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Life Cycle Analysis of a Green Building

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Abstract - *Building facility has been a human need for most of the activities. On the other hand, building construction has both positive and negative that not only in construction but also in the operation and maintenance phase. Building operational phase and its life cycle is a significant factor in which it is responsible for the reduction in energy, water and material resources. Today, buildings worldwide account for up to 40% of total end-use energy. Developed countries consume most of their energy in the building sector. There is over 50% saving potential in the building sector and thus it is considered as a potential sector to meet the challenges of global energy and climate change. "Going Green" seems to be the new and popular thing to do. Nowadays everyone is talking about green construction. However, there is a way in which common can afford it. It is an easy statement to make but gives very little detail of how one will address such a global issue.*

Key Words: **Revit MEP, Revit Architecture, Life Cycle Analysis, Green Building Material (GBM).**

I. INTRODUCTION

1.1 What is a green building?

A Green Building, also known as a sustainable building, is a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. To build a green building we have to consider the parameters such as sustainable site, water resources, energy & atmosphere, materials & resources and indoor environment quality.

Although new technologies are developing constantly to complement current practices in creating greener structures, the common objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Efficiently using energy, water, and other resources
- Protecting occupant health and improving employee productivity
- Reducing waste, pollution and environmental degradation

1.2 Why go for green building?

Nowadays due to excessive population growth, people require several houses to stay within but they generally built a normal building in which energy consumption is more which inefficient. However, the energy source is decreasing very fast, so by implementing green buildings throughout the world, we can reduce conventional energy consumption and so by reducing pollution.

1.3 Problem statement

Enhancing the use of green building materials in construction instead of traditional building materials that helps to improve environment quality by making models of cost an energy consumption with the help of Revit Architecture and Revit MEP.

1.4 Aim

Aim of this research paper is to identify various ways from which we can reduce operational cost and maintenance cost required for energy consumption in green building.

1.5 Objectives

- To estimate cost required for green building construction and normal building construction by preparing models in Revit software.
- To analyse the difference between cost of green building materials and normal building materials after estimation.
- To find energy required for both buildings in operation period by doing a study of Energy models made in Revit MEP.
- To find out how much energy and units of electricity will green building save because of used green building materials.
- To estimate time required to recover extra cost required in green building construction by saving cost in energy consumption in maintenance and operation.

1.6 Motive of green building construction

The green building movement originated from the need and desire for more energy efficient and environmentally friendly construction practices. There are many motives for building green, including environmental, economic, and social benefits. Also known as, sustainable design, this approach integrates the building life cycle with

each green practice employed with a design-purpose to create a synergy amongst the practices used.

1.7 Components of green buildings

Following components of green building needs to be studied:

a) Material efficiency (using sustainable construction materials and such other strategies)

b) Water efficiency (using low flow plumbing fixtures, rooftop rain harvesting and porous paving)

c) Energy efficiency (using energy conservation Building Code ECBC 2007, Smart lighting fixtures with control and renewable strategies)

d) Indoor environment quality (using microbial resistant materials, heating & cooling system ensuring ventilation and such other strategies)

e) Waste management (using green architecture standards, producing less amount of waste, harvesting waste and reusing material, deconstruction and such other strategies.

1.8 Life cycle analysis (LCA)

Life cycle analysis is said to be analysis of building products. It is 'Cradle to Grave' analysis; LCA starts from raw material to the ultimate disposal point. The stages of LCA include selection of raw materials, manufacturing, distribution and installation to ultimate reuse or disposal.LCA can help avoid a narrow outlook on environmental, social and economic concerns by assessing a full range of impacts associated with all the stages of a process from start to end

1.9 Modelling in Revit software

The Revit allows users to manipulate whole buildings or individual 3D shapes. Users can create realistic families ranging from furniture to lighting fixtures, as well as import existing models from other programs. Revit families can be created as parametric models with dimensions and properties. This lets users modify a given component by changing predefined parameters such as height, width or number in the case of an array. In this way, a family defines a geometry that is controlled by parameters, each combination of parameters can be saved as a type, and each occurrence of a type can contain further variations

Modules of Revit Autodesk:

1. Revit Structure
2. Revit Architecture
3. Revit MEP

Revit Structure is useful for the design of structural elements. This module includes design of foundation, column, beam and slab.

