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Carbon Calculator: A Methodology Proposed to Evaluate Some Case Studies in Terms of Embodied Energy & Carbon Emission for Building Materials

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Abstract—The area of construction is considered to be an extremely polluting activity of modern production. Almost 60% of the raw materials extracted from the lithosphere for civil works and building construction which are involved with significant amount CO2 emissions. It is fundamental to take into account both the environmental and economic costs when identifying the most eco-efficient technology. For minimizing the environmental impact for building construction and selecting the best material, its need to compare with alternatives materials in terms of energy and carbon emission. These paper aim to evaluate the impact of the alternatives materials in term of energy and carbon emission and the environment of the construction materials most used in building construction. Through this carbon calculator, user can evaluate the impact in terms of energy and carbon emission (to environment) of the construction materials mostly they used. Now a days building sector is considered with the reduced impact of different eco-materials and specific measures for the reduction of these impacts (Energy & Carbon Emission) in all stages of the product: manufacturing, transportation and final disposal. In the development of carbon calculator first we consider the energy and carbon emission for manufacturing (embodied energy) and transportation of the building construction materials. Microsoft Office Excel software is used to developed the carbon calculator and evaluate the results for some cases.

1. INTRODUCTION

Global warming along with climate changes have become a major concern for mankind that's why it's need to ensure that empowering those projects for the development and environment conservation around the world to slow down depletion of natural resources.

The building construction is considered an extremely polluting area and therefore any development or measurement policies to reducing of the energy and CO2 emission leads to more sustainable and environmentally friendly technologies. One survey tells that civil works and building construction consumes 60% of the raw materials extracted from the lithosphere from which building represents 40% {For example: In Spain, every habitable square meter of a conventional building requires a total of 2.3 tons of more than 100 types of materials}. [1] These materials (such as steel, concrete and glass etc.) manufacturing, transportation and installation in a building construction area require a large quantity of energy and involved with significant amount CO2 emissions.

The aim of this carbon calculator is to evaluate the impact in terms of energy, the environment of the construction materials most used in building construction and the alternatives materials in term of energy and carbon emission.

2. EMBODIED ENERGY

Energy is one of the most critical aspects in sustainable development of building simulation analysis. The energy consumed by all the processes associated with the production of a building (Building Materials), from the acquiring of natural resources to product delivery is called Embodied energy.

The parameters that are being evaluated are the energy consumed during the construction and the operation of a building, as well as its toxic behavior and the different pollutants that appear in the various stages of its lifecycle. This includes the mining and manufacturing of materials and equipment, the transport of the materials and the administrative functions. [2]

Energy is embodied in everything we use every day: from food to clothing to cars, as well as buildings and all materials used in them. In the United States, 6% of all energy consumed is used to manufacture and transport building materials. As buildings consume less energy in operations, the energy embodied in the building's materials will become increasingly important as a percentage of a building's total energy footprint.

Embodied energy is generally expressed in MJ/kg (1MJ= 0.948 kBtu or 0.278 kWh) and values for Material Life have

been converted to MJ per construction unit (i.e. ft2 for flooring) and are listed for the cradle-to-gate portion of the product's life cycle (raw materials, transportation to factory, processing and manufacturing, transportation to site, Construction, Maintenance, replace & recycle materials etc.). Academic studies have illustrated that embodied energy accounts for the majority of a building's energy footprint for approximately the first 15-20 years of a building's life-cycle. [3]

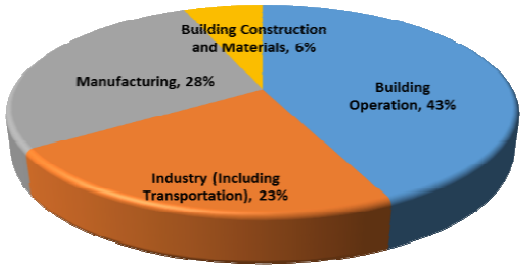

Fig. 1: Annual Energy Consumed in USA, 2009. [3]

The embodied energy of each part of the construction (Steel, Wood, Concrete etc.) is summarized and determines the embodied energy of construction, with the use of proper software, the required energy for the residence is being calculated. As a result, an energy-time diagram is formed which indicates the long-term energy behavior of residences, starting from their embodied energy.

3. GREEN BUILDING AND MATERIALS

Conventional construction materials uses natural resources like as clay, sand, wood and rocks, even twigs and leaves have been used to construct buildings. Through this many man-made materials (more and less synthetic) are used as construction materials. Manufacturing of building materials is an established industry support different construction materials segmented into different trades such as plumbing, roofing, carpentry and insulation work. They support the make-up of habitats and structures including residences.

