"BIM MODELING TO INVESTIGATE, SIMULATE TOTAL ENERGY CONSUMPTION IN EQUIPMENT USE ON A CONSTRUCTION SITE"

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Abstract : Construction Projects consume large amount of energy during Construction as well as Operation Phases in various forms for transportation, manufacturing, labour and machineries in construction activities. Energy efficiency is the key factor of any building project. In recent years, many energy optimization techniques have been used to make energy utilization efficiently. Most of the research conducted towards quantifying the energy consumption in buildings focuses only on the operation phase and hence neglects on the opportunity to decrease other building-related energy consumption. These energy utilizations in construction during construction phase have large scale cumulative environmental impacts at the national level. This paper demonstrates a method to automatically determine the Embodied Energy in the Equipment use of construction phase of building projects. For this, BIM technology has been used and a convenient linkage between the BIM model and external energy databases has been established through plug-ins developed exclusively for this purpose.

Index Terms - ***BIM, Net Beans IDE 8.2,Plug-In Development, Energy Consumption*.**

I. Introduction

Construction projects are becoming more complex and difficult to manage and as technology develops, more construction professionals are familiarizing themselves with Building Information modelling (BIM). The BIM technique is relatively new and has been developed extensively in recent years. BIM is described as a data model built by integrating three-dimensional digital techniques with various manner of relevant information about a given engineering project. BIM is mainly used in the design stage, construction stage, and late operation and management stages. It can considerably improve efficiency and reduce risk throughout the entire constructional engineering process.

Now a day's primary concern is the use of energy and the issues arising from its use. Based on data from the International Energy Agency (IEA), the 2017 global Total Primary Energy Supply (TPES) peaked at 13651 million tons of coal equivalent (Mtce), releasing a whopping 32.316 million tons of CO2-related energy into the atmosphere [1]. These figures are at all time high and a dreadful concern for climate scientists. Building and combining sectors are responsible for 36% of global final energy expenditure and almost 40% of total direct and indirect CO2 emissions. [2]. These figures show the urgent need to work towards an actionable plan to reduce energy consumption and try to reduce our industry's ecological impact on a war-foot.

Buildings are associated with two types of energy consumption, embodied energy and operational energy. Embodied energy encompasses all the energy that is consumed before the operation phase of a building i.e. energy consumed during Equipment use on constriction site during construction operation.

The main goal of this study is to use BIM technology to automate the process of Embodied Energy of equipment use on site Computation in a specific building. Two main domains revolve around the study. One is the general energy requirement of equipment in construction projects, , while the other with special emphasis on Embodied Energy of equipment which are going to used nowadays in construction site with the help of BIM technology.

II. Literature Review

The energy consumed in a building project is classified into embodied content and operational energy.

A. BIM-

As an innovation, BIM is more than software but rather a new design paradigm and methodology using sophisticated computer tools [11]. Seen as a solution for the many challenges which bedeviled the paper based drawings in the building environment, BIM Handbook [12] defined BIM as a "modeling technology and associated set of processes to produce, communicate, and analyze building models". From another perspective, BIM is seen as "an intelligent model–based design process that adds value across the entire lifecycle of building and infrastructure projects" [13].

B. Embodied energy-

We use the process of Life Cycle Assessment (LCA) method to estimate Embodied Energy material. LCA is done by three methods: Input-Output Analysis, Process Analysis and Hybrid Analysis [4,5]. The material phase impacts are obtained from the energy usage in the form of fuels like petrol, diesel, gas and electricity during the procurement and processing of raw materials into finished elements [8].

The energy used in the manufacture or extraction of a material is embodied energy. It differs from the energy usage due to operable use. The significance of evaluating and attempting to reduce this Embodied material can be emphasized by the fact that it may account for up to 60% of the building's overall energy use [6]. Also majority of the scientists' and policy makers' acknowledge that that it is highly important to evaluate the potential of reducing environmental impacts of the construction project at the early design stages [7]. To quantify these impacts, the *Inventory of Carbon and Energy* [9] is mostly used by researchers around the world. This is a large database of various materials along with their Embodied Energy Coefficients and is often used in conjunction with the Bill of Quantities (BOQ) and project drawings obtained from the site.