Revit Architecture is used for all architecture aspects of building construction. It includes internal design of building such as, doors and windows.

Revit MEP is a tool, which analyse all mechanical, electrical and plumbing activities of building construction. Revit MEP is used to analyse simulation models of buildings

1.10 Comparison of Green Building Construction and Normal Building Construction with the help of Revit software.

For this comparison, Revit Autodesk is a very useful software. Revit Autodesk Software helps to find out the quantity of material required for construction by analysing building models. These material quantities help to find cost required for materials. This software is also helpful for the calculation of electricity required for building in a year by analysis of energy simulation models made in Software. These energy simulation models can used to calculate cost required for energy consumption throughout a year.

II. PROPOSED METHODOLOGY

The methodology started with the literature collection related to the green building materials and journals associated with the topic. Building model was prepared in Revit Autodesk Software from details taken through Case study. After building model and its simulation, cost of building materials and energy required in building life cycle was analysed. With the help of Revit Autodesk and Microsoft Excel, this cost comparison between green building and normal building was carried out.

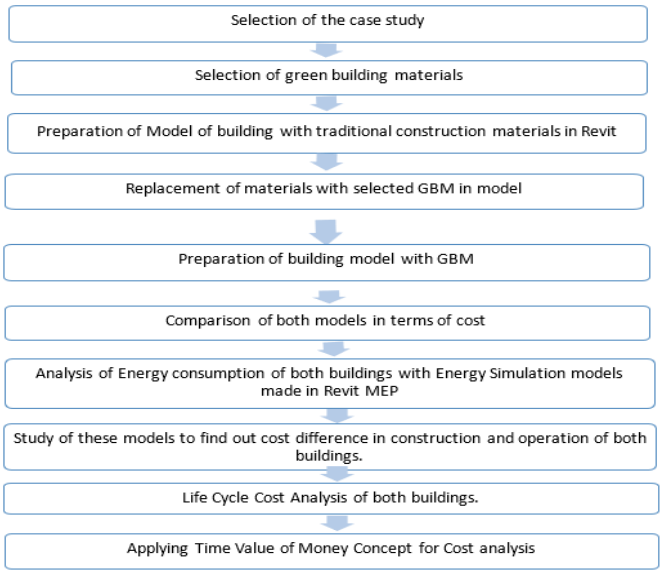

Fig 2.1: Research Methodology Chart

III. LITERATURE REVIEW

This research paper is a case study of green building cost analysis. The concept of green building in the construction industry is indispensable for mitigating environmental issues such as waste, pollution, and carbon emissions.

Some countries have Green Building rating tools. Development of building construction is depended on building investors or owner initiation, so this research conducted to get the building aspects that have significant effect on the attractiveness using The Green Building Concept. The method in this research is work breakdown structure method that detailing the green building activities. The particular activities processed to get the cost elements for the green building achievement that it targeted to improve better than conventional building.

This paper describes what green means, green labelling program and conditionally green material like bamboo, concrete forms and low VOC paint. Each of these have similar yet quite different versions of rating systems and qualifying characteristics that they look for in a green building. Some focus on only the results and completely overlook what happens during the gathering and manufacturing of materials.

The purpose of this paper is to highlight how sustainable building material can contribute to lessen the impact of environmental degradation, and generate healthy buildings, which can be sustainable to the occupant as well as our environment

A growing body of literature suggests that green buildings outperform conventional (non-green) buildings in all performance areas, particularly in term of economic benefits, which are typically, assessed using life cycle costing as an economic appraisal technique. However, reports and studies show a performance gap once buildings are occupied. Therefore, merely relying on performance simulation and modelled design is not satisfactory to convince building owners and real estate investors that green building is a rational economic decision and a cost-effective long-term strategy

In this paper two cases for a same building are studied in which one include the conventional approach while the other include relative sustainable approach. This paper states that now-a-days due to excessive population growth, people require more number of houses to stay within but they generally built normal building in which energy consumption is more which inefficient. However, the energy source is decreasing very fast now days, so by implementing green buildings throughout the world, we can reduce the conventional energy consumption and so by reducing pollution.

