysis, energy efficiency, green building, energy saving, sustainability

1. Introduction

Every day, significant amounts of energy, water and raw materials are used by the buildings thus creating a large environmental footprint. This paved way for the conclusion that buildings must turn out to be greener and environment friendly. To evaluate the building performance and to implement modifications in the buildings, the review process must be realistic, easier to repeat the procedure any number of times and procure results in lesser time. To carry out such analysis, Building Information Modelling can be used.

Various researchers have done extensive research work in the field of BIM and sustainability. In a study by Solla, Ismail and Yunus [1], the possible use of BIM in certification of green buildings and the prospect of bringing about credit in sustainability was examined with the help of integrating BIM tools and analysis software. Feedback for changes in material, design and orientation can be achieved by BIM fairly in a quicker manner [2]. Raffee, Hassan and Karim [3] proposed the enhancement of sustainability by the integration of BIM tools with Microsoft Visual Studio enabling and facilitating the design team and stakeholders to improve their beset sustainability performance. Results show that, by the use of exclusive software analysis, BIM energy performance assessment can be a feasible alternative to performing manual building energy use calculations, the reason being the precision and speed of evaluating including the most complex models [4]. The traditional design practices can be changed by the integration of sustainable design strategies with BIM technology resulting in a high-performance design of buildings [5]. A more accurate assessment of design is procured by the designer due to the development of a schematic model preceding the detailed building model thus improving the performance and overall quality of the project [6-8]. The life cycle costs of a building are intensely affected when early decisions are made in the project [9, 10]. Different combinations of materials were assessed using BIM and alternate, green solutions were identified for reducing the overall operational energy consumption [11-13]. The use of renewable energy effectively can minimise the use of artificial resources thereby making a building more energy efficient [14-15]. Based on the research reviewed from various literature on achieving sustainability in BIM, another effort has been made to enhance the sustainability of a conventional building and thereby making it a green building.

The main objective of this research is to modify an existing conventional building into an energy efficient building by enhancing sustainability inducing energy concepts. This can be done by creating a 3Dimensional (3D) BIM model of the conventional building and analysing the energy performance of the building using Autodesk Revit. Environment friendly materials are used in the building model to improve the sustainability for the outcome of an energy efficient and green building model. The energy results regarding various parameters are compared between the conventional and green building model demonstrating the efficiency of BIM in sustainability aspect.

According to the Autodesk Committee, “Building Information Modelling (BIM) is an integrated process for exploring a project’s key physical and functional characteristics digitally before it is built.” “Building Information Modelling (BIM) represents the process of development and use of a computer-generated model to simulate the planning, design, construction and operation of a building facility” [16].

2. Background and Methodology

2.1. Background

Building energy simulation or building energy modelling is extensively recognized as a realistic way for architectural design assessment and energy analysis [17]. For using the simulation confidently and efficiently, it is necessary to have a detailed understanding of the different features of the software used for energy simulation. The accuracy of the results of the analysis is based on the input given. Being one of BIM tools, Revit software is used to develop more accurate and higher quality model designs. In a study by Pimplikar and Esmaeli [18], Revit Architecture is used as a modelling platform and integrated with Autodesk Ecotect and Green Building Studio for daylight analysis.

2.2. Methodology

Autodesk Revit software is used for the building modelling and energy analysis. Autodesk Revit is a BIM software which is used to model designs with precision, optimised performance and conceptualisation. It is specifically built for BIM which allows the construction professionals to implement their ideas into a view in the early stages of design. Revit is a single application which includes the features for Architecture, MEP (Mechanical, Electrical and Plumbing), Structures and Construction. For this study, BIM model creation and the energy simulations for the building are carried out using Autodesk Revit.

3. Building Modelling and Energy Analysis

3.1. Project Details

Name of the project: Creative Home

Project type: Villa

No of storeys: G+1

Project location: Mahabalipuram

3.2. 3D Modelling Using Autodesk Revit

A 3D model of the chosen building is created using Autodesk Revit. The model creation is started with importing the plans of the ground and first floor into the model. The model is created using different tools of Revit and the input data required are given. Materials are assigned to different elements of the building like walls, roof, doors, windows, flooring, etc. The created model is viewed in 3D which can resemble an actual view of the building. By enabling the building to be viewed as a 3D model, the required modifications which are to be implemented in the building to be modified into a green building can be easily analysed. Figures 1 and 2 show the 3D models of the conventional and green building models.

