Embodied Energy Analysis by Data Comparison for High-rise Building

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Abstract— Energy is required in every aspect for the life time of any building. Buildings are evaluated in terms of their energy requirement and eventually their impact on environment to find their sustainability. This assessment of energy is a widely developed topic. This energy in building is divided into two main types based on their functions, i. Operational Energy ii. Embodied Energy. The Operational energy is the energy that is required to function the energy, whereas the Embodied energy is the energy that is enveloped in making the building initially. The selection of the materials or techniques used for construction or infrastructure project directly affects the total embodied energy of the structure. Thus selecting a structural system with less Embodied energy may reduce the overall embodied energy of the building. In this study, embodied energy is derived through rigorous exercise of counting the total materials used, their material, transport and different process energy and the total accounted for two different structural systems in high- rise buildings. For which earlier works done in the field is used and help of professionals taken. At the end of the study, it is concluded that the embodied energy for RCC frame building per unit area of that high- rise building is more than the embodied energy of similar scaled Steel composite building. The difference for the case studies used is almost 15%. The percentage figure looks not so significant, however, the total embodied energy difference which is counted in GJ is huge when compared toe to toe. The study thus suggests, that selection of structural system, especially for high- rise buildings with respect to their embodied energy can affect positively on the overall environment impact of the structure.
Key words: Embodied, Infrastructure, Energy, Environment, High-Rise

I. INTRODUCTION

Embodied Energy is the total amount of energy required for a product or material to have achieved the current state or properties. This will include the energy used at different stages like extraction, processing, manufacture and transportation. This energy consumption at various stages produces Greenhouse Gases (GHG) like carbon dioxide, which eventually contributes to the greenhouse effect and harms the environment. Reducing Carbon Dioxide (CO2) emission from buildings and nonrenewable resources consumed during construction is a priority in the fight against global warming (Lam et al, 2010). Thus, embodied energy reflects the overall impact of a material or system on the environment and hence the study on embodied energy is important in general. Unlike other industries, construction industry has lot many distinctiveness. As per past research works, using alternative building construction systems, methods and techniques can reduce the overall environmental effect and also reduce embodied energy as well as CO2 emission in the process. (Balubaid et al, 2014) However, there is a difference between Embodied energy and the life cycle assessment (LCA), LCA computes all the impacts over the complete life of a material or element, while embodied energy only considers the early aspect of the impact of a building material. It does not include the energy used during the operation or disposal of materials. The total energy consumed by the building throughout its life cycle includes embodied energy (EE) and operating energy (OE). Embodied energy is embedded in building materials during all processes of production, on site construction and final demolition and disposal while, operating energy is consumed in operating and maintaining the inside environment (Ding, 2004). Also there are two types of embodied energy considered for building materials as per definitions, i. Initial Embodied energy ii. Recurring Embodied energy .The difference between both the types of embodied energy is that the Initial embodied energy of a particular material is the energy used to produce that material in that state up till their construction phase. While the recurring embodied energy is the energy used after the installation or construction phase to retain that phase of the specific material, or in other words their maintenance. Wherever the word embodied energy is mentioned in the paper, which should be considered as Initial Embodied energy only as the Recurring embodied energy has many unpredictable factors affecting to it, which may be very site specific.

In recent past the race to build vertical has been increased day by day, the reasons for which are many and varied; the shortage of suitable land, the increasing land price, the desire to live close to CBDs, builders to gain more profit, vast construction techniques and structural freedom, shortage of housing spaces etc. are the main factors. Although there is no precise definition of high-rise building that is universally accepted, various bodies have tried to define what 'high-rise' means, as per NBC any buildings more than 16m high are considered as high- rise buildings. In this study however, we will consider super tall buildings of around 40-50 floors as high-rise, looking at the current trend of development in India that can be viewed as justified. High rise buildings are one of the top most structures in demand in construction world today. In general almost each and every construction companies today are working on it. Analysis of such an apartment building project showed that the material manufacturing stage had the largest amount of energy consumption and GHG emissions (Taehoon Hong et al, 2013). Considering that the amount of materials being used in this kind of structure is very high compared to low and mid-rise structure, they are the prime choice of study in case of embodied energy.This is partly due to the unawareness or lack of knowledge of such requirements which is prevalent among them. Because of imperfect solutions on construction, planning & design as well as services in high-rise buildings, a huge amount of energy resources is being consumed. (Parasonis & Keizikas, 2010) Energy consumption during manufacturing can give an approximate indication of the

