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Economic Evaluation and Comparison of Green Building with Conventional Building using Carbon Footprint and Embodied Energy Calculator developed using MATLAB

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Abstract- *The idea of Green architecture, also known as "Sustainable architecture" or "Green building," is the design and construction of buildings in accordance with environmentally friendly principles. Green house strives to minimize the number of resources consumed in the building's construction, use and operation, as well as lessening the harm done to the environment through the emission, pollution and waste of its components. Embodied energy is the amount of energy consumed to extract, refine, process, transport and fabricate a material or product (including buildings). It is often measured from cradle to grave. Likewise, embodied carbon footprint is the amount of carbon (CO_2 or CO_2e emission) to produce a material.*

This paper aims to develop a MATLAB program to estimate the carbon footprint and embodied energy of the building and suggest simple economical way of constructing a green home. Also, the structural stability of conventional building and green building is compared using ETABS Software.

In an effort to improve the accuracy of embodied energy and carbon footprint calculations, this paper presents a tool that estimates the total carbon footprint and embodied energy of buildings by taking into consideration various project characteristics (e.g size, location, material choices).

Key words: *Green architecture, Embodied energy, Carbon footprint, MATLAB, ETABS*

1. INTRODUCTION

Various researches prove that construction industry consumes large quantity of environmental resources and it is one of the largest polluter of the environment that is it contributes approximately 30% to total global GHG emissions. We know, every year millions of new buildings are being constructed and new construction materials are being introduced.

Now, green construction practice has gained tremendous popularity these days due to the increased population and pollution. It is the application of processes that are environmentally responsible and resource-efficient. Green building is considered as a way for the building industry to move towards protecting the environment. Main aim of this construction practice is to obtain a balance between economic, social and environmental performance in implementing construction projects.

Every building has a life time. If we consider this as a cycle, the building has its life cycle from cradle to grave. Therefore, in order to study the emissions caused from a building, a complete life cycle analysis is needed. This is an internationally standardized method. So once the carbon footprint and embodied energy of the building is known, a strategy can be developed to reduce its impact on the environment.

2. SCOPE

The scope of this paper highlights the benefits of green construction. We know, overall benefits of a green home includes energy efficiency, design flexibility, resource conservation, better indoor environmental quality etc. Also, reducing a buildings carbon footprint reduces its running cost, raises property values , improves LEED scores etc., thus the buildings become environmentally responsible, profitable and better place to live and work in.

Research on green building design and materials is already firmly established. There are many global platforms that discusses on environmental protection which aims to create a better earth. Green buildings when compared to conventional buildings are same in building use but differ in operational savings and takes into account for human comfort, indoor quality and environment and also enjoys the benefit of saving energy.

Considering the relevance of this topic, green construction is one of the most important and one of the most discussed topics worldwide in this age of global warming and climate change. The goal of this research is to assess the environmental performance of a high-rise building in terms of carbon footprint and embodied energy consumption. Here the calculation of carbon emission and energy consumption during a buildings life cycle exposes the environmental impacts of that particular building. This work can also be used for future references.

3. OBJECTIVES

1. To develop carbon footprint and embodied energy calculators
2. Validation of results from calculator by comparing with the manual calculation results
3. Check for the structural stability and economic savings of green building compared to conventional building

4. METHODOLOGY

In this work, Life Cycle Assessment(LCA) method for the estimation of a high rise residential building under construction is adopted. . This paper focuses on construction stage and the usage stage.

4.1. COLLECTION OF DATA

The accuracy and validity of Life Cycle Assessment method is reached from the datas collected. Necessary data required to go on with the assessment covers the details of building namely location and purpose, supply and quantity of construction materials used, construction machineries and equipments used and finally electrical equipments used during usage stage.

4.2. INVENTORY ANALYSIS

It is a quantitative data analysis of resource, energy consumption or emissions to the environment. All the floor plans and the foundation plan were taken, then the length, breadth and height of the foundation wall was multiplied to get the quantity of materials used, subsequently the same was done for all the walls and the final quantity was acquired. The quantity of plaster was calculated by the surface area of the walls multiplied by the thickness. The total diesel consumption for the supply of materials and machinery at site, electricity consumed during construction stage and usage stage (for 50 yrs life span considered) are also calculated.