IV. CASE STUDY

4.1 Site selection

For this project, the first step is to finalize one residential building completed by using traditional construction materials. The site has been selected, which is a G+4 storeyed residential building located in Pune. Area of this site is 385.717 SQM with total F.S.I. of this building is 1.75. There are total eight no. of flats and providing separate parking for each flat. Finalisation of green building materials, which can replace used construction materials, is next step. Fixing of energy generation equipment such as roof top windmill, solar panels also important to reduce non-renewable energy sources use. Provision of proper water harvesting system can help to increase water efficiency

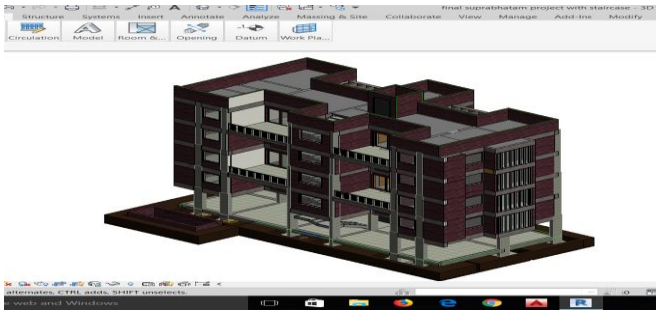

Fig 4.1 G+4 Residential building selected as a case study

4.2 Selected green building materials

a) Porotherm Bricks

Porotherm Smart Bricks are 60% lighter than conventional brick thus allowing substantial savings on structural cost due to reduction in dead load. This also allows for faster construction and ease of handling.

Fig 4.2 Porotherm Bricks

Source: Wiener Berger official Website

Advantages of Porotherm bricks

- Lightweight, Strong & durable
- Excellent Thermal and Sound Insulation

• Provides greater durability

b) EnvoPlast

EnvoPlast is used in place of traditional plastering, it is a convenient and easy-to-use plaster that is stronger, looks smooth and binds better to its base. Prepared with a mix of special binders and additives, EnvoPlast is water resistant with high quality and sustainability.

Walls with EnvoPlast have lesser chances of developing cracks in comparison to conventional methods. EnvoPlast is a plaster made by the right composition of raw materials. It passes through stringent quality controls and made with graded sand, which enhances the durability. EnvoPlast is not only convenient for use but it also maintains cleanliness at work place and considerably reduces wastage than conventional methods at the time of execution.

Fig 4.3 Envoplast

Source Envoplast official website

c) Bamboo Flooring

Bamboo flooring is becoming a popular and attractive alternative to hardwood flooring because of its cost, durability and eco-friendly properties. Bamboo is a regenerating grass so it grows much faster than hardwood trees, making it more sustainable and environmentally friendly. Flooring made from bamboo is a dimensionally stable product.

Fig 4.4 Bamboo flooring Revit Autodesk image

d) Eco Tiles

A unique composition of naturally occurring puffed siliceous material, white cement blended with fibrous polymer. It acts as radiant barrier, provide significant resistance to heat transfer and increases the building comforts. In addition, helps Reducing in Energy Costs. Eco tiles are white insulating fibrous green tiles made up of White cement, special insulating additives fibre filaments. Weight of eco tiles is 37.66 Kg/m2. Eco tiles are impervious to water. Size of one Eco tile is 12" x 12" with 25 mm thickness.