environmental impact of the material and for most building materials, the major environmental impacts occur during the initial processes. The total amount of embodied energy, therefore accounts for large amount during the construction stage, so reducing embodied energy can significantly reduce the overall environmental impact of the building. The selection of the materials or techniques used for construction or infrastructure project directly affects the total embodied energy of the structure; therefore it is important to choose the right materials as well as right methods. There has been good amount of research done in the field regarding the embodied energy for building materials and construction activities for small scale buildings, but the lack of knowledge is found where the embodied energy is considered for the techniques of construction mainly the structural type of the building, that too in the high rise building e.g. RCC Frame structure, Composite structure etc. The selection of building's structural system has to be made carefully as each system has different impact on energy efficiency. Development of tools to select embodied energy based construction systems is considered timely as it may help many designers, engineers and developers in conscious decision making. (Balubaid et al, 2014). In case of high-rise buildings, considering the amount of materials and therefore the amount of embodied energy that can be saved by the right decisions of choosing right construction method or structural system, and by doing that reducing the significant impact of the structure on the environment, the importance of this study is undoubtedly substantial.

II. METHODOLOGY

The methodology of the research work will be as shown below, Basic introduction to the concept of embodied energy and various definitions.

III. SCOPE & LIMITATIONS

- Building typology to be considered for the study is high-rise/Mid-rise structures only (more than 16m high).
- The Recurring embodied energy has many unpredictable factors affecting to it, which may be very site specific, therefore that will not be considered in this study.
- Case-study comparison between the total initial embodied energy will be between any two or more structural types/technique.
- The context of the study will primarily be considered in the Indian construction industry.

IV. ASSUMPTIONS FOR CALCULATIONS

Following assumptions are made while calculating the embodied energy of the structural system, these assumptions are based on the on-site work information received from the architect's team and the field experience of the author, Embodied energy for Site-clearing, Earth-work, layout markings etc are not considered for the study, since they are necessary processes and will change little with respect to selection of structural system. Steel reinforcement calculations are based on the industry thumb rules, (percentage of volume for each structural member). All the materials are calculated based on the latest architectural and structural drawings received from the architect. Wastage quantity is added wherever required and the wastage quantity/proportions are as mentioned in the calculations. The EE data for Steel, Concrete, formwork, Machines, processes and other Manual energy are as per the earlier work of department and are crosschecked from the ICE data (University of Bath), which are more or less similar. Although the actual site conditions may have required a different strategy, techniques or method of work, it is limited by the scope of this study to consider that these processes are typical. The Embodied energy for formwork provided in her Thesis report is as the total embodied energy for the material, however as per the industry rule, steel plates and props are used at least 120-150 times before being discarded and eventually recycled. Therefore, the unit EE used in this calculation is a division of the total unit EE and their subsequent reuse. Recycling is not considered here, since recycling for steel is proven to be much less energy consuming than mining. Also, it is not possible to track the material to its root for such time bound study. No. of reuse considered here is 150. Similarly, the Plywood formwork is supposed to be reused for 15-20 times, the total unit embodied energy provided in her report does not consider this part.

Therefore we shall be using the division of the Unit EE provided in her report by the number of their subsequent reuse. Again recycling/discarding is not considered here. No. of reuse considered here is 20. As a common practice, It is considered that 50% of the material is procured from the nearest supplier, remaining is procured from the other sources equally. This is a very site specific and preferential matter to generalize, therefore the decision to divide the procurement is considered. The Embodied energy for transportation is taken from the Seminar report of Suniti churiwal (2008), where she has shown the method of calculations as well. The mode of transport is considered by road here for distances less than 500Km, since the location of site is well connected through road, it is assumed that the transportation is done by the most common transportation method in shorter distances. For longer distances rail transport is considered. The vertical transport is considered for Concrete and steel only, shuttering plates and props etc will not be considered for this transport because they are generally transferred on one after another floor which is a manual labour work too. The Labour requirement for the Reinforcement binding and Concrete work is derived from the Delhi Schedule or Rates-2014, IS:7272 and total quantity of work.This calculation does not consider any other processes, such as Curing, Finishing etc, since they are either very site specific processes, for which calculating EE is not possible for such time bound study, and also they are comparatively negligible energy consuming activities as compared to the ones which are considered here. Quantification of materials for calculation is done floor wise and item wise, since even for the same material (i.e. Cement concrete and Steel) the construction processes and vertical transportation data are different. This will make a huge error if considered as one single entity. Any particular assumptions are stated for each calculations as and where made.

