Optimization of Embodied Energy of building with alternative materials: A Case Study

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ABSTRACT
Considerable amount of energy is spent in the manufacturing and transportation of various building materials. Conservation of energy becomes important in the context of limiting of greenhouse gases emission into the atmosphere and reducing costs of materials. In the present paper a case study of reduction in embodied energy of building is been carried out. Energy consumption in manufacturing of basic building materials is calculated and total embodied energy of building is compared for various alternative materials. Comparison of cost for various options of brick, and cement has been done. Also embodied energy of cost for various options of brick, and cement has been calculated and compared. It is found that embodied of building with alternative materials can be reduced up to 50%.

KEYWORDS
Green building, Green energy materials, Embodied energy, Energy efficient materials, Energy optimization, Alternative materials, operating energy.

1. INTRODUCTION
Buildings, as they are designed and used today, symbolize unrestrained consumption of energy and other natural resources. They account for 40% of energy use in most of the Countries and the demand is persistently increasing especially in developing countries such as China and India [1]. Analysis of both operational energy and embodied energy is required for complete understanding of building energy needs. For energy efficiency, technology is the principal instrument that will facilitate more rational use of resources during the entire life cycle of a building, through the phases of construction, use and demolition [2]. Selection of materials and technologies for the building construction should satisfy the felt needs of the user as well as the development needs of the society, without causing any adverse impact on environment. In recent years, awareness of environmental aspects has grown in the building and construction sector. Manufacturing processes of building materials contribute greenhouse gases like CO_2 to the atmosphere [3]. There is a great concern and emphasis in reducing the greenhouse gases emission into the atmosphere in order to control adverse environmental impacts. Present paper discusses reduction in embodied energy of building with alternative materials.

2. BUILDINGS AND ENERGY
Energy consumption of the building depends on its type, usage and total occupancy. For different types of building energy requirement per unit area is different. Buildings can be divided in three major types, residential, public and industrial. Each building has a specific pattern of energy usage.

Energy consumed in building may be divided in two parts embodied energy (EE) and Operational Energy (OE). EE is defined as the commercial energy. Embodied energy is an accounting methodology which aims to find the sum total of the energy necessary for an entire product lifecycle. This lifecycle includes raw material extraction, transport, manufacture, assembly, installation, disassembly, deconstruction and/or decomposition. (OE) is a significant measure of sustainability which enables straightforward comparisons between alternative building technologies. Buildings consume energy for heating, cooling, ventilation, lighting, equipment and appliances. Passive energy systems rely on the building enclosure or envelope to take advantage of natural energy sources such as sunlight, wind, water, and the surrounding soil which reduces operating energy of building. With a limitation to consume a part of conventional energy as operating energy; reducing embodied energy of thermal mass of building is one option to reduce overall energy account of building [4]. In the present case study the educational building has occupancy of 250 and is operated for maximum 8 hours a day. Operation includes class room lighting and cooling and running heavy laboratory instruments. Laboratory instruments cannot be run on nonconventional sources of energy so scope of energy optimization remains with administrative building and classrooms.

3. METHODOLOGY
Methodology adopted in the study includes.

- An educational building of campus is selected.
- Cost estimate is prepared.
- Energy estimate is prepared for two basic building materials.
- Several options have been analysed.

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- Best option from energy and cost is suggested.

4. CASE STUDY

To assess the energy consumption pattern in educational structures, a R.C.C. framed structure, located in Nagpur, in composite climate, is studied. The composite climatic zone of India is where maximum temperature is around 48^0C and minimum temperature is around 25^0C. Building comprises of three storeys and has a design life of sixty years. The ground floor of the building comprises of 4 rooms and 3 laboratories. The area considered for the proposed study is 89.5 m^3 having long wall in east- west direction and short wall in north-south direction. Thickness of walls is 230 mm. The cost of conventional and green material have been compared and shown in fig. 1 and the comparison of the embodied energy between conventional and green material is given in fig. 2. A comparative analysis of EE of these options has been done.

Total occupancy of the building under consideration is 250 with eight hours operation on an average.

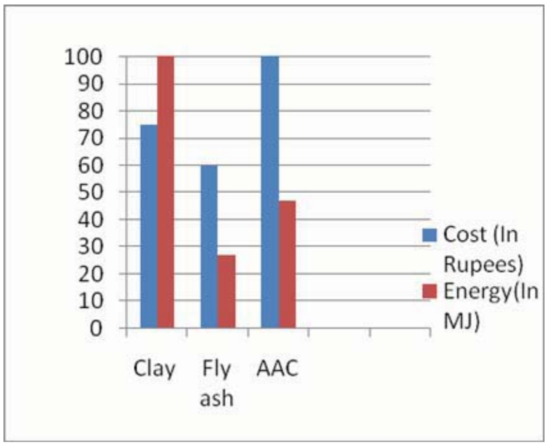

Fig. 1 Comparative study of walling material

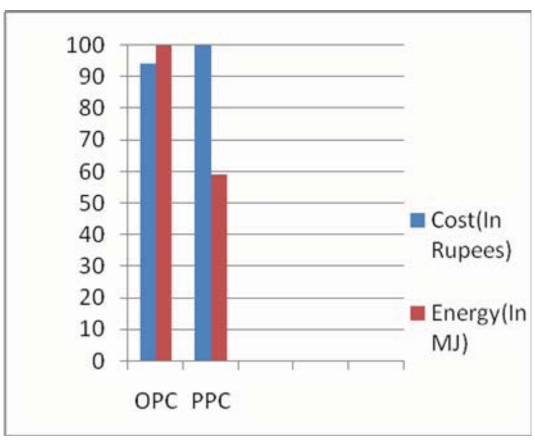

Fig. 2 Comparative study of cement

The transportation distance also has the considerable impact on the total energy of the building, as more the transportation distance, considerably more will be the energy required for the transportation which in turns adds to the total energy requirement. Table no. 1.

Table No. 1. Transportation Energy

Sr. No