Properties of Eco tiles:

- 100% environmentally, eco-friendly tiles Aids in reducing HVAC power consumption
- Durable, low thermal conductivity, Permanent and long lasting

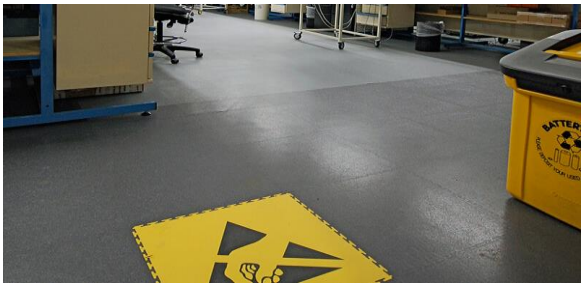

Fig 4.5 Eco tile flooring

Source: Eco tile flooring official website

e) Rice husk Ash

Rice Husk Ash is a green building material used in concrete. For gain of a design strength of concrete only 25% of total cement replaced by RHA.

The following properties of the concrete are altered with the addition of rice husk:

- RHA is very important component in green concrete.
- The heat of hydration is reduced. This itself help in drying shrinkage and facilitate durability of the concrete mix.
- There is a higher increase in the chloride and sulphate attack resistance.

4.3 Other Energy generation Equipment used

- **Solar Panels**

Investing in rooftop solutions leads to great savings, while protecting the environment. Tata Power Solar offers solar rooftop for home. Save and Earn from your idle rooftop space. Tata solar power is one of the leading companies in solar power generation in India. Tata solar power provides

rooftop solar panels with various varieties on the basis of area available. Central government also provides subsidies for provision of solar panels.

- **Rooftop wind turbine**

Archimedes Green Energys (P) Ltd., is a Hyderabad based company that came out with India's first Rooftop Wind Turbine to generate Green and sustainable energy. The silent rooftop wind turbines are capable of generating half of an Indian household's energy needs in a renewable, clean and green way (As wind power is one of the cleanest sources of renewable energy in the world).

Fig. 4.6 Windmill

Source Archimedes Green Energy official Website

V. RESULTS

This research is about comparison of cost required for construction of normal building and green building. As mention above G+4 residential building selected for case study. First model of this case study was made with traditional building materials. This model also gives volume of all building elements. This volume of elements assists to calculate quantity of materials required. Second model was made with green building materials. After same method, which based on volume of elements, quantity of materials was calculated.

After that, total cost of traditional materials, which can be replaced by green building materials, was calculated. Similarly, cost required for green building materials was calculated.

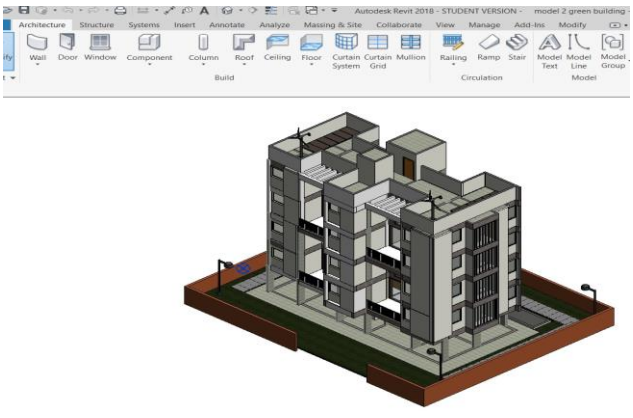

Fig. 5.1 Building models made in Revit Software

- Total cost of traditional materials which can replaced by green building materials was INR 24.65 lakhs.
- Total cost of green building materials is INR 29.40 lakhs. Also, energy generation equipment cost is nearly INR 3.57 lakhs.
- Green building took INR 8.31 lakhs extra than traditional building for materials and energy generation equipment.