C. Energy use and construction industry-

The construction projects create large scale environmental impacts in the form of air emissions, waste generation and the use of land, water and energy [10].
The construction industry uses the most materials by weight than any other industry in the U.S and globally too. A building's life-cycle can be divided into extraction of raw materials, processing them, transporting the materials and components to the site and installing the same, operation & maintenance, repair and finally demolition. Each of the above phase includes several sub-phases and demands energy for the successful completion of various activities in them.[3]

D. BIM linking with Energy Data-

BIM is an excellent visualization tool in the hands of project stakeholders, especially planners, designers, and energy managers. But BIM in itself doesn't store or contain energy data. Hence there is a need to link the energy data from outside source with the BIM environment to enable smooth and efficient energy modeling and simulations to quickly find and compare various alternatives and achieve the optimum solutions with least wastage of time.
The energy analysis process can be expedited by linking a BIM model to energy performance analysis tools. BIM facilitates the evaluation of different sustainability strategies by performance evaluation of various design parameters and enables integrated project delivery through an actual project [14].

Summary-

From the literature review conducted herein, it was found that previous researchers have conducted extensive studies on both BIM and energy usage but the main focus of this study lies in integration and automation of the energy values. The conclusions of the literature review study have been summarized as below:

1. BIM technology has existed since a few decades now, but remained in the shadows until lately. BIM offers an excellent tool in the hands of the project stakeholders and enables a shareable, multi-dimensional real-time view of the project.
2. Energy consumption in general and especially in the development industry is a major challenge faced by global policymakers. Hence, major studies have been conducted by researchers till now in an attempt to reduce the energy usage on construction projects.
3. Most of the studies conducted till now have only focused on energy saving during the occupational phase only and very little attention has been paid to reducing the embodied content of materials and development activities during the construction phase.

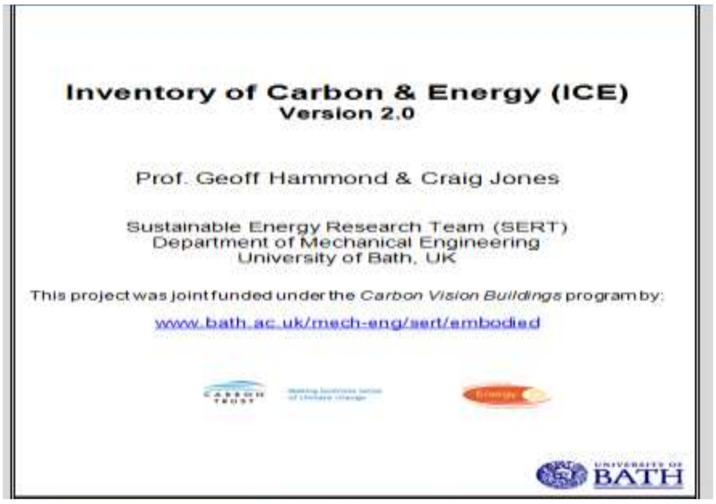
III. METHODOLOGY

The entire process has been divided into 3 parts: Data Collection, External Energy Database, BIM Model, Development of Plug-in, and Embodied Energy Calculation. Main aim of this analysis is to demonstrate a method to quantify Energy in Production in equipment which are mostly used in construction Project during construction phase[13].
The International Finance Corporation (IFC) has developed a database of environmental impacts of a comprehensive set of construction materials used in India. The same have been used and relevant data have compiled and named as External Database. To link this external data with the BIM model, a plug-gin has been developed using Structured Query Language (SQL). So once the BIM model is ready the Embodied Energy content in any desired equipment used in the structure can be easily and automatically found by running the query on that particular material. The entire flow of the review has been shown below.

Flow of the study
All in all, the entire process flow will be divided in the following steps:
Step#1: Development of 2D CAD Model → Autodesk AutoCAD 2016
Step#2: Development of 3D BIM System → Autodesk Revit 2018
Step#3: Acquiring Embodied Energy Database → IFC Database
Step#4: Developing a Plug-in (Bridge between BIM and External Database) → Programming Language C#
Step#5 Finding Energy Usage Values

IV. DATA COLLECTION

Two databases have been identified to acquire the values of the embodied energy coefficients of various construction materials:
1) Energy Inventory (ICE) and Carbon is an international benchmark for all industries. It contains the various materials ' embodied energy coefficients and includes an exhaustive list of over 200 materials. The ICE V2.0 database is used in this project to collect data on the energy coefficients embodied [3].