Green building (also known as green construction or sustainable building) refers to a structure and using process that is environmentally responsible and resource-efficient throughout a building's life-cycle : from sitting to design, construction, operation, maintenance, renovation, and demolition.

The aim of green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment by a) efficiently using energy, water, and other resources, b) Protecting occupant health and improving employee productivity, c) Reducing waste, pollution and environmental degradation.

Green Buildings-Materials

- Site Considerations
- Reduce, Reuse, Recycle
- Exterior Building Materials (Color, Decking, Foundation, Fly ash, Drainage, Roofing etc.)
- Interior Building Materials (Floors, Paints and Primers,
- Heating and Cooling, Ventilation & Air Conditioning, Windows, Lighting).

4. CARBON CALCULATOR

For selecting the best material and minimizing the environmental impact for building construction, we should compare all of available materials and there alternatives in terms of energy and carbon (CO2) emission. The aim of this calculator, user can evaluate the impact in terms of energy and the carbon emission (environment) of the construction materials most they used at the moment in the building sector in comparison with the reduced impact of different eco-materials, proposing and assessing, whenever possible, specific measures for the reduction of these impacts in all stages of the product: manufacture, transport and final disposal. At the first stage we consider the energy and carbon emission for manufacture (embodied energy) and transportation of the construction materials. For calculation we use the Microsoft Office Excel.

The calculator consist of four part, namely

a) Input:

Input section consists of the user information, material list, used amount, transportation medium and transportation distance. From material list, user can chose the material type form the drop down list of the materials. User should put the used material in terms of kilogram (Kg), chose the transportation medium and insert the transportation distance in kilometer for corresponding materials.

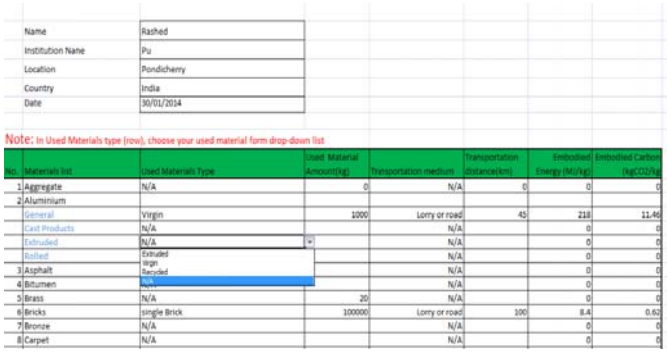

Fig. 2: Snap shot of Input Section.

b) Source:

Source file contain the Impact calculation coefficients for transport stage from production plant to building construction site, embodied energy and embodied carbon content for corresponding material. User can add more material in the source section.

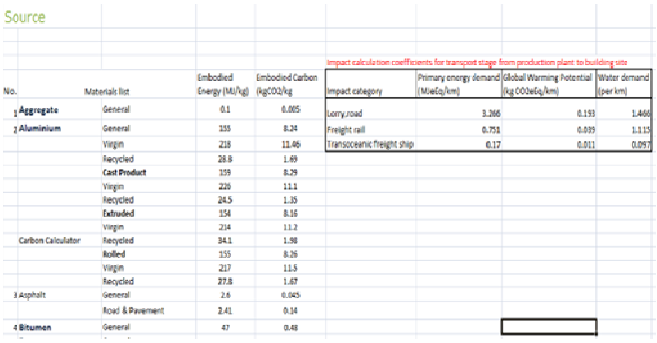

Fig. 3: Snap shot of Source Section.

c) Calculation

In calculation section we calculate the total energy and carbon content for corresponding material including the embodied and transportation of the materials.

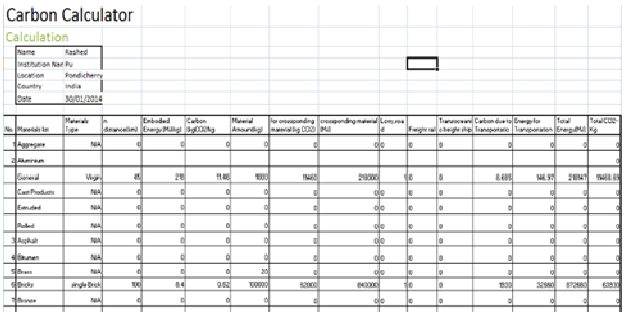

Fig. 4: Snap shot of Calculation Section.

d) Output:

Output of the calculator gives the used material list and their corresponding energy and carbon. It also the gives the total amount of energy and carbon for used material.

