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Environmental Sustainability Assessment of Industrial Construction Technologies (Case Study: In-situ and Precast Concrete Construction Methods)

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ABSTRACT: Construction industry has been one of the most energy and material consuming industries in recent years. Environmental assessment of construction methods that includes energy consumption and emission release are important for implementation of improvement option to life cycle of construction. Despite the significant effect of selecting appropriate method on reducing amount of material, energy and emission, the studies often do not consider or incompletely model the environmental impact. The research has studied the energy consumption and carbon emission of two conventional and industrial methods of construction for concrete buildings: in-situ concrete and pre-cast concrete structural methods. This study has figured out how implementing precast concrete structure affects on environmental sustainability of the construction process. In addition the features of construction methods that can help the designer to achieve more sustainability have been assessed. The model developed to use the life cycle assessment (LCA) as a comprehensive sustainability methodology to quantify the environmental impact of several phases of building construction from extraction of raw materials to end of construction phase (cradle to gate). To investigate the environmental impact of each construction method two designed concrete structures with in-situ and precast elements modeled in building information modeling (BIM) and linked to the designed spread sheet.

Extracted results indicated using the high strength concrete for precast concrete structure, just in construction periods, is an effective way that reduces energy consumption of process and decreases carbon dioxide but in manufacturing process precast concrete consumes more energy and emits more carbon to environment. In Recognition of different features of energy consumption, material use and emission release of proposed method of construction, assist the project team in better decision making from environmental impact point of view and enable designers to provide recommendations toward achieving sustainable construction methods.

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1- Introduction

Construction industry has a substantial impact on sustainable development of building sector. It has been one of the most energy consuming industries in recent years. Concrete is one of the widely used materials in construction industry. Concrete production and implementation requires large input of resources and cause several negative environmental effect. Concrete is used in several forms and methods as in-situ and pre-cast structural systems. This indicates that efficient use of this type of material could have significant effect on the environmental impact of construction industry.

The main goal of this study is to develop a comprehensive tool that considers environmental impact of construction process as other effective parameters of construction like time, cost, quality and man hours need. In this study to achieve the appropriate evaluation, life cycle assessment (LCA) methodology is implemented in order to consider, compare and assess the environmental performance of material production phase and on-site construction activities for two types of concrete structures: in-situ concrete and pre-cast concrete methods. This study has been conducted to find answers for following questions:

- How LCA of construction process affected by construction methods selection?
- What aspects of construction process enroll more significant impact on environmental sustainability of the process?

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2- Methodology

In order to produce a clear and detailed picture of the individual processes, the life cycle assessment is divided into categories. According to ISO 14040, these categories for LCA are consisting of four components or steps: 1) Goal and scope definition 2) Inventory analysis 3) Impact assessment and 4) Interpretation [1].

2- 1- Goal and scope definition:

In this phase, the product(s) or service(s) to be assessed is (are) defined, a functional unit is chosen, and the required level of detail is defined [2]. System boundary and functional unit definition are important elements of this component [1]. For this inquiry, the scope of LCA has been limited to structural component of buildings and the study does not consider the other non-structural components of building like walls, windows, etc. The concrete frame structure consists a number of life-cycle phases including raw material extraction, material production, construction, use and end of life. Although a LCA study should ideally be set from the extraction of raw materials to end of production lifetime (cradle to grave), in this study according to main objective, which is emphasizing on the differences between the two construction methods, it is specific on three initial stages that include raw material extraction, material production and construction.

2- 2- Inventory analysis

A life cycle inventory (LCI) is a combination of energy and material inputs and the emissions output to air, land and water associated with the manufacture of products, operation of processes, or provision of services [3]. An inventory of all inputs and outputs to and from the production system is prepared in this step.

2- 3- Impact assessment

During the impact analysis stage, publicly available databases and studies can be used to assess the actual environmental and health effect associated with a product life cycle [4]. In the environmental impact assessment step of this study with respect to the targets, the inventory outputs, carbon dioxide and energy consumption are weighted and characterized in terms of environmental impact.

2- 4- Interpretation

In this step, results from the inventory analysis or impact assessment are interpreted to identify the major impact of process. The results are often presented in the form of tables and graphs, which is especially helpful when comparing two competing design options or products.