Table 5.1 Cost comparison of materials

Cost Comparison			
Materials	**Cost**	**Green Material**	**Changed cost**
Red Bricks	₹ 800275.00	Porotherm Bricks	₹ 894960.00
Steel	₹ 887235.69	Reduced Steel	₹ 754150.34
Plaster	₹ 38252.80	Envo Plast	₹ 56272
C+S+A	₹ 513992.00	C+RHA+S+A	₹ 534996
Tiles	₹ 226050.00	Wooden and EcoTiles	₹ 371853.50
Ceiling	₹ 0.00	Ceiling Acoustic Tiles	₹ 328066
Energy Generation Equipment	₹ 0.00	Solar Panels and Wind Turbine	₹ 357112
Total Cost	**₹ 24,65,805.49**		**₹ 32,97,411.07**

- In this stage, analysis of building was done with the help of Revit MEP. In Revit, all building element analysed by simulation technique, on the basis of their properties.
- From first energy simulation model electricity bill for one year was estimated nearly 20.7 USD/m2. In this stage, area taken into account was parking floor of 116 Sqm.
- From first energy simulation model electricity bill for one year was estimated nearly 20.7 USD/m2 for same area.
- After study of all energy simulation models, concluded that energy cost per year for traditional material building is equal to 1 lakh 69 thousand INR and cost require for energy consumption in green building is 1 lakh and 56 thousand INR only.
- Renewable energy generation equipment helps to reduce cost required for energy used in building life cycle.
- According to Tata solar power, provided solar panels generate 4320 KWh per year. This energy saves INR 22,248. Rooftop wind turbine also benefits nearly 45000 INR.
- These wind turbines are designed by 1 KWh at 12 m/sec wind speed. In actual conditions, it may not possible to get this wind speed. Hence, energy

generation from wind turbine taken as 25 % of its designed capacity. Total two wind turbines generate 8760 KWh combined. This energy costs nearly equal to INR 44 thousands.

- In total renewable energy generation also helpful for generation of 13000 units annually. Which helps to save nearly INR 67 thousand annually for energy consumption.
- After study of energy simulation models, we get to know that this G + 4 residential building requires 32.8 thousand units for energy consumption.
- From the following specification, we can gain future cost incurred for various usages in building:
- After material and energy cost, maintenance cost of a material has also an important role.
- Wind Turbines have maintenance cost for their batteries INR 40,000 per 5 to 6 years. Life span of a Wind turbine is nearly 15 years.
- Solar panels reduce their efficiencies per year by 0.5 %.
- According to manufacturer of a Wooden tiles, it also has life span of nearly 15 years.
- From all these studies, we come to result that by using these green building materials and energy generation devices we need 15 years to recover extra cost require during construction. Also, In 30 years, Green Building benefits nearly INR 9 lakhs.
- In practical, this value of this cost won't be same after 30 years. Hence, to estimate value of this cost after 30 years, Time Value of Money should be calculated for future studies.

Time value of money,

Here,

i = interest rate or other return that can be earned on the money

t = Number of years to take into consideration

n = Number of compounding periods of interest per year

Sample Calculation:

FUTURE VALUE = PRESENT VALUE x $[1 + i/n]^{nt}$

For 10 years in Normal Construction,

FV =4154186.67 INR x $[1 + 0.074]^{10}$

FV = 8482596.75 INR

For 10 years in Green Construction,

FV = 4458695.08 INR x $[1 + 0.074]^{10}$

FV = 8755073.20 INR

- After calculation we come to result that TVM of normal building after 30 years is INR 6.41 Cr. TVM of green building is INR 5.62 Cr.
- From all this analysis, we can save Nearly 80 lakhs INR after 30 years, if inflation taken into account.

VI. CONCLUSIONS

- Green building construction is generally 20 % costlier than normal building construction because of its material costing.
- After well planning this cost can be optimise and also recover in buildings life cycle period.
- To analyse building life cycle Revit Autodesk is very useful Software. Revit Autodesk can assist in planning, execution as well as forecasting of a building work.
- Green building helps to reduce energy consumption in its life cycle. This increase in energy efficiency helps to recover extra material cost required during construction.
- Renewable energy is an important factor in energy consumption. Solar energy and wind energy have very powerful source of energy.
- We can save up to 40% of energy by providing green building and renewable energy generation equipment.
- Green building is very helpful for improve indoor environment quality, but for average income family, cost is very important factor. Therefore, this cost analysis is very important.
- Green Building helps to reduce Carbon emissions and helps in reduction global warming.

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