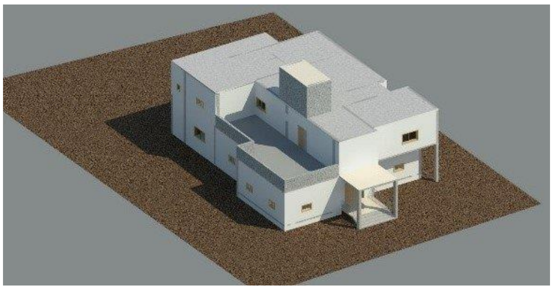

Fig. 1. 3D model of the conventional building

Fig. 2. 3D model of the green building

3.3. Energy Analysis

The conventional building model is taken for energy analysis using Autodesk Revit. The project location and the basic project details are mentioned first. The thermal properties of all the materials used for constructing the building are given. Energy settings are set before running the energy analysis. An energy analytical model is created to run the energy analysis and then the energy analysis is performed. Considering the results obtained from the energy analysis, energy saving materials are introduced in the conventional building model to modify it into a green building.

3.4. Eco-Friendly Materials Used

The choice of materials affect the energy performance and the costs of the building. The energy needed to operate a building can be considerably reduced by improving the thermal insulation of the building [19-21]. The thermal performance is greatly influenced by factors like geometrical parameters, thermal properties of materials, climatic conditions and usage of building [22, 23]. Hence materials were selected for the project based on their thermal properties and their green benefits. The heat transfer coefficients of the green roofs vary from 0.02 to 0.06 W/m^2K, 0.2 W/m^2K and 6 to 16 W/m^2K for well insulated, moderate insulated and non-insulated roofs respectively which results in a decrease in the estimated heating and cooling loads of the building [24]. The overall heat coefficient and emissivity of low emissivity glass is U=1.8 $Wm^{-2}K^{-1}$ and ε =0.100 compared to ordinary glass with U=2.9 $Wm^{-2}K^{-1}$ and ε =0.837 respectively [25]. The U value of AAC (Autoclaved Aerated Concrete) blocks is 0.67 W/m^2K [26]. The thermal conductivity of cork insulation board is 0.042 W/mK [27] which is used as flooring for the green building. The materials used and their green benefits are shown in Table 1.

Table 1. Materials used and their green benefits

Elements of the Building	Materials Used in the Green Building	Green Benefits
Roofing	Green roofing	Reduced energy costs
Glazing	Glazing with low emissivity coating	Reduced CO_2 emissions
Walls	Autoclaved aerated concrete blocks	Excellent thermal protection reducing heating and cooling costs
Flooring	Cork flooring	Reduced heat losses

3.5. Parameters Studied

Various parameters were studied and analysed regarding the energy performance of the building. The parameters are listed below in Table 2.

Table 2. List of parameters

Building Performance Factor	Monthly Cooling Loads
Energy Use Intensity	Monthly Peak Demand
Lifecycle Energy Use/Cost	Monthly Electricity Consumption
Annual Carbon Emissions	Monthly Fuel Consumption
Monthly Heating Loads	

4. Results and Discussion

4.1. Building Performance Factor

The performance factors of the building are listed in Table 3.

Table 3. Building performance factor

Location	Mahabalipuram, Tamilnadu
Weather station	726142
Outdoor temperature	Max: 40°C/Min: 17°C
Floor area	$400m^2$
Exterior wall area	$329m^2$
Average lighting power	$4.84W/m^2$
People	3 people
Electrical cost	Rs. 3.34/kWh
Fuel cost	Rs. 9.34/therm

4.2. Annual Wind Rose

A wind rose gives a pictorial representation of the speed and direction of wind. It is an appropriate tool which is used for showing anemometer data like the wind speed and direction for analysis [28]. 16 cardinal directions are used by the wind rose. Based on the prevailing wind patterns at a location, decisions are made by the designers regarding natural ventilation strategies for placement of windows and protection of buildings from cold winter winds.

The wind rose shown in Fig.3 shows the frequency of winds in a circular format which are blowing in specific directions at the project site located in Mahabalipuram, Chennai. It shows that the wind from SW direction is most common (more than 10% of annual hours). Of the winds from the SW direction, wind speeds are most often in the 9-13 and 13-17 knot range (yellow and light blue).

