Quantum of Embodied Energy for Residential Buildings

Abhishek R Patil, Suraj D Shinde

Abstract: Embodied energy(E.E) is the total amount of energy that is required in the production of a material which include all the processes, from the mining and processing of natural resources to manufacturing, transport and product delivery and this helps in choice of materials and construction methods, to maximize the energy efficiency of a building during its operation. The E.E. in products and energy conservancy are the ecological features included in eco-labelling schemes. Embodied energy in materials is a significant aspect in GB rating systems. This paper discusses the influence of different construction units on the E.E. of the structure.

Keywords: Embodied energy (E.E), Buildings, Cement, Steel and Brick.

I. INTRODUCTION

The Consideration of green building rating systems for evaluation of building materials is still in the developing state in our Country. The perception of sustainable construction ancient units such as stones, adobe, cobe, thatch, earthbags, etc. are being exercised since times of human era. However, the compassion of people regarding strong and durable construction resources has led to use of modern-day resources like steel, plastic, fibers, cement, glass, etc. During production of such materials huge amount of energy is consumed in the form of fuel. Also, these being the industrial products are required to be transported to a large distance before getting used in the buildings. Hence, if the estimate is prepared for the energy consumptions by various materials and techniques will be helpful in appropriate selection and thus reducing the embodied energy consumption.

A building with low quality building units cannot be considered as sustainable even if it is energy efficient. An energy efficient building with poor building material choices may not be considered sustainable, to measure the sustainability it may be categorized in a common unit; i.e. in the unit of energy, or the total life-cycle energy demand. [8] It includes

- the embodied energy involved in the acquisition, processing, manufacturing, and transportation of construction units throughout the erection phase;
- the operation energy of the building; and
- the demolition energy is removal, and recycling of building materials.

Embodied energy for a building may be defined as the energy related to construction of building, which includes extraction of raw material to the manufacture of the building products and construction on site, as well as any energy for the transport of the former activities. [4].

II. THE CASE STUDY

In this section, calculation of embodied energy for different materials will be done. A case study building which represents a residential building of two floors is studied. The building is built with reinforced concrete and brick masonry

A. Site analysis

The site Considered for Study is located in Jamkhandi, dist-bagalkot, Karnataka. It is G+1 Residential dwelling & also the area around the house is residential development. The total Plot area is 2152 square ft. The toatal area covered at ground floor is 1019.77 Sq. Ft. Similarly, area covered in first floor is 679.095 Sq. Ft.

B. Climate analysis:

a) Rainfall: - Annual Seasonal Rainfall is 647mm 22% less compared to the normal of 834mm.

b) Temperature: - Over the course of the year, the temperature typically varies from 63°F to 100°F and is rarely below 57°F or above 104°F.Humidity: - Except during monsoon season when humidity is high the air is generally dry.

c) Cloudiness: - In Jamkhandi, the average percentage of the sky covered by clouds experiences extreme seasonal variation over the course of the year

d) Winds: - The wind is most often from the west for 6.9 months, from March 9 to October 5, with a peak percentage of 100% on August 1. The wind is most often from the east for 5.1 months, from October 5 to March 9, with a peak percentage of 73% on January 1.

C. Plan of the Building

The plan of the building whose case study is carried out in this work is shown in Fig.1.

