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Development of Environmental Life Cycle Assessment Tool for Residential Building

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Abstract : *Environmental & health issues nowadays represent attracting & increasing attention in our society. Understanding the importance of quality of their surroundings, people are beginning to pay attention towards their consumption patterns and the related potential impacts on the environment and wellbeing of the current as well as future generation However, design and construction of residential buildings is often not conducted with an analysis of the life cycle costs and environmental impacts. In this paper, we outline an approach to the development of soft-tool for a life cycle assessment of residential building in terms of environmental impact such as carbon emission. It highlights the need for its use within the building sector, and the importance of LCA as a decision making support tool, also to facilitate the implementation of sustainable practices into building material selection. The two criteria as identified in this research are energy consumption and environmental impact.*

Keywords: *Residential building, Carbon Emission, Environmental Life Cycle Assessment.*

I. Introduction

In recent studies it has been seen that human activities are causing environmental related problems such as global warming, drought condition, floods, resource depletion etc. To reduce such problems large initiative are taken worldwide. During various national conferences held for environmental related problems it has been seen that built environment are causing more problems. Hence to reduce these problems caused by built environment preventive measures should be taken for which some innovative techniques are developed globally. One of the techniques is Life Cycle assessment (LCA). LCA is tool used for sustainable assessment of building. LCA is a tool used to evaluate energy and raw material consumption, emissions, and other wastes related to a product or system's entire life cycle. It characterizes and quantifies the inputs, outputs, and environmental impacts of a specific product or system at each life-cycle stage (ISO, 2006).

Greenhouse gases such carbon dioxide are major factor for climate change. Buildings are accounted for 40% of total carbon emission. Carbon is generated while building construction, using and demolishing period. The main cause behind carbon emission through the building is embodied carbon emission during construction material production such as cement, steel, brick etc. During our survey in Pune region in India it has been seen that contractors are not much concern about the embodied carbon emission of their building the reason behind this are: 1.Less awareness among the people about the carbon emission through building construction. 2. Inadequate supply of sustainable material. 3. Unavailability of any soft tool for calculation of carbon footprints of building.

II. Objective And Scope Of The Work

The main objective of this study is to develop an evaluation soft tool that would assist the decision makers in selecting the right construction material which will have less impact on environment as well which will have less market value. Material selection plays a very significant role in sustainable building right from the construction, operation and till demolition of building. During life cycle of material its extraction, processing, transportation, use and disposal can have negative effect on health and environment such as water and air pollution, energy losses and depletion of natural resources. Hence it is very important to choose right material for construction in planning phase only. In 2001 a study in India focused on embodied energy in load bearing masonry buildings. A brickwork building and a soil–cement block building were compared, and the study showed that the total embodied energy can be reduced by 50% when energy efficient building materials are used [1].

After developing the soft tool our aim is to use it for environment performance evaluation of residential building located in Pune so as to test the developed soft tool. By showing the test results to contractors our aim is to suggest them to calculate embodied co2 emission of their buildings and reduce it by replacing traditional building material by sustainable building material which has less carbon emission.

III. Methodology

The manufacturing of some materials results in a chemical release of CO2 to the atmosphere. The main cause behind carbon emission is combustion of fossil fuel during manufacturing process of construction material. The main objective is to develop soft tool for calculation of embodied carbon emission of residential buildings in which building design features, material selection for construction and their life cycle are taken into consideration. The basic principal used in the development of soft tool is cradle to gate concept of LCA. In which estimation carbon footprint of the building is based on energy and resource consumption by building during its whole life span. The general life span of residential building is considered as 5o years for Indian condition.

The soft tool for calculation of building carbon footprint is divided into two stages. In first stage, embodied carbon emission for building material used in construction is calculated based on type of material, quantity of material used and their carbon emission factor. A second stage includes calculation of carbon emission due to electricity consumption in building based on the number of electricity units used and their carbon emission factor. Calculation of embodied carbon at design stage of building using estimated quantity to be used in construction will give an idea to contractor about carbon emission through the building. Hence contractor can take preventive measures to reduce carbon emission by using sustainable material in design phase.

1. Embodied carbon emission in a life cycle of construction material.
   Carbon emission (Kg) = Quantity of material used in (Kg) X Carbon emission factor (Kg / Kg of material use) After calculation of embodied for each construction material by using above formulae the summation of all values give Total carbon emission due to material consumption for whole building.
2. Carbon emission due to electricity of consumption.
   Carbon emission (Kg) = Electricity consumption per year (Kwh) X Carbon emission factor (Kg / Kwh)
3. Total carbon emission = Total carbon emission due material use + Total carbon emission due to electricity.

