Journal of Basic and Applied Engineering Research
p-ISSN: 2350-0077; e-ISSN: 2350-0255; Volume 4, Issue 5; April-June, 2017, pp. 360-363

http://www.krishisanskriti.org/Publication.html

"Assessment and Reduction of Carbon-dioxide Emissions in the built Environment: Climate Resilient Structures–A Critical Review"

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Abstract—*The energy harnessed by human endeavors has seen an enormous intensification over the decade. However, in retaliation to imminent climate change issues, the energy consumed in diverse technological sectors has to be reduced and much attention needs to be delineated to carbon dioxide emissions augmenting to the GHG scenario. The construction industry has been significantly contributing to carbon emissions associated with materials used, methodologies adopted, and orientation of buildings. Through this paper an attempt has been made to study the varied methods of estimation and attainment of tangible reduction of carbon emission, for progressive migration towards zero-emission building target. It also emphasizes on the carbon emission calculations at sub-provincial level, the issues related to limited data and non-unified measurements inhibiting accurate data analysis and modelling approaches. An insight has been provided into standardized methodologies as life cycle analysis and decomposition analysis. Substantial attention has been given towards lowering the embodied energy of a building by reuse and recycle of materials for low emission and high efficiency, suggest a few mitigation strategies on reducing phase emissions, with an objective to establish a sustainable environment. However, further explorations have to be made on the concept of carbon-saving potential and climate resilience of structures.*

Keywords: Climate change, carbon dioxide emissions, life cycle assessment, embodied energy, building emission and orientation.

Introduction:

The constructional industry's ventures involve dissipation of energy in one form or another, accounting for nearly 40 % of the total worlds energy consumption and nearly 36% of global greenhouse gas emissions. Traditional construction methods, draw its source of energy from human potency or biomass energy which intern is used as a source of thermal energy. However, Modern construction methods employ variable amount of energy for a series of procedures such as Equipment production and material transportation augmenting to emissions of carbon dioxide. The structural elements contribute to nearly 84.2% of carbon dioxide footprint, associated with high raised buildings or superstructures, Residential, commercial, and industrial sector accounting for 60% of the emissions. On the other hand, significant attention has to averted towards reducing the embodied energy associated with structures, whose analysis although seems to be a trivial, is however necessary for interpretation of carbon emission calculation. Increasing Urban density, and spatial organizations contribute to nearly 80% of the total Greenhouse gas emissions on a global scale. Thus, the increasing environmental awareness and inevitability of climate change the dire need of the hour is proportioning of phase carbon dioxide emissions through life-cycle analysis (LCA), Global sustainability assessment system (GSAS), Decomposition Analysis and Modelling of structures for Energy Performance Analysis. The combined effect of the GHG scenario – water scarcity with reduced quality, reduced air quality are affecting the public health leading to greater challenges in lifestyles especially in urban areas. Through this paper, however, an attempt has been made to emphasize on the methodologies adopted for assessment and estimation of carbon emissions and strategies to avert a large proportion of the emissions, along with the challenges for modeling emissions of high-rise buildings in high-density urban environment.

Material Utilization: (in Structural and Non-Structural components)

Numerous materials are used in construction industry, most commonly being concrete, steel, aluminum, wood etc., whose carbon emissions are nearly equal to 7.7 % of global carbon emissions. However, with increasing awareness on impact of climate change, substantial efforts are being made to reduce the energy utilization with experimental innovations on cutting-edge renewable energy resources.