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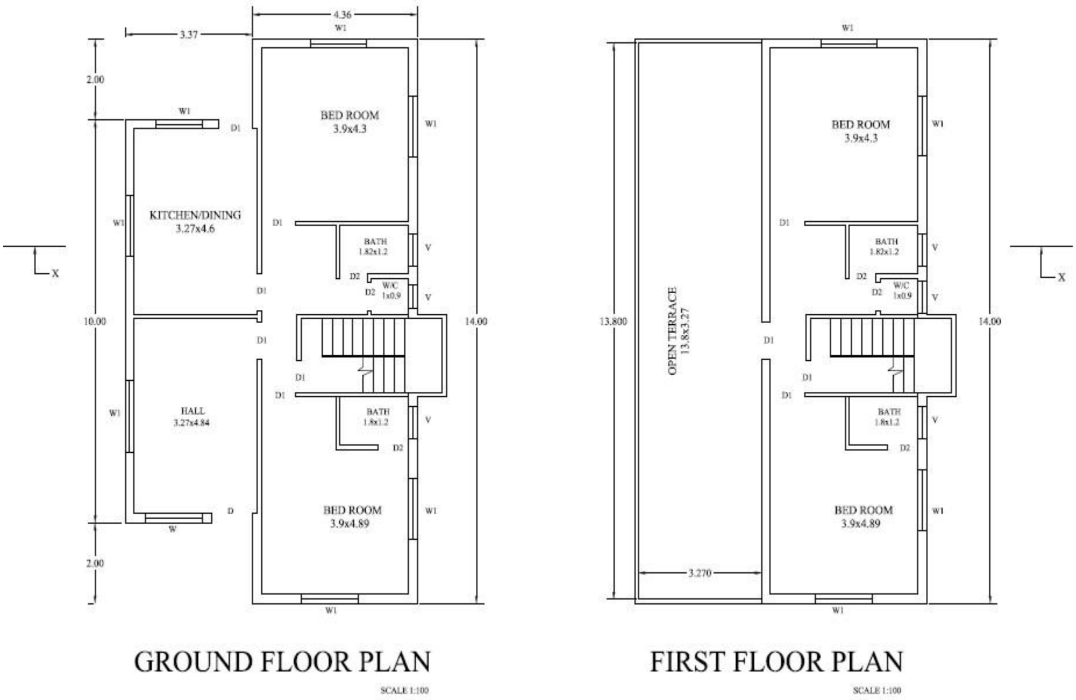

Fig. 1.Building plan considered for case study.

D. Estimating energy consumption for the dwelling unit

The various Resources required and their quantities are estimated from the plan of the building. The Estimated resources are shown in table below.

Table 1: Estimated construction Resources

S. No.	Resources	Req. Amount	Unit
1	Steel	5.8	Metric Tn.
2	Cement	34.25	Metric Tn.
3	Blocks	43000	No.
4	Aggregates	50	Cum.
5	Sand	59	Cum.

E. Estimating the energy embodied in materials of the building:

The estimation is done as shown in table no. II, for various building materials. The total embodied energy is calculated by multiplying the energy required to produce one-unit of raw material by the total material requirement for the entire building.

F. Estimation of E. E. consumed during the Transportation of materials of the building:

The transportation of raw materials is done by various modes which consume fuel. Hence consideration of transport E. E. is also necessary. So, it is done in two steps. First the fuel energy required to transport the material from plant to distributor and then from distributor to the site were finally the material is used. Single side transportation is considered and it is as shown in the following table no. III

Table II: Energy Embodied in materials of Building

S.	Resources	Req. Amount	unit	energy	Unit	Total Energy (MJ)
1	Bricks	43000	No.	5.34	MJ/brick	252410
2	Cement	34.25	Metric Tn.	4.2	MJ/Kg	143220
3	Steel	5.8	Metric Tn.	23.23	MJ/Kg	134734
4	Aggregates	50	Cum	35.98	MJ/cum	1799
5	Sand	59	Cum	37.31	MJ/cum	2201.29

The Overall E. E. by resources=534360.29 Mega Joules

G. Material Fixing energy

Energy consumed during various operations of building are considered in this category. They are estimated as shown in following table IV

Table IV: Material Installation Energy for Building

S. n..	Type	Amount	Unit	Energy	Total Energy
1	Electricity	1440	KWh	3.6 MJ/kWh	5184
2	Diesel	83.65	Litres	38.08MJ/Lit	3185.39

Total E.E. during installation=8369.39 MJ

Table III: Transport Embodied Energy (Manufacturer to dealer) for Building Material

Sr. No	Material	Location of plant	Distance of site from plant (KM)	Vehicle used	Mileage (Km/lit)	Total distance travelled (Km)	Diesel consumed (ltr)	Calorific value of diesel (MJ/lit)	EE(MJ)	Capacity of vehicle	Number of trips	Total EE
1	Brick	Algur,Karnataka	10	Tractor	10	20	2	38.08	76.16	2500 no.s	18	1370.88
2	Steel	Bicholim,goa	238	Truck	4	476	119	38.08	4531.5	10 ton	1	4531.52
3	Cement	Lokapur,Karnataka	38	Truck	5	80	16	38.08	609.28	500 bags	2	1218.56
4	Aggregate	Mudhol,Karnataka	18	Hywa	3	36	12	38.08	456.96	3 brass	6	456.96
5	Sand	Kadkol,Karnataka	8	Tractor	5	16	3.2	38.08	121.86	3 brass	7	852.992

Overall E. E. by transportation (plant to site) = 10715.71 Mega Joules.