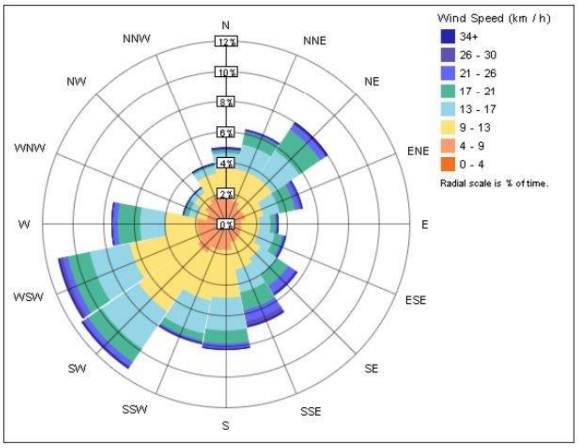

Fig. 3. Annual wind rose for Mahabalipuram, Chennai

4.3. Annual Carbon Emissions

A negative number of energy potential denotes the amount of carbon in tons which can be eradicated from the building with the use of renewable energy resources. The net CO_2 is the deduction of energy generation potential from the energy consumption of the project. The estimated carbon emissions are analysed for both the conventional and green building from Fig.4 and 5. It is seen that the net CO_2 released from the green building has become zero.

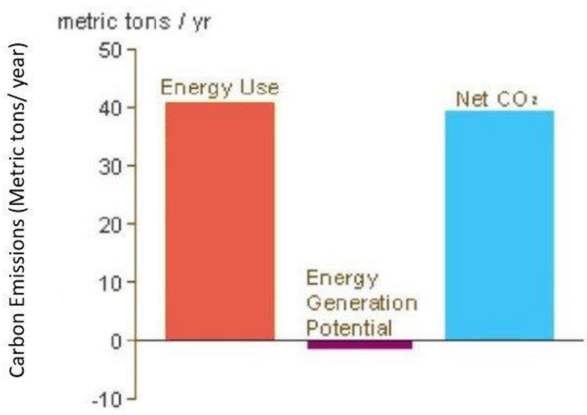

Fig. 4. Annual carbon emissions for conventional building

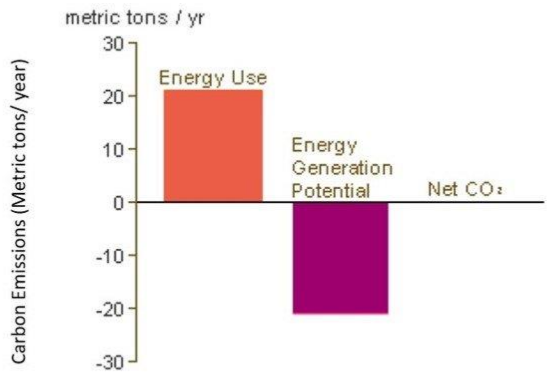

Fig. 5. Annual carbon emissions for green building

4.4. Monthly Heating Load

Figures 6 and 7 show that the heating loads are high during the months of January, February and December. Any load below the zero axis shows the heat energy being lost. Heat needs to be added to compensate the loss and maintain thermal comfort. In this project, roofs are losing the most heat. On the other side of the axis, walls and light fixtures have a positive impact on the building. The external thermal loads (coming from heat transfer like conduction, convection and radiation through building envelope from sun, wind and weather) have more heat losses and gains than the internal thermal loads (coming from heat generated by people, lighting and equipment) as the project is a residential building.

