Retrofitting of an Existing Structure: An Experimental Study Demonstrating Use of Building Information Modelling and Rating Systems for Sustainable Development

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***Abstract*— In India the construction industry being the second largest industry after agriculture, contributes around 7% of India's GDP growth, is forecasted to grow at a rate of around 9.2% as compared to the global average of 5.5%. According to one estimate, this industry consumes 40% of total energy and about one half of the world's major resources. Thus, the issue of energy security and green building initiatives is required to be taken up seriously. The potential for energy savings is 40%-50% in new buildings designed based on green design whereas for existing buildings it can go up to 20%-25% based on retro fitting measures. Integrating dynamic simulation energy efficiency methods such as building information modelling with green technologies, an existing institutional structure has been retrofitted in this bonafide work.**

***Keywords*— Sustainable Development, Building Information Modelling, Green Building, Building Energy Performance, Retrofitting, IGBC Green Existing Building O&M Rating System**

I. INTRODUCTION

A. Background

Developmental activities carried out by human beings have fulfilled their basic needs of food, shelter and clothing and created improved living conditions on one hand and have changed the face of surroundings on the other hand. Dirty streams of water, garbage strewn land and smoke filled air are just instances of the deadly damage humans are doing to the natural environment around them. More is on the anvil with the rising energy consumption at the global level, which has given birth to phenomena such as global warming, climate and ozone depletion.

According to the data gathered by the International Energy Agency (IEA), primary energy consumption has increased by 49% and carbon dioxide emissions have gone up by 43% with an average annual increase of 2% and 1.8% respectively between 1984 and 2004. The growing trend is likely to continue with energy use of emerging economies (Southeast Asia, Middle East, South America and Africa) growing at an average annual rate of 3.2 % and exceeding that by 2020 for the developed world (North America, Western Europe, Japan, Australia and New Zealand), which is growing at an average annual rate of 1.1% only.

Promotion of developed nations' lifestyle in emerging economies through rapid construction of buildings with a wide variety of uses and energy services (heating, ventilation and air conditioning (HVAC) systems, domestic hot water (DHW), refrigeration, lighting, food preparation), and increased time spent in them has caused the energy needs to rise to such consumption levels that current energy and socio-economic systems have become unsustainable. The building sector accounts for about 40% of the total energy consumption and 38% of the CO_2 emissions in the US. About 27% of the emissions are due to the building in the UK. Similarly, in developing countries like Malaysia, 30% of the total energy is consumed by residential buildings and the heat loss by different building components is: windows 50%, walls 35%, ceilings 7.5% and floors 7.5%. Almost 70% of the electrical energy is consumed by air conditioning and refrigeration systems in residential buildings of Malaysia while this share is down to 45%-50% in the developed countries though they contribute about 10%-20% of the total energy consumption.

In a bid to adapt their needs to the existing resources and achieve energy saving while still trying to maintain their standards of living and comfort, the developed countries have begun to propagate the concept of 'sustainable development' and taken steps to reduce the further environmental degradation through Earth Charter, action plan Agenda 21 and international policies like Kyoto protocol. Promotion of energy efficiency in every domain of human activity forms a key part of each of them and failure to comply can result in international sanctions. Further tools and parameters are being developed to monitor this promotion in every domain and corrective measures are adopted to rectify any errors if observed.

Among the used technologies is the use of Building Information Modelling (BIM). It allows for multi-disciplinary information like data regarding a building's form, materials, context, and mechanical–electrical– plumbing (MEP) systems to be superimposed within one model, thereby creating an opportunity for sustainability measures to be incorporated throughout the design process. According to Kriegel and Niels (2008), BIM aids in the following aspects of sustainable design: Building orientation (selecting a good orientation can reduce energy costs); Building massing (to analyze building form and optimize the building envelope); Day lighting analysis; Water harvesting (reducing water needs in a building); Energy modelling (reducing energy needs and analyzing renewable energy options can contribute to low energy costs); Sustainable materials (reducing material needs and using recycled materials); and Site and logistics management (to reduce waste and carbon footprints).