Inventory of Carbon & Energy (ICE)
Version 2.0

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This project was joint funded under the *Carbon Vision Buildings* program by:
www.bath.ac.uk/mech-eng/sert/embodied

Fig 1 Inventories of carbon and energy

2) India Construction Materials Global Warming Potential and Embodied Energy Database (ICMDEEGWP), an embodied energy database prepared by the International Finance Corporation (the World Bank Initiative) with the support of the European Union, specifically prepared for Indian conditions. [4] .

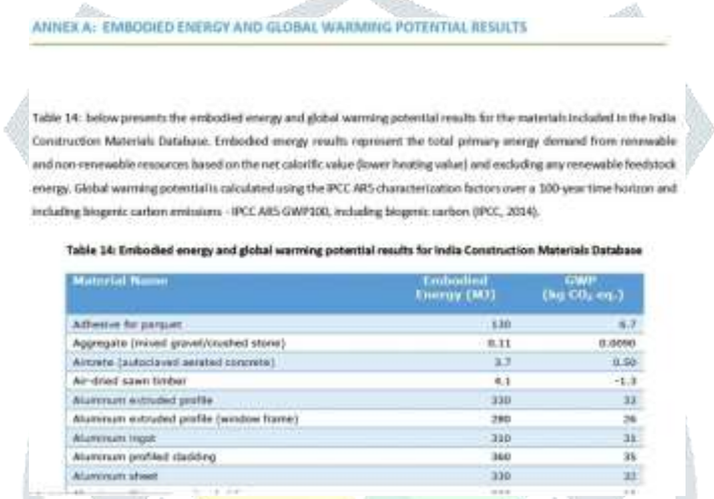
ANNEX A: EMBODIED ENERGY AND GLOBAL WARMING POTENTIAL RESULTS

Table 14: below presents the embodied energy and global warming potential results for the materials included in the India Construction Materials Database. Embodied energy results represent the total primary energy demand from renewable and non-renewable resources based on the net calorific value (lower heating value) and excluding any renewable feedstock energy. Global warming potential is calculated using the IPCC AR5 characterization factors over a 100-year time horizon and including biogenic carbon emissions - IPCC AR5 GWP100, including biogenic carbon (IPCC, 2014).

Table 14: Embodied energy and global warming potential results for India Construction Materials Database

Material Name	Embodied Energy (MJ)	GWP (kg CO_2 eq.)
Adhesive for parquet	130	6.7
Aggregate (mixed gravel/crushed stone)	0.11	0.0090
Aircrete (autoclaved aerated concrete)	3.7	0.50
Air-dried sawn timber	4.1	-1.3
Aluminum extruded profile	330	33
Aluminum extruded profile (window frame)	280	26
Aluminum ingot	310	31
Aluminum profiled cladding	360	35
Aluminum sheet	330	33

Fig 2 Annex A : Embodied Energy Coefficient

Development of Plug-in

Finally, a plug-in was developed to fetch embodied energy data for various construction materials as recorded in the External Database (as shown above in Fig No 5.4.1) The software programming of the plug-in was done in C#[5]. It acts as an smart bridge between the BIM information and the External Database to automatically calculate the values of Embodied Energy for a variety of building activities

Net Beans software information

Net Beans is an built-in development environment (IDE) for Java. Net Beans lets in applications to be developed from a set of modular software program aspects known as modules. Net Beans runs on Windows 7 and other all windows, Linux, macOS and Solaris. It has extensions for other languages as well as Java development such as C, C++, PHP, HTML5,[4] and JavaScript. Third-party developers can extend applications based on Net Beans, including the Net Beans IDE.
Net Beans IDE 8.2 was released on 3 October 2016.