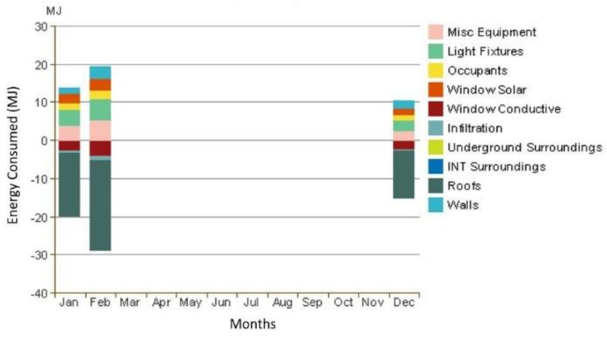

Fig. 6. Monthly heating load for conventional building

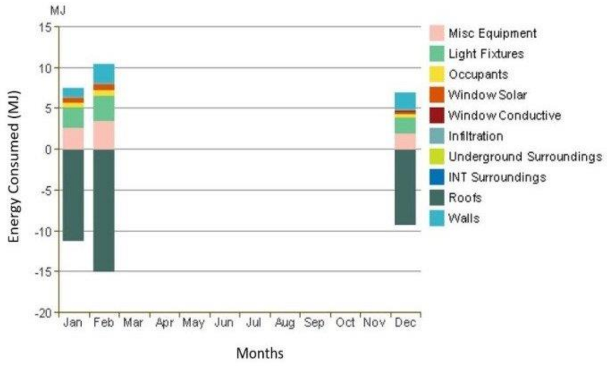

Fig. 7. Monthly heating load for green building

4.5. Monthly Cooling Load

Figures 8 and 9 show the monthly cooling loads for the conventional and green building models respectively. The loads above the zero axis equate the heat energy being gained. Balance must be brought for the extra heat being added by removing the heat from the building for maintaining thermal comfort. For this project, almost everything contributes to the cooling loads with roofs and walls contributing more. The cooling loads are higher during the summer months.

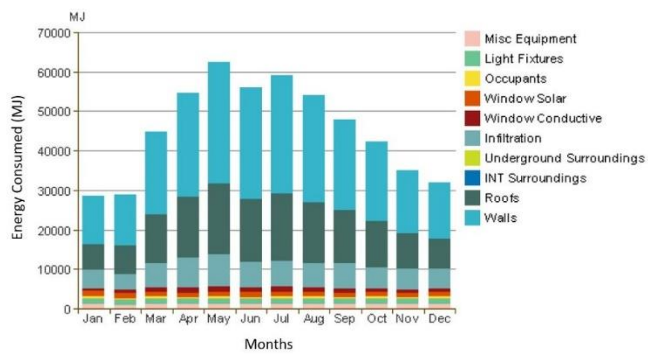

Fig. 8. Monthly cooling load for conventional building

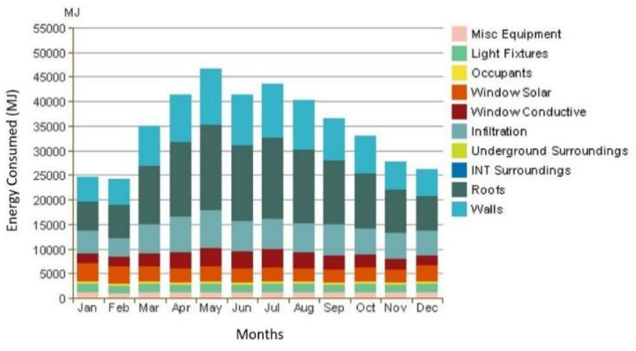

Fig. 9. Monthly cooling load for green building

4.6. Monthly Peak Demand

Peak demand is the highest instantaneous electrical load. Peak demand is in kW whereas the total electrical consumption is in kWh. It is the highest capacity or speed that is required which is different from electrical consumption where it is the overall electricity consumed. For this project, peak demand is the highest during May which is the hottest month of the year. From Fig.10, the electricity peak is 11 kW for the conventional building whereas it is reduced to 10 kW for the green building making the building more energy efficient. The change in peak demand is due to the minimisation of artificial resources which is replaced by allowing renewable energy resources like sunlight, wind, etc. to be used to its maximum level.

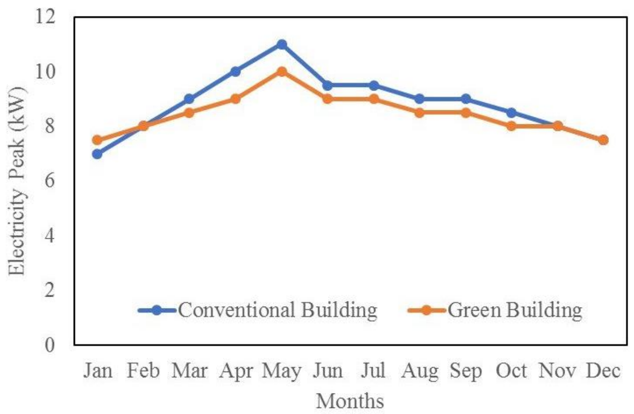

Fig. 10. Monthly peak demand for conventional and green building

4.7. Monthly Electricity Consumption

The electricity consumption is higher during the hotter months of the year and lesser during the winter months. The overall electricity consumed is usually calculated by multiplying the electricity used with the number of hours which is in kWh. From Fig. 11, it is seen that the electricity consumed by the green building is lesser than that consumed by the conventional building every month.