The practitioners of BIM in the United States and Europe have begun to realize that their building performance analyses are time saving as well as cost saving compared to the traditional methods. They have also been to provide a host of information for earning the credits under certification systems like Leadership in Energy and Environmental Design (LEED), United States Green Building Council (USGBC) for their projects. Taking cues from the West, the Eastern world countries have also initiated studies into this subject and have found out that BIM designed buildings lead to a life cycle savings of upto 20% of the initial project cost. However, these studies have been carried out only in select countries like Malaysia, Iran, Japan and China to name a few.

B. Need for the Present Study

The usage of Building Information Modelling (BIM) for creation of "sustainable" buildings has gained widespread acceptability in the West over a decade or so due to credible research and successful case studies carried out on this subject for the past many years. However, limited studies exist for the developing world, in particular India, where this concept is in infancy stage. Hence this study is an attempt to adopt this worldwide practice to the Indian setting and visualize whether it can be used to reduce energy consumption and environmental impact or not.

II. LITERATURE REVIEW

The concept of 'sustainable development' when applied to the building sector gives rise to 'sustainable construction' which aims for effective usage of energy, raw materials and water along with protection of human health and improved productivity. The traditional methods of design, construction and operation of buildings have been rendered ineffective while considering the aspect of sustainability especially the use of energy.

Achieving energy efficiency in this domain requires effective planning of building, its envelope, interiors, air-conditioning and other gadgets. The requirement is to recognize the areas where the use of natural resources of energy can be maximized to make the building effective and sustainable. This has given rise to a new category of buildings called green buildings, whose main virtue is the optimization of all the available resources.

A green building is a structure that is designed, built, renovated, operated or reused in an ecological and resource efficient manner. It is also known as a high performance building. Practitioners of green building often seek to achieve not only ecological but aesthetic harmony between a structure and its surrounding natural and built environment, although the appearance and style of sustainable buildings is not necessarily distinguishable from their less sustainable counterparts. Green construction methods can be integrated into buildings at any stage, from design and construction, to renovation and deconstruction. However, the most significant benefits can be obtained if the design and construction team takes an integrated approach from the earliest stages of a building project.

Green buildings incorporate several sustainable features such as efficient use of water, energy-efficient and eco-friendly environment, use of renewable energy and recycled/recyclable materials, effective use of landscapes, effective control and building management systems and improved indoor quality for health and comfort. It uses less energy, water and natural resources than a conventional building. It also creates less waste and provides a healthier living environment for people living inside it compared to a conventional building.

In terms of appearance or use, there is no difference between green buildings and conventional ones. Green buildings have been observed to have tangible and intangible benefits. The tangible benefits such as the economical advantages are not immediately visible. However, the lifetime payback is much higher compared with that of conventional buildings, which mainly accrue from operational cost savings, reduced carbon emission credits and potentially higher rental or capital values. The intangible benefits such as social advantages are due to the positive impact of green buildings in the neighbourhood environment.

Whether, a new green building is created or an existing building is retrofitted to be made "green", it is expected to minimize storm water runoff, reduce the risk of erosion, minimize habitat disturbance, protect open space and save energy. To assess whether the structures meet these objectives or not, many countries have developed tools to evaluate the performance of the structures on a range of parameters over a definite period of time say one year or six months. These tools are standards of energy efficiency and are called rating systems. Green Rating for Integrated Habitat Assessment (GRIHA) and Leadership in Energy and Environmental Design (LEED) are the rating systems currently in use in India. Indian Green Building Council (IGBC) has launched 'IGBC Green Existing Building O&M Rating System'. Through its implementation existing buildings can be made sustainable over the life cycle of the building. It is the first rating programme developed in India, exclusively for existing building stock. It is based on accepted environmental principles and strikes a balance between known established practices and emerging concepts. The system is designed to be comprehensive in scope, yet simple in operation. The payback period for existing green buildings range from two to seven years, depending upon their certification level.

III. Scope Of Present Work

The scope of the present work is limited to the mapping of the various plans of an existing institutional structure in building modelling software, here Autodesk Revit Architecture, and obtaining the energy consumption patterns of the existing structure on the basis of the other input like location, rainfall and climatic data. On the basis of the results obtained, the structure under consideration has been rated as per the IGBC Criteria for existing building. Suitable measures in the form of rainwater harvesting, passive downdraught evaporative cooling, usage of reflective paints and thermal insulation to name a few have been suggested to enhance the energy efficiency of the existing structure. A cost comparison has also been carried out to validate the economic viability of the same.