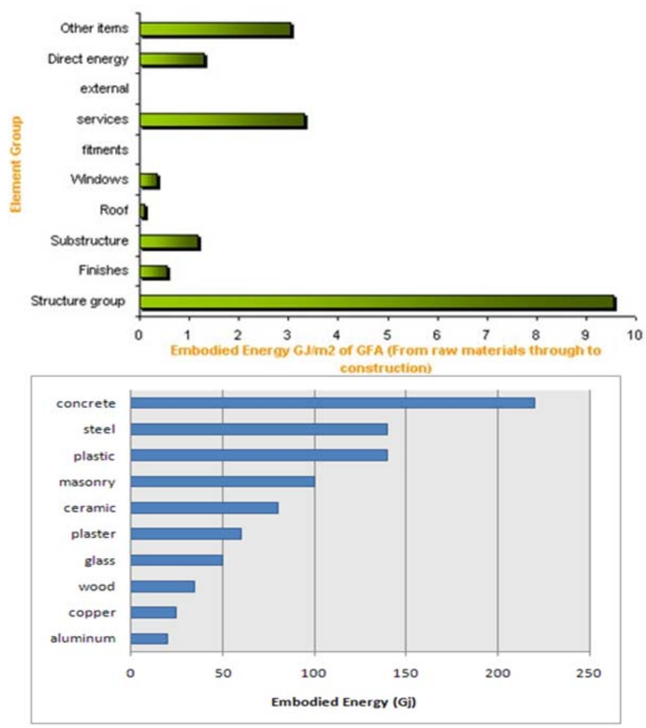
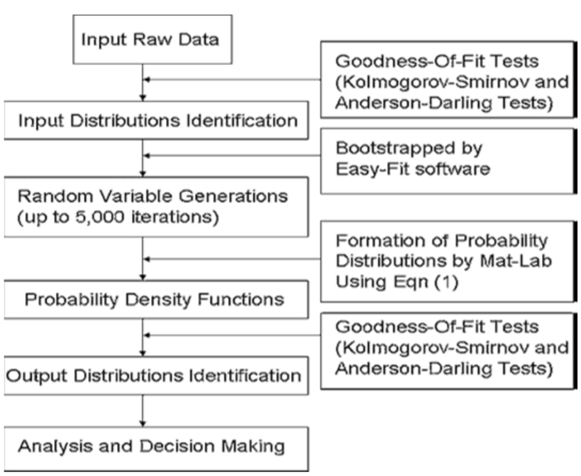


Fig 1: Graphical representation of Embodied Energy of both constructional materials and structural units of a building. (Source: Google).

C K Chau, W K Hui, W Y Ng and G Powell intended to generate a probabilistic distribution profile for portraying the carbon footprint due to the materials used in the structures using the Monte Carlo Method. Determination of Replacement factor: to quantify the number of times that resource input is required was carried out to determine amount of material required for further analysis using LCA. The Monte Carlo method was used for generating probability distributions to define the boundaries for Carbon emissions of various materials and also to identify the various building components which significantly account for carbon-dioxide emissions.



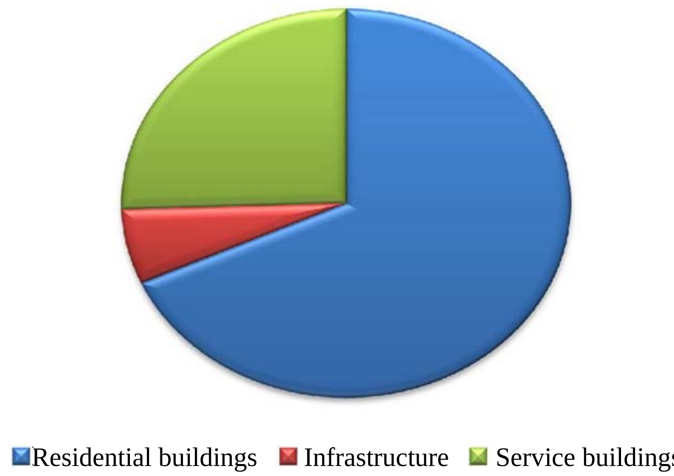


Fig 2: Monte Carlo Process Protocol (Source: Assessment of Co2 emissions reduction in high-rise concrete office buildings using different material options)

Life Cycle Analysis:

Life Cycle analysis has proved to be a boon, for this concept forms a baseline for models of building carbon emissions assessment. It is an essential tool to measure environmental factors by quantitatively evaluating carbon emissions, its ecological impacts, and assess the alternatives for improvement of the building industry. Energy consumption and carbon emissions are however hard parameters to assess as construction materials used are varied with inconsistent methods of production. The study on life cycle analysis aims to consider the total amount of carbon emissions exhausted in a full life cycle of a building including: phase of design and planning, resource input, manufacturing, operational use and maintenance, with demolition and reuse. Thus, the LCA of the building sector has been divided into five stages – material preparation, construction and reformation, operation, demolition, and recycling or reutilization.

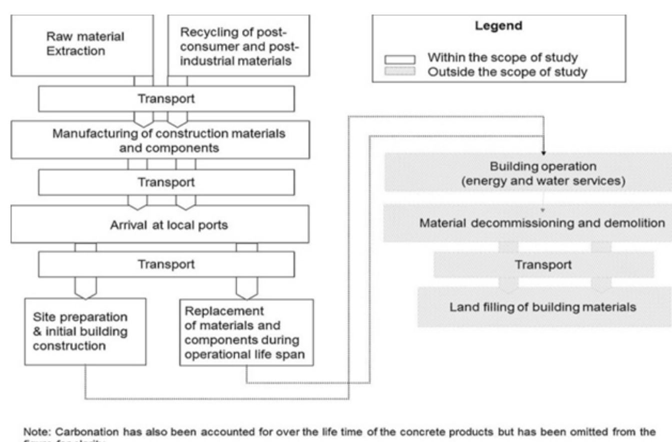


Fig 3: Various Phases of construction augmenting to Carbon emissions (Source: Assessment of Co2 emissions reduction in high-rise concrete office buildings using different material options)