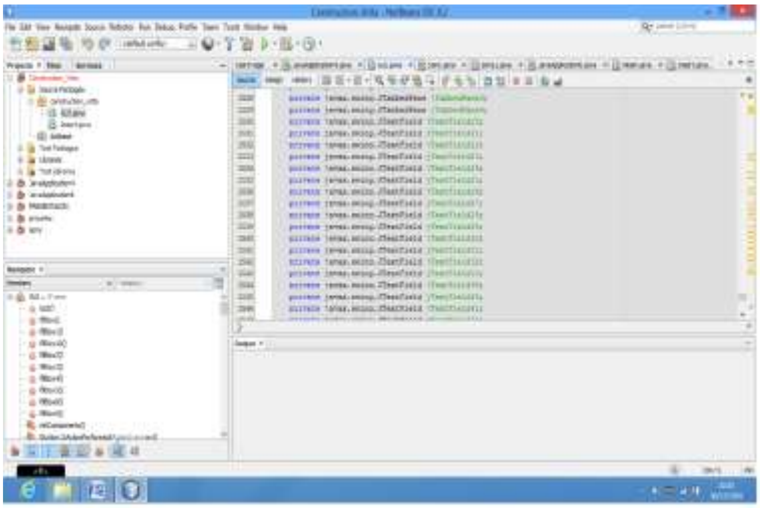

Fig 3Net Beans IDE 8.2 software programmed

Case study details-

The ongoing project of Jaikumar construction is of high-rise residential mass-housing project of PARKSYDE HOMES at Adgaon, Nasik. In this project they have total 5 phases of construction. They have handed over or we can say fully constructed 3 phases out of total 5 phase. The 4th phase is about 90 percent completed and last phase is under construction. There are total 27 building is going to be construct some of 2bhk and some of 3bhk so from this study this paper is included calculation of whole site construction equipment used on site

They have used on site autoclaved aerated concrete blocks. Also they have their own RMC plant on site.

Site details-

Name Of Company : Jaikumar construction LLP. Nasik
Project Name : Parksyde Homes
Owner : Mr. .Gopal Atal and Mr. Manoj Tibriwala
Location : Parksyde Homes, Hanuman Nagar, Opp. Rasbihari High School, Adgaon, Nasik.
Area Of Site : 25 acres
Type of Building : High-Rise Structure
Type of Structure : G+ 15 RCC Constructions
RCC consultants : J.W. Consultants
Architect name : Mr. Umesh Bagul

Energy in Equipment use-

Various activities on site require machine power and hence fuel energy is consumed in these activities in the form of Electricity and Diesel. This data is collected and recorded for embodied energy computation

Table I Equipment workload.

Sr. no	Drive power	Energy consumption source	Energy consumption	
			Aug'18 (kwh)	Sep'18 (kwh)
A	Electricity	RMC plant	224.9	217.4
		Fabrication works	454	337.9
		All civil work	12057.1	14446.7
		Marketing office	2645.8	4586.4
		Labour colony	2069	1780
		Machine/ Equipment	**Time Factor (Hrs/Building)**	
B	Diesel	Poclain	30	
		JCB	90	
		Dumper(2nos)	60	
		Concrete pump	102	
		DG set		
		125 kva	200	
		82.5 kva	150	

IV. ANALYSIS RESULTS AND DISCUSSION

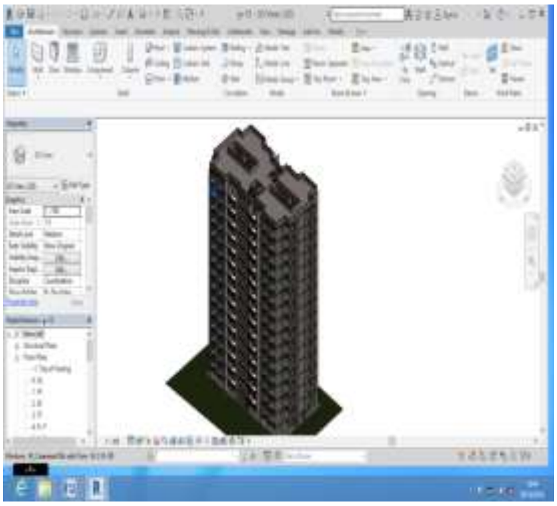

Fig 4 BIM model

Equipment Data Analysis:

The equipments also use a large amount of energy in the form of Diesel and Electricity on a creation site. This data is fed into the specially designed form in the software and the embodied content in the equipment use is obtained automatically.