IV. Execution Of Soft Tool

A web data based software is developed as "Soft tool for calculation of Building Carbon Footprints" to estimate the total environmental impact due construction of residential building. The input data for this software is Quantities of various material used in construction and electricity consumption. The output from software is carbon emission obtain in terms of kg of CO_2 equivalent. The testing is done by applying this software to a residential building located in Pune region for calculation of carbon footprints of that building.

Table 4.1 General Information

Building Type	Residential Building
Construction Type	Framed Structure
Location	Pune , India
Start of construction	2014

1. DATA ANALYSIS

As discussed above there are two types of data required for calculation of carbon emission of building. First is a detail of building material used in construction process like quantity of material, type of material and their carbon emission factor. Second type of data consists of details of electricity consumption by a building and carbon emission factor for electricity. The carbon factor for each material depends upon their production processes. In our soft tool, IPCC guideline carbon emission data are taken for calculation. Quantity of material used for construction is obtained from detail estimate of the project.

2. CARBON EMISSION CALCULATIONS FROM BUILDING MATERIAL

Construction materials are the backbone of the infrastructure of the modern society. For example, cement, which is one of the most commonly used materials in buildings, accounts for about 70-80% of the energy use in non-metallic minerals production, and it accounts for almost one-quarter of the total direct CO2 emissions in the construction industry (International Energy Agency, 2010). For calculation of carbon emission through the building materials quantity of each material required in construction process is calculated. After calculating quantity of material the weight of that material in Kg is multiplied by its density. Thus, total embodied carbon emission is obtained by using carbon emission formulae (1).

Ex. Quantity of concrete required for construction is 706 cubic meter and Density of concrete is 2400 Kg/m3
Weight of concrete= 706 X 2400 = 1694400 Kg.
Carbon emission factor for concrete is = 0.16Kg / Kg of concrete
Carbon emission due concrete (Kg) = 0.16 X 1694400 = 271104 Kg

Table4.2 Result of carbon emission for residential building.

Material	Co2 emission (Kg)
Cement	37250
Concrete	271104
Corr. Iron	219830
Bricks	71136
Concrete blocks	6177.6
Ceramic tiles	36694.75
Glass	15832.32
Timber	7002.36
Aluminum	54600
Gypsum plaster	28952

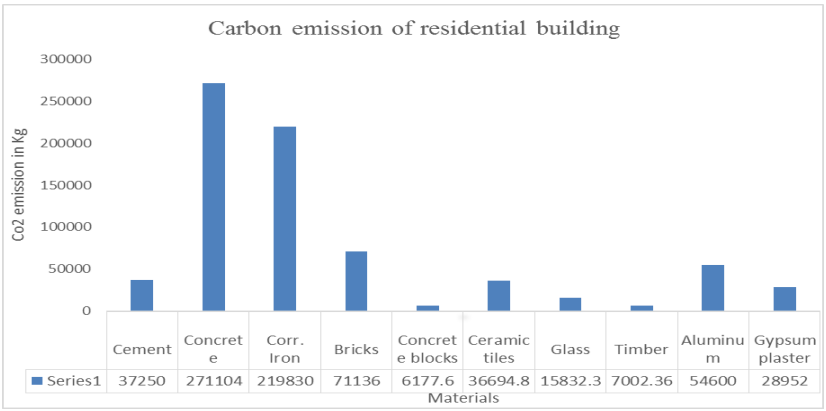

Fig.4.1 Carbon emissions graph from building materials

3. CARBON EMISSION THROUGH ELECTRICITY CONSUMPTION

Carbon emission through the consumption of electricity is calculated by collecting energy requirement of building in each month. The carbon emission factor for energy is depend upon the method of energy generation such energy generation by using hydrostatic, coal, diesel, thermal power plants, etc. Carbon emission factor for Indian condition is 0.87 Kg / Kwh for coal based power generation (coal energy report, 2005). By using formulae (2) the carbon emission due electricity consumption is calculated as follows.

Table4.3 Result of carbon emission through electricity consumption of residential building

Month	Co2 emission (Kg)
January	6699
February	7155
March	7004
April	7065
May	7612
June	7380
July	7261
August	7105
September	7095
October	7041
November	7009
December	6897
Total	85323 Kg / Year
Total Co2 emission through life span of building (50 years)	4266150 kg

V. Result and Conclusion

The total embodied carbon emission due to construction material for residential building is about 748579 kg. It has been seen that the major material responsible for embodied carbon emission are concrete, corr.Iron, Bricks, ceramic tiles, cement and aluminum. The results shows opportunities for use of sustainable material instead of conventional building material so as reduce the carbon emission.

The total carbon emission due to electricity consumption throughout the life span of building for residential building is about 4266150kg. To reduce this nonconventional energy sources such as solar energy, wind energy, hydropower etc. should be used. This study highlights the importance of material selection during the design phase of the building. The optimization of conventional material in construction ensures the high environmental and energy performance.

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