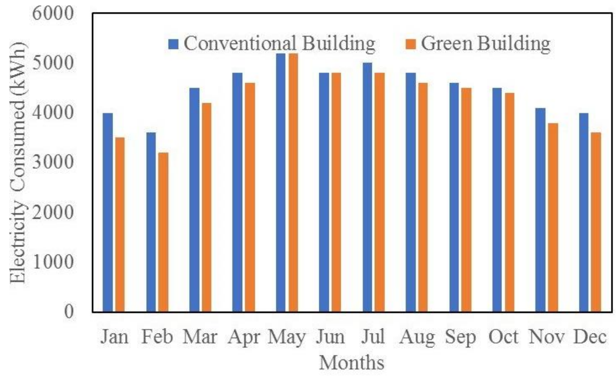

Fig. 11. Monthly electricity consumption for conventional and green building

4.8. Monthly Fuel Consumption

The fuel consumption is based on the heating and cooling of the building. From Fig.12, it is seen that the overall fuel consumption is reduced for the green building due to the utilisation of environment friendly materials.

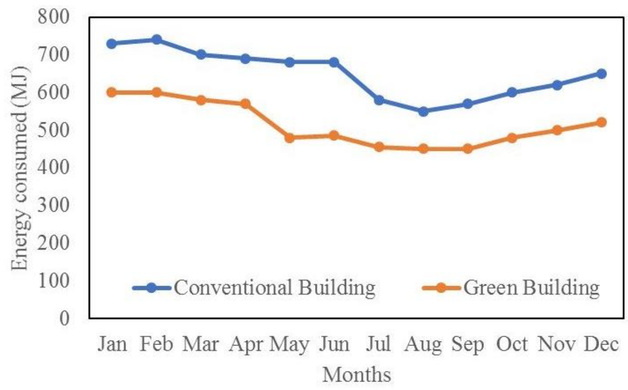

Fig. 12. Monthly fuel consumption for conventional and green building

4.9. Energy Use Intensity

The Energy Use Intensity (EUI) shows the energy consumption of the project per unit floor area. The EUI is calculated for both the conventional and the green building. In Table 4, it is shown that the EUI has reduced in the green building compared to the conventional building. A low EUI shows a better energy performance. This shows that the eco-friendly materials used in the project have brought a change in the energy consumption of the project.

Table 4. Energy Use Intensity for conventional and green building

Energy Use Intensity	**Conventional Building**	**Green Building**
Electricity EUI	144 kWh/sm/yr	135 kWh/sm/yr
Fuel EUI	21 MJ/sm/yr	19 MJ/sm/yr
Total EUI	541 MJ/sm/yr	505 MJ/sm/yr

4.10. Lifecycle Energy Use/Cost

The lifecycle energy use/cost shows the energy consumption and cost of the project for a 30-year life span. This is an estimate for the analysed models. The lifecycle electricity use, fuel use and energy cost are calculated and compared between the conventional building and green building in Table 5.

Table 5. Lifecycle energy use/cost for conventional and green building

Lifecycle Energy Use/Cost	Conventional building	Green building
Lifecycle Electricity Use	1,619,132 kWh	1,508,030 kWh
Lifecycle Fuel Use	227,927 MJ	205,621 MJ
Lifecycle Energy Cost	Rs. 23,14,410	Rs. 18,24,661

5. Conclusion

Energy simulations are conducted on the model for the modification of the conventional building model into a green building model. Based on the results obtained, it is seen that the energy consumption and the lifecycle energy use and costs are reduced in the green building model than the conventional building model. The lifecycle electricity and fuel use can be reduced by 6.86% and 9.78% respectively from the conventional to green building. With the energy consumption being reduced, the lifecycle energy cost can also be reduced by 21.2%. The use of green materials in the project has increased the energy performance of the building due to its thermal properties and green benefits. The use of renewable energy resources to a maximum extent has minimised the use of artificial resources. Overall, the various parameters analysed for the project show that the energy performance of the conventional building has improved making it a green building.

The modification of the conventional building model to the green building model showed how efficient BIM is. Based on this study, it can be concluded that:

- BIM makes the design process faster and easier as all the important decisions regarding the design of the building can be made at the initial design stage.
- Any errors occurred during the creation of the building model are rectified immediately instead of dealing with the consequences later.
- Greater energy efficiency and minimised costs are achieved by the building model by implementing changes as and when required.

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