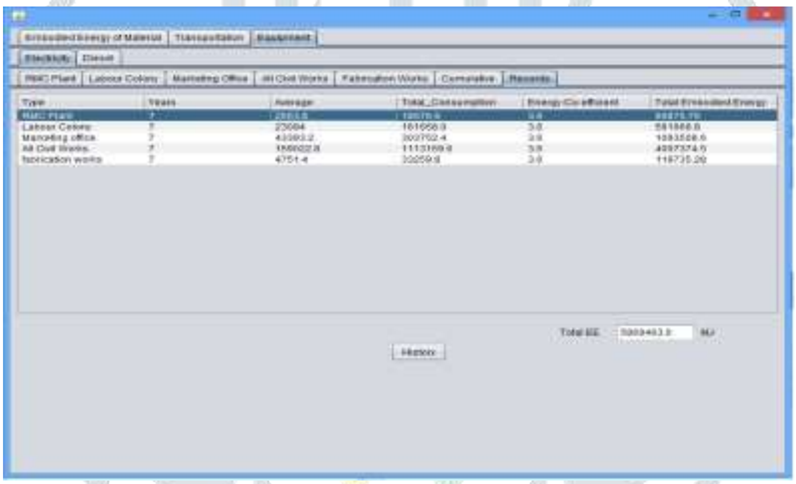

Fig 5 Equipement Data Analysis And Summary

4.1 Results of Embodied energy of equipment used on site

The following results were compiled from the work done to date regarding the Embodied Energy Quantification. These results show the energy consumed in equipment use for the whole project during the design phase.

Table II Overall energy usage in building equipment on site

Sr. No.	Type of Energy	Source of Consumption	Embodied Energy (MJ)
A	Electricity	RMC Plant	66875.76
		Fabrication Works	4007374.56
		All Civil Works	4007374.56
		Marketing Office	1093508.64
		Labour Colony	581968.8
	Total EE in Electricity		**5869463.04**
B	Diesel	Poclain	349920
		JCB	437400
		Dumper (2 Nos.)	29160
		Concrete Pump	495720
		DG Set	
		125 kVA	3888000
		82.5 kVA	1458000
	Total EE in Diesel		**6658200**
	Total EE in Equipments		**12527663.04**

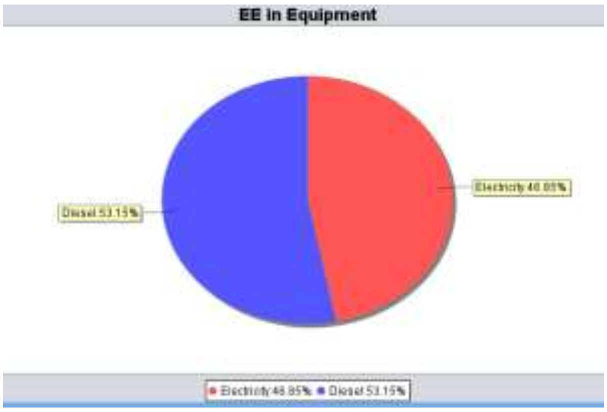

Fig 6 Equipment data analysis in percentage

V. Acknowledgment

With a deep sense of gratitude I would like to thank all the people who have enlightened our path with their kind guidance .I am very grateful to these intellectuals who did their best to help me during the seminar work.

The special gratitude goes to **Mr. S. M. WAYSAL,** Head of civil engineering Department **Dr. M.P. Kadam,** who guided me especially in academic activities and to all the staff members of the civil engineering Department for their precious suggestions and guidance in completion of this dissertation work.

I remain indebted to **Mr.R.V.Devalkar,** for their timely valuable suggestions and excellent guidance for completion of this dissertation work.

I feel proud and find privilege to express deep sense of gratitude to our principal **Dr. N.S.Patil** and vice Principal **Prof.N.B.Desale** of NDMVP'S KBTCOE, Nashik, for his comments and kind permission to complete this work.

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