3- Results and Discussions

The overall calculation of energy consumption and CO_2 emission for production phase, which compares different stages of two construction method is shown in Figures 1 and 2. In this comparative study, the main activities which have significant impact on environment are presented into four bars. The three main categories of concrete material extraction, concrete material production and steel production presented individually and total amount for this three phases has shown respectively. It indicates that if the constructors aim to achieve more sustainability in production phase, three main areas are available to manage the energy consumption and emission reduction of construction processes. In material production stage, values for embodied energy of reinforced concrete, the energy used for material production of precast construction method is slightly more than the values for in-situ method. The differences are results from the amount of material and the high strength concrete has used for compare with moderate strength concrete used for in-situ method. Figure 2 shows that for carbon emission, the differences are more explicit. This indicates that with increase of cement content the amount of CO_2 precast concrete elements which requires more cement emission, in compare with energy consumption, increased more dramatically. The results in Figure 3 and 4 indicate that for this case study, in construction phase, for pre-cast concrete construction method there is reduction in energy consumption and carbon emission that release to the environment, since for material production phase this reduction could not be achieved by implementing pre-cast concrete method. For installation phase, there is a significant difference between methods of construction. For in-situ construction method, because of further equipment operations for on-site construction activities; it has consumed more energy in compare with pre-cast concrete method. Hence, for precast concrete structure, most of activities are delegated to the fabrication yard; under protected area, the operations can more effectively be performed and save more energy. In this method, the operations that remain for on-site activities are almost, lifting and installing the components by crews with crane.

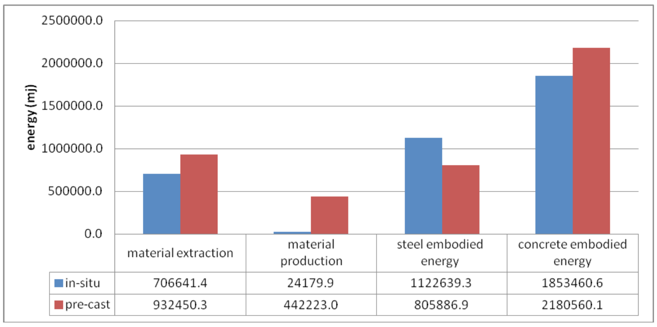

Figure 1. Energy for material production (embodied energy)

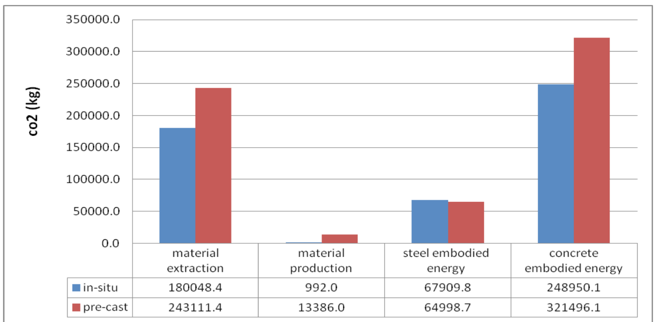

Figure 2. CO_2 released from production phase

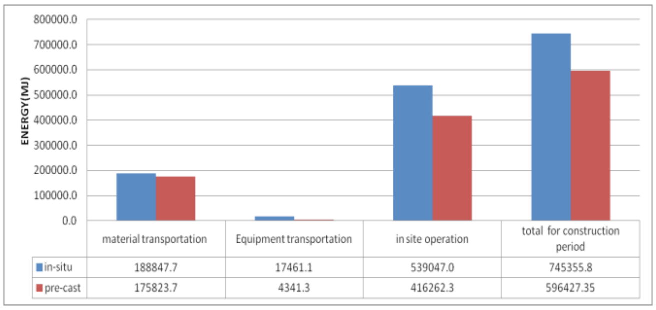

Figure3. Energy consumption for construction phase

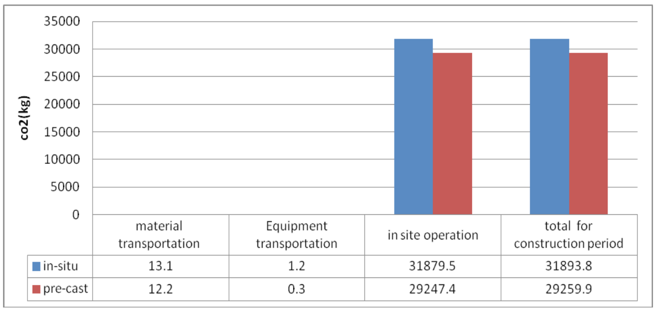

Figure 4. CO_2 emission for construction phase

4- Conclusions

The overall view of study indicates comparison life cycle assessment of construction process (cradle to gate), while not considering the use and end of life phase, is an effective way to compare and analyze the parameters that has initial impact on energy consumption and emission released and is as important as the other life cycle stages. Modeling the program that represent and compare the proposed construction methods from energy and emission point of view is necessary to help the construction industry to achieve sustainability goals and help in decision making process. The created model can be adopted for series of LCA studies of different construction method to help designer and construction manager for comparing construction methodology together and asses and analyze each method individually as well. In addition, because of capability on defining different features of building component, the model can be extended to study the other phase of life cycle assessment including use and end of life.

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