4.3. IMPACT ASSESSMENT

To estimate the effectiveness of the organised works done, carbon emission and energy consumption are determined. Generally, carbon footprint and embodied energy are calculated from mathematical equations ie

Carbon emission ($KgCO_2e$) = Q x C

Tot. Embodied Energy(MJ) = M_{wt} x EE_{coef}

Where,

Q = Quantity of Material / Power /Diesel/Petrol Used

C = Carbon Emission Factor

M_{wt} = Quantity Material / Power /Diesel/Petrol Used

EE_{coef} = Embodied Energy Coefficient

4.4. DEVELOPMENT OF CALCULATOR

The programming is done on the editor window of the MATLAB software. Once the program is run, the command window appears and required data is fed. The results are displayed on the command window once all the details are entered.

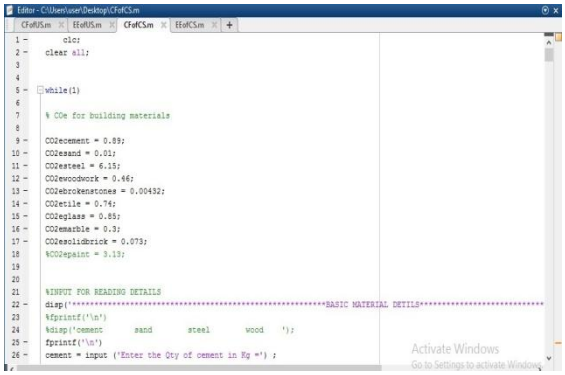

Fig -1: MATLAB calculator (editor window)

Fig -2: Command window

4.5. STRUCTURAL STABILITY

When idea of green construction is put forward, the structural stability of the building is taken into account. Here in this paper in order to make a comparison between the stability of a conventional building and green building, ETABS software is used. Modelling of the building was done and displacement and drift was compared. Here, once the conventional building is analysed, green building with 15% replacement of cement with fly ash for the same floor plan is also analysed and both the results are compared.

5. RESULTS AND DISCUSSION

Carbon footprint of each building is different depending on their location, purpose, material choices etc. The results of manual calculation and that obtained from the calculator developed using MATLAB were compared. It was observed that both results are the same. This concludes that the MATLAB calculator can be used to reduce the time and energy spent for the manual calculation of carbon emission and embodied energy. Here, the input of total quantity of materials directly gives you the total corresponding carbon emission or the embodied energy. Also, the calculator developed can be used to perform any number of iterations the result comparison for different quantities of materials can be done.

Various plans for mitigation of carbon emission are being practiced which includes replacing cement with fly ash , post tensioning, using low U value materials , zero or low VOC paints ,BEE rated appliances etc. It was observed that on replacing 15% of cement by fly ash about 14.5% reduction in carbon emission was obtained.

The Chart 1 shows the variation in carbon emission on replacing 15% of total cement by fly ash. Similarly, the reduction in carbon emission on providing post tensioning(PT) was calculated and the findings are shown in Chart 2 and Chart 3.

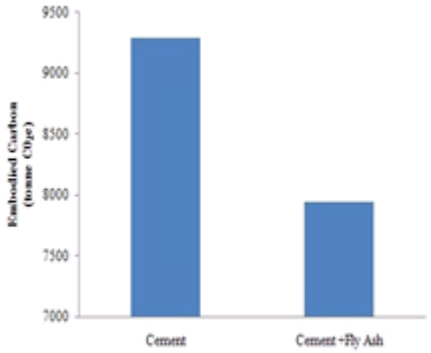

Chart- 1: Variation in carbon emission on replacing 15% cement by fly ash

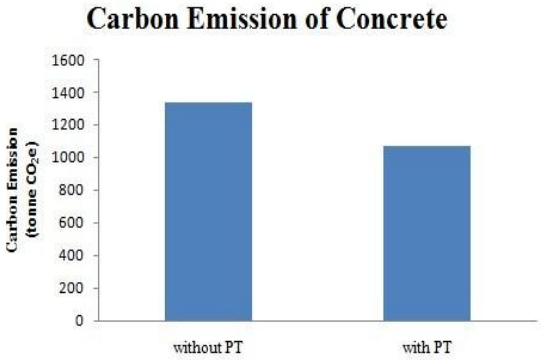

Chart- 2: Variation in carbon emission in concrete without and with PT

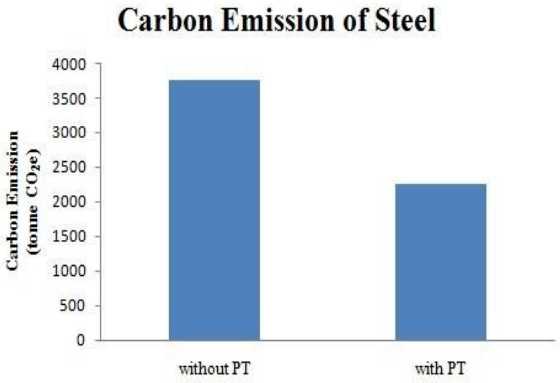

Chart- 3: Variation in carbon emission in steel without and with PT

Considering the usage stage of the building, when the total electronic equipments that might be used was replaced with BEE rated appliances, a considerable reduction in carbon emission was observed and is shown in the Chart 4.