V. CALCULATION OF MATERIAL QUANTITY & THEIR EMBODIED ENERGY

The calculations are done with the above assumptions and the material quantity are derived from the working drawings from architect and structural designers as mentioned in the calculations.

VI. ANALYSIS & CALCULATION OF ENERGY REQUIREMENTS FOR PROCESSES

From the assumptions, author's experience and site visits the data for processes and techniques were derived. From where the energy requirements were calculated.

VII. COMPARISONS AND ANALYSIS OF THE CASE-STUDIES

From the earlier chapters, the Total Embodied energy per sq.mts. of building is compared here for analysis.

VIII. CONCLUSION

After the detailed calculations of embodied energy of RCC Frame structure and Composite structure, it is concluded that the Embodied energy of Composite structure is significantly lesser than the RCC frame structure. Therefore it is safe to say that the Composite structure system is better than the RCC frame structure in High-rise buildings with respect to Embodied Energy.

IX. FUTURE SCOPE OF WORK

Although the calculations and analysis for the Embodied energy derivation of the RCC Frame structure and Composite structure are done thoroughly in detail, the analysis of structure system is not completed in the sense of the number of technology compared. It will be better to compare the same data of other structural systems as well to look at the broader/complete comparison.

REFERENCES

[1] Balubaid et al. (2014). Embodied Energy in Building Construction.
[2] Crawford, & Treloar. (2004). Assessment of embodied energy analysis methods for the Australian construction industry.
[3] Ding, G. (2004). The development of a multi-criteria approach for the measurement of sustainable performance for built projects and facilities.
[4] Dixit, e. a. (2008). Protocol for Embodied Energy Measurement Parameters.
[5] GBCA. (2010). Dollars and sense of Green buildings. Retrieved from Green Building Counsil of Australia: http://www.gbca.org.au
[6] Boustead, G. H. (1979). Handbook of Industrial Energy Analysis. Ellis Horwood Limited.
[7] Lam et al, P. T. (2010). Factors affecting the implementation of green specifications.
[8] Parasonis, & Keizikas. (2010). POSSIBILITIES TO REDUCE THE ENERGY DEMAND FOR MULTISTORY RESIDENTIAL BUILDINGS.
[9] Taehoon Hong et al. (2013). Retrieved from http://dx.doi.org/10.1061/(ASCE)ME.1943-5479.0000199
[10] Treloar, G. (1997). Extracting Embodied Energy Paths from Input-Output Tables: Towards an Input- Output-Based Hybrid Energy Analysis Method. Economic Systems Research.
[11] Treloar, G. J. (1998). A Comprehensive Embodied Energy Analysis Framework.
[12] Anshu Gupta, (2010). Embodied Energy of various items of work. BEM Dept.,SPA-New Delhi.
[13] Anil Kumar, (2000). Scheduling of Embodied Energy for items of work in building. BEM Dept.,SPA- New Delhi.
[14] Shounak Ray, (1996). An Enquiry into Energy - Conscious considerations in building materials and construction. BEM Dept.,SPA-New Delhi.
[15] Tingmansang Guite, (2015). Thesis report On cost and quantity coefficients for highrise buildings in various earthquake zone and their design requirements. BEM Dept.,SPA-New Delhi.
[16] Autodesk Eco Material Advisor (14/04/2015). http://inventor.grantadesign.com/en/notes/attributes/material/material_processing_energ y.html
[17] Inventory Of Carbon & Energy (Version 1.6a). Prof. Geoff Hammond & Craig Jones, University of Bath.