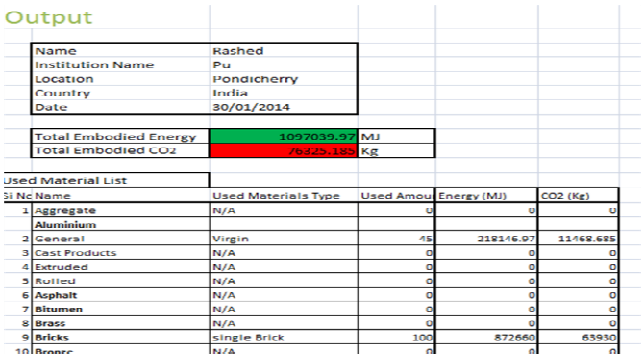

Fig. 5: Snap shot of the Output Section.

5. CASE STUDY: LOCATION: ANDHRA PRADESH–GUNTUR (DIST.)-VINUKONDA

Conventional Materials Used:

Construction of building: The materials used to construct a house are Bricks, Sand, Cement, Concrete, Iron etc.

Other materials: PVC pipes, Ceramic, Plastic Materials, Wood, Marble, Glass, Paint and paper etc. These materials used for interior construction of the house.

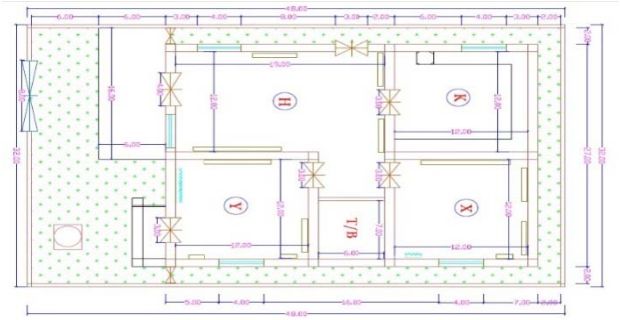

Fig. 6: AutoCAD Building Drawing of the Case Study.

Dimensions of total site:
Total Length: 44.10 ft.
Total Width: 28.35 ft.
Total Area of the house is 1250.23 sq. ft.
House plan:

Table 1: Dimension of the Building for Taken Case Study.

Sl. No.	Dimensions of each room	Length x Width (feet)
1	Living Hall	18x12
2	2 Bed Room	2 (12x12)
3	Kitchen	12x12
4	Bathroom	6x6
5	Portico	6x15

Table 2: Typical Materials used in Construction site.

Material name	Quantity in Kg	Transportation Distance in Km
Cement	16100	80
Sand	64000	120
Aggregate	28000	95
Bricks	35000 bricks	20
Iron	300	350
Paint	50Lt	80
Marble	3624	65
Ceramic	54	120
Plastics(PVC)	800	250
Glass	200	80
Paper	5	2

With this materials using carbon calculator the total amount of embodied energy and embodied carbon are calculated.

Alternative for conventional:

House constructed with locally available bamboo for RCC roof. The house look like as normal house constructed with Iron. The wood or bamboo used for construction doesn't need any pretreatment and they treated as iron bars which are using in conventional construction.

How bamboo is useful for construction:

Bamboo is a versatile plantation species and its raising is ecologically sound and economically viable.

There are two important species of bamboo occurring in the State–

a) Dendrocalamus strictus (Sadanam or solid bamboo), and
b) Bambus bambo (Mullem or hollow bamboo).

- The walls are composed of "vascular bundles" of which there are five types.
- The outside portion of the culm wall is dense, containing about 5% silica. It has an exterior waterproof film which occurs on the softer interior portion as well.
- Bamboo is particularly strong at the node, where there is an inner disc called the septum which connects the outside walls, strengthening the stalk and separating in into compartments.
- Bamboo is widest at ground level, but is quite consistent in diameter throughout its length.

Fig. 7: Construction Site used Bamboo.

Table 3: Unit taken for calculating Embodied Energy and Carbon calculation. [3]

Material	Embodied Energy per Kg	Embodied CO2 per Kg
Bamboo	0.015	0.00203

6. RESULT

If we calculate separately the embodied energy and the emission of CO_2 for the conventional construction of the building with the alternative materials (here we only used the bamboo for some purposes), carbon calculator gives the amount of embodied energy and the CO2 emissions saved.

Table 4: Saving calculating through using our Carbon calculator.

Construction	Embodied Energy per Kg	Embodied CO2 per Kg
Conventional	13813556.3	832989.849
Using Bamboo	13770323.3	829466.767
Savings	120432.33	3523.082

7. CONCLUSION

It is clear from the calculating results that the savings obtain from green building is able to calculate embodied energy and CO2 by using carbon calculator. Carbon calculator is used to evaluate the impact in terms of energy, the environment of the construction materials most used in building construction and the alternatives materials in term of energy and carbon emission. So any further development of carbon calculator gives the opportunities to analyses any constructed building to become a Green Building.

8. ACKNOWLEDGEMENTS

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