It was observed that on replacing usual domestic appliances by BEE rated appliances has reduced the amount of carbon emission by 36%.

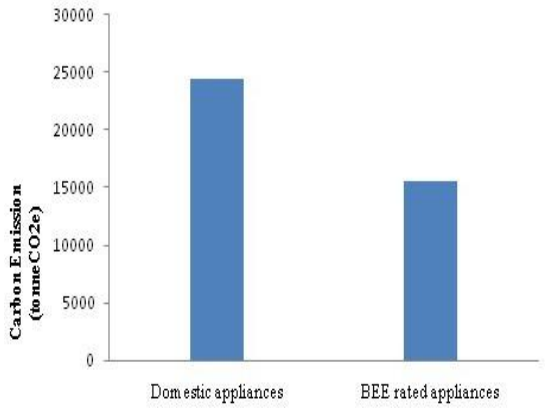

Chart- 4: Variation in carbon emission on using BEE rated appliances

The structural stability of a green building (considering replacement of 15% cement with fly ash) compared to the conventional building, the results for storey displacement and storey drift are shown in Chart 5 and Chart 6. It is seen that green building shows slightly better performance that is it has lesser value of drift and displacement.

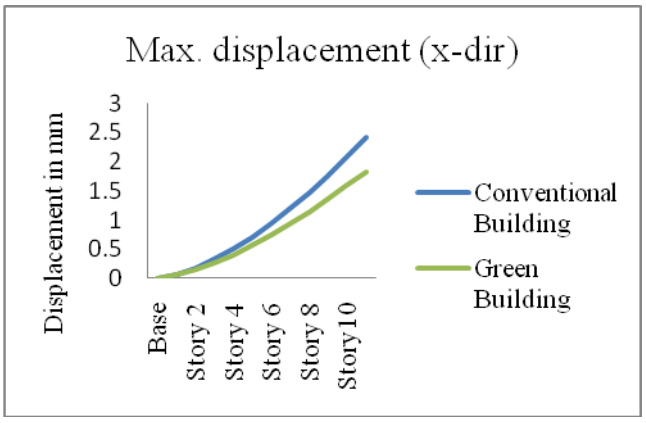

Chart- 5: Comparison of maximum storey displacement

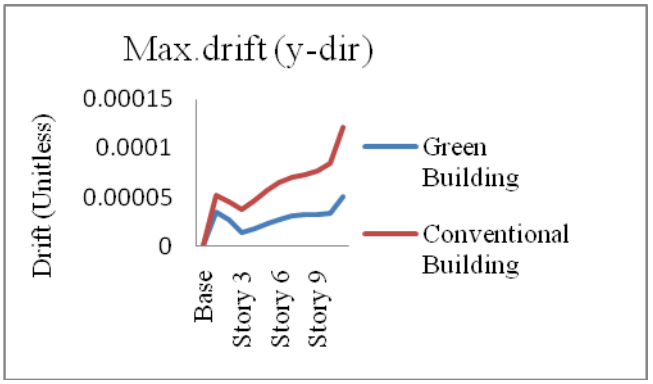

Chart- 6: Comparison of maximum storey drift

Finally taking into account the economic variations between conventional construction and green construction, several studies suggest that green construction results in economic savings by improving employee productivity, increasing benefits from advancement in health and safety .Also, green buildings cut costs due to reduced energy, water use, lower long-term operations and maintenance costs. A 15% reduction in material cost was observed when 15% of cement was replaced with fly ash when only the material cost was considered.

6. CONCLUSION

The purpose of this study is to estimate the carbon emissions and energy consumption of a building during its life cycle by Life Cycle Assessment method.The various factors affecting the design of Green Buildings have to be considered and each of these parameters should be analyzed. The mathematical modelling is done with the help of MATLAB software and this MATLAB calculator developed is used as a tool for uncomplicated calculation of carbon emission and energy consumption. As mentioned the calculator results and that from manual calculations were the same which means this calculator is a substitute for lengthy manual calculations. Developing such tools also helps to reveal the individual contribution of each building and offer solutions for the same. Now taking into account the structural stability of green buildings and conventional building, the results were alike.

Additionally the green buildings can also be delivered at a price comparable to conventional buildings, with investments recovered through savings in operational cost and with the right design features, creating a better productive workplace.

CONFLICTS OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

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