With the following analytical background, Yuanyuan Gong and Deyong Song studied the carbon emissions at the sub-provincial level conducting decomposition analysis using logarithmic Mean divisia Index (LMDI), data sources being the China Statistical Yearbook. The consumption assessment of the urban building systems was carried out in two stages: Direct and indirect LCA, where detailed estimation of energy consumption was carried out using mathematical relations for every manufacturing process of building materials such non-ferrous and non-metallic materials. The total life cycle energy consumption was given by:

$$E_W = E_1+E_3+(E_2+E_4) + Q_W$$

Where, E_w denotes the total life cycle of the structure energy consumption in the considered city and E_1,E_2 … representing energy consumption in each stage, and Q_w is indirect energy consumption. Decomposition analysis was conducted to determine the energy consumption and the carbon emission quantitatively. A relationship was established between the following parameters i.e. population, affluence environmental impact per unit given by: I= P*A*T, with an extended behavioral model. The Carbon emissions of various structures can also be estimated using the Carbon emission assessment framework consisting of two assessment models: one for construction phase assessment and the other for use phase assessment. However, both are applications of the hybrid LCA. Jukku Heinonen, Antti Saynajoki and Seppo Junnila studied the residential development in Finland. However, here the emissions were estimated or assessed for a specific area. Both these methodologies concluded that the carbon emissions increase with increased constructional area.

Modelling Carbon Emissions:

Increased structural carbon emissions has attracted increasing attention to the approach of low or zero carbon buildings. In this context, dire need of the hour is to develop strategies for modelling carbon emissions of buildings. However, modelling has always proved to be a challenge for the conversion of data from BIM models to energy simulation is not an easy task. Also the interdependence of building materials to building service systems and the renewable energy usage are not largely known. Y Zhao, W Pan, and Y Ning considered the urban environmental factors, such as temperature variation, pressure, wind speed and additional environmental factors in Hong Kong for they create a microclimate that can vary from floor to floor of a building. The buildings were divided into numerous thermal zones (nearly 25) based on the different geometric locations, orientations and multiplying factor. Although innumerable problems were faced in simulating the human/occupant behavior for their significant interaction with the building control systems is unmeasurable, the carbon emissions were estimated based on the electricity consumed per unit which is also based on the fuel mix used.

Conclusion:

The concern for mitigation of global warming testifies for the effort and response to estimate and reduce carbon emissions Through this paper an attempt has been made to study the varied methodologies adopted for analysis and estimation of carbon emissions from materials used to the structural components of any considered constructed area. Quantifying human interaction however still proves be an obstacle in modelling building operational simulations due to its nature incompatibilities. Heat waves are likely to intensify in urban areas due to the heat island effect and issues of water scarcity will particularly acute effect on cities. Thus the carbon emission estimation is necessary for reducing its effects to further reduce mass climate change. Estimation of energy consumed by various components prove to be immense importance. Energy performance - methods of expression and its indicators: the systematic estimation and expression of energy performance provides a means for defining energy ratings and compliance for certifying building regulations. This evaluates the energy consumption at ecosystem level. This thus leads to the application of low emission power generation technology, hence increasing the cutting edge renewable energy, which is the major objective of global sustainability assessment system.

Recommendations

- The increased awareness of climate change has introduced the concept of climate resilient structures which is a combination of planning, designing, construction and its utilization.
- Urban areas are often vulnerable to major climate changes and it is necessary to avert it by achieving building energy conservation and emission reduction. As mentioned previously, it is very important to consider the life cycle of structures through their phase emissions, i.e construction, operation demolition and recycling.
- The buildings operational efficiency can be increased by reducing the carbon emissions in each of its components such as heating, lighting, ventilation, air conditioning systems, based on the climate characteristics.
- Utilization of clean energy to indirect energy consumption in the process of manufacture, processing and transportation of building materials. Low carbon architectural ideas need to be enhanced formulating relevant laws, regulations and standards.
- Material use: different material utilization is available for implementation at its design stage for minimizing the carbon emissions. Alternative low carbon materials available locally can be utilized thus reducing transportation costs. Maintenance of the existing structural and non- structural components,

re-utilization of existing resources, diversion of constructional wastes and use of prefabricated materials are all alternatives which reduce carbon emissions nearly 15-30%.

However, it must be noted that the above mentioned alternatives are few in number and further exploration of mitigation strategies needs to be carried out. Thus we must aim towards establishing a sustainable environment with the concept of low carbon emission and low energy consumption structures.

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