Overall E. E. of building includes energies estimated in Tables I, II and III.

Table V: Overall E. E. of Building

Sr. No.	Energy Source	Quantity of energy (MJ)	Total
1	Material manufacture	534360.29	553.44 GJ
2	Material transport	10715.71	
3	Material installation	8369.39	

III. DISCUSSION

In Fig. 2 we can see that the embodied energy consumed while the manufacturing of bricks is more as compared to other construction materials, even though bricks are locally available, but the quantity required is more. Cement and steel have nearly equal E.E. requirement.

Fig 3 shows the consumption of energy during the transportation of the units from manufacturer to dealer. As, steel and cement plants are located generally at remote distances, the transportation energy required for this materials is more as compared to bricks and aggregates which are generally available near the site.

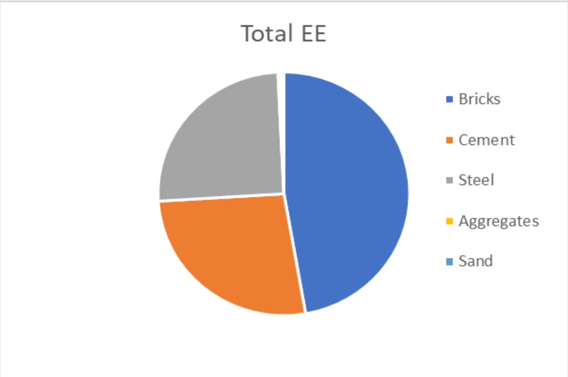

Fig. 2. E.E. consumed by material manufacture.

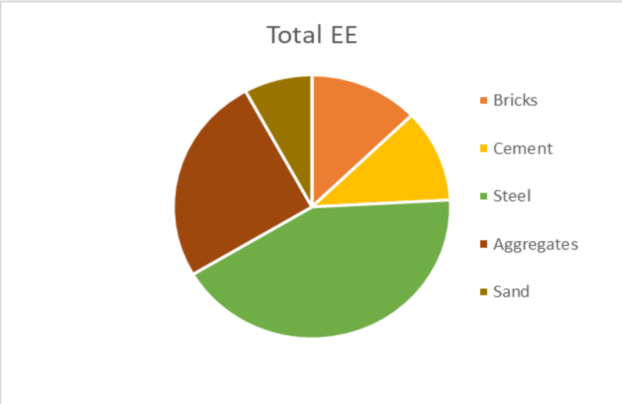

Fig. 3.E.E. required for material transport

The E.E. in a building can be decreased by using the construction materials which are eco-friendly, materials with low maintainence cost and also it should be looked that the transport energy consumed will also be low.

IV. SUBSTITUTES FOR TRADITIONAL CONSTRUCTION MATERIALS AND METHODS

A. Aerated light weight cement blocks

ALC Blocks are modern solution and substitute for traditional bricks, they are made of 50% fly ash and 50% cement these are light in weight and ecofriendly.

For manufacturing of one cumec of alc block using ALC agitator, 15 kilowatt of electricity and 8 ltrs of diesel is required. Therefore, for a block of size 6"x 9"x 24" 0.318kwh of energy and 0.212 ltrs of diesel is essential.

Embodied energy-

CV of diesel is 38.08 MJ/ltr and that for electricity is 2.77 MJ/ kwh.

Manufacturing of 1 alc block EE req. is

2.77*.318 + 38.08*0.212

=8.95 Mega Joules

The energy required for manufacturing one alc block is 8.95 MJ

Table VI. Energy required for alc blocks and red bricks for area of 3.15 x .4.84 x 3 m

Material	Amount rq.	Mode of energy	Energy required	Total E.E. (MJ)
Red brick	3655	Firewood	5.34 MJ/brick	19517.7
Alc blocks	352	Electricity	8.95 MJ/block	3151.74
% Saving of energy=83.85%				

While considering the embodied energy associated with transportation of material will depend upon which factory is nearer to the construction site

B. Filler slab

The filler slab is based on the principle that for roofs which are simply supported, the upper part of the slab is subjected to compressive forces and the lower part of the slab experience tensile forces. In filler slab the bottom region is filled with batters such as broken tiles red burnt bricks pieces etc.

Table VII: E.E. for one cumec of slab

Material description	Embodied energy	Conventional slab		Filler slab	
		Quantity	EE	Quantity	EE
Cement (kg)	4.2 MJ/kg	403.2	1693.44	342.35	1437.87
Sand (cum)	37.31 MJ/cum	.42	15.67	0.39	14.55
Aggregate (cum)	35.98 MJ/cum	0.84	30.22	0.78	28.06
Steel (kg)	23.23 MJ/kg	28.2	655.086	17.48	406.06
Total EE (MJ)			5328.506		4144.88
% Saving of energy= 22.21%					

C. Ready mixed concrete

The concrete is assorted in batching plant, according to the desired mix proportion required for the client, and then transported to the construction site with the help of lorry mounted in transit mixer. Ready mixed conc. is chosen over on-site mixing concrete due to machined mixing and reduced human errors. The energy required for the mixing of concrete is current, approximately 1 kilowatt energy is required to mix half cum of concrete. Hence the Ready mixed conc. is energy efficient as compared to site mixing concrete. While calculating E.E. the transportation energy of concrete from RMC plant to site is considered, in the present case RMC plant is located within the 20 km from the site so it is feasible.

Table VIII: Energy assessment between RMC and site mixing for case study

Type of conc.	Quantity of concrete	Mode of energy	Energy required	Total E.E. (MJ)
RMC	10 cum	Electricity	2.25 kwh/ cum	62.23
Site mixing	10 cum	Diesel	0.5lit/cum	190.4
% Saving in energy=67.31%				

D. Crushed sand

The artificial sand produced by the crushing of stones by proper machines is a very good substitute for river sand.

For crushing one and half brass of sand approximately 20 kWh electricity is used. Hence for manufacturing one cm. crushed sand approximately 4.713 kWh energy is consumed during process.

Embodied energy of Crushed Sand=4.713 x 2.77=13.05 MJ/cum

Table IX: Energy assessment between m sand and natural sand

Category	Amount required	Mode of energy	Energy required	Total E.E. (MJ)
M. sand	59 cum	Electricity	20.98 MJ/cum	1237.82
Natural sand	59 cum	Diesel	37.31 MJ/cum	2201.89
% Saving of energy=43.75				

V. CONCLUSION

Through a simple case study, this paper demonstrates the embodied energy consumed by most commonly used building materials. Also a attempt is made to compare and suggest some alternative materials which can be used in construction. Various building materials manufactured using different methods at the same place and same time may lead to varied energy consumption. This may lead to a difference in E.E. for various materials.

1. The Materials which lead to increased energy consumption in buildings are Steel, Bricks and Cement.
2. Reducing or replacing the traditional materials with preference to the local materials may lead in the reduction of E.E. in buildings.
3. Transportation energy is the next big consumer in line, As the brick, sand and aggregates are locally available material, unlike the other suggested alternatives which are located at remote distances.
4. Energy consumption for steel and cement is more due to consideration of transport energy for raw material which is not available near the manufacturing plant.
5. A 22.31% energy saving may be achieved in when slab is made by filler technique than the conventional slab.
6. Replacing Red bricks by Alc blocks decreases the energy consumption by 83.85%.
7. By using RMC instead of site mixing leads to reduction of 67.31% energy consumption on site. & also increases the strength and workability of concrete.
8. The use of crushed sand in the replacement of river sand causes the energy difference 964.07(43%) MJ.
9. Proper site selection and proper building orientation plays an important role in deriving maximum benefits from natural resources, availability of material and transportation of material to site.

The embodied energy includes the material transport energy (factory to dealer and factory to site); hence maximum use of locally available material causes the reduction in transport energy.

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