IV. Methodology

The B-Block plan was obtained by the Estate Department of the Nirma University; these plans were implemented in Autodesk Revit Architecture 2016 Software. The model generated was exported in Green Building XmL format (gbXmL) which is compatible with Green Building Studio of Autodesk. The isometric view of the model is shown in Figure 1 below.

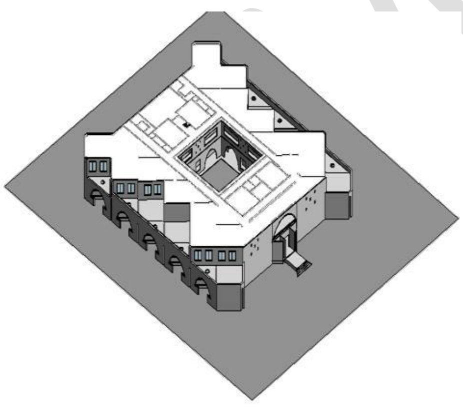

Fig. 1 Isometric View of B-Block Model

Green Building Studio (GBS) is cloud based energy-analysis software which enables architects and designers to perform whole building analysis, optimum energy consumption and work toward carbon-neutral building designs. The model was uploaded to cloud using the GBS software and it was analyzed for energy and other data accordingly. The software assumes a large number of data which is not mentioned by the user and generates file for each kind of assumption it has taken giving relevant energy analysis report and thus a comparative statement to the user for the implementation of the various energy efficient measures. Studying the reports generated by the GBS software various measures were suggested to make the building more sustainable. Due to unavailability of the detailed structural, architectural and MEP plans the suggestive measures were studied and calculated manually.

V. Results And Discussions

The changes suggested include factors keeping in mind the IGBC factors to increase the IGBC ratings to signify how green the building is such as energy efficient fixtures, insulated roof and wall material rain water harvesting system and passive cooling systems.

Taking the electric fixtures in consideration two changes have been suggested out of the many options considered like sensors, different type of tube lights and different air conditioners.

The idea is to use Light Emitting Diode (LED) tube lights and LED bulbs instead of fluorescent bulbs and tube lights in such a way that the output that is the amount of lumens generated by both the tube lights remain equal but the energy saved along with its life is advantageous over the latter. On comparing the cost for over a long period of time adding the initial investment also, on an average 5.73 lakh rupees can be saved per year from tube lights and also Rs 5234 from led bulbs. A comparison between LED Light Effect in 9x 9 m Room (First Image) and 36 W Fluorescent Tubelight Effect in 9x9 Room (Second Image) as generated by the open source software Relux has been shown in Figure 2 below.

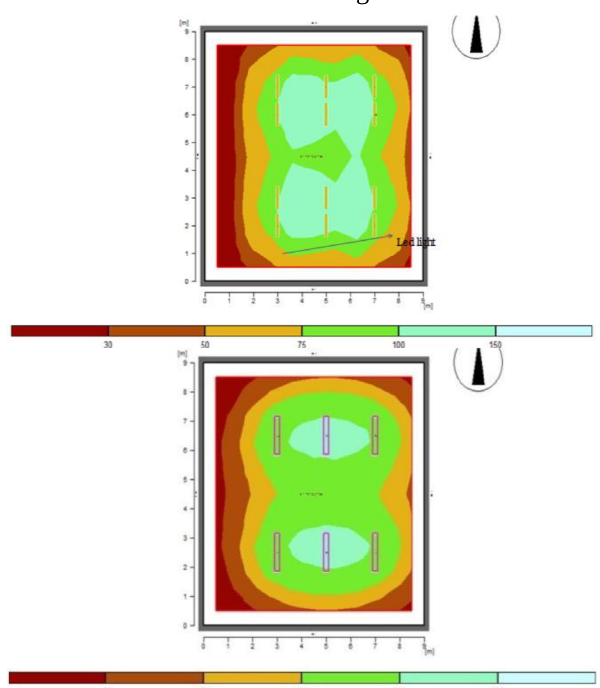

Fig. 2 Comparison between LED Light Effect in 9x 9 m Room (First Image) and 36 W Fluorescent Tubelight in 9x9 Room (Second Image) as generated by Relux

The Air conditioners used in the building are 1.5 ton with no star rating. Air conditioners of the same capacity are suggested with 5 star rating. The units per hour for a 5 star Air conditioner is 1.52 whereas it is 2.12 for a 5 star air conditioner. The total cost saved per day is RS 924 and is around Rs 2.58 lakh taking 280 days of regular working of college.

As no rain water harvesting system is present, it is suggested to use one in such a university with large roof area having agood potential of rain water harvesting. The design is based on the Central Public Works Department (CPWD) guidelines. Taking into consideration the following data: Roof top area = 4021.48 sq.m.; run off coefficient = 0.8; coefficient of evaporation = 0.85; and amount of rainfall in Ahmedabad = 803.4 mm, the total rainwater which can be harvested is calculated to be 2196.983 cu. m. and the pipe to be used for the same is of 150 mm diameter assuming that 50% of the harvested rainwater goes to the storage tank of the existing sewage treatment plant available in the campus.

Considering the insulation criteria either the roof material could be changed or the insulating paints could be applied. The second option is chosen considering the high cost of changing the roofing materials which was not as beneficial as using the insulating paints which are capable of reducing the room temperature of room by around 7 degrees and cost around Rs 20/sq feet along with application charges. This is quite cheap considering the return on investment by reducing the load of air conditioners and keeping the non air conditioned room cool. The other benefit is that the Volatile Organic Compounds (VOC) content of these paints is very less giving a final comfortable and healthier environment.

The other material suggested is the thermal break windows. The cost of such windows is high compared to other conventional windows i.e., the thermal break windows cost around Rs 1700 per square feet where as the conventional windows cost around Rs 430 but the insulation properties lead to lot of electricity saving and also provide comfort.

The last system change suggested is the Passive Downdraught Evaporative Cooling (PDEC) system which with high one time initial investment will be a permanent set up in the institute reducing the air conditioning loads basically by keeping the rooms cool by the method of evaporative cooling. Such an arrangement helps in the reduction of the temperature by 5-10 degrees Celsius.

Therefore using all these recommendations in the building under consideration and comparing it with the IGBC ratings of the building we see a rise of 20 which includes 14 ratings for improved electrical efficiency, 4 ratings for thermal comfort and indoor air quality, and 2 ratings for rainwater harvesting.

VI. CONCLUSIONS

The report generated by Revit is based on many assumptions taken by Revit itself to do proper analysis such as area lighting, space cooling etc. In real life practice it is not a good approach to design or retrofit on the basis of assumptions. Thus use of Revit should only be put into place when appropriate data is available. And it can be used in a much beneficial way where the building is to be designed rather than where it is already designed and it is to be retrofitted.

In retrofitting it is not possible to make changes in the original construction materials of the building as it would lead to high cost to break the structure and rebuilt it. Thus other factors are considered such that over all energy consumption is reduced though the initial cost might be high compared to the conventional methods but giving better return environmentally as well as economically.

VII. FUTURE SCOPE

The use of the concepts of building information modelling for achieving sustainable development has just initiated a new area of study, which has a wider scope in the years to come. Some of them could be:

- The present work has been performed for hot and dry climate in the Indian subcontinent. More such works can be carried out for structures existing in other climatic conditions. Some of these could be hot and humid, cold and dry, temperate etc.
- Further, future research work should focus on the development of region specific BIM software packages so that decision making process can become more accurate and predictable while planning and designing a green building or retrofitting an existing building. The current work uses a software package suited for American conditions and hence the results obtained could be erroneous.
- The PDEC system design has been left untouched in this project work. Feasibility of implementing such a system in the current existing building can be carried out.
- Further the economic viability of implementing these reforms in the university on a pilot basis needs to be studied.
- How these recommendations impact the micro-climate of the university area is one area where in-depth analysis has to be carried out.

ACKNOWLEDGMENT

The authors would like to thank the scientific community for carrying out note worthy research over the years in the areas of sustainable development and building information modelling without which the above experimental study would have been incomplete. The authors would like to thank their families for their constant support at every step during the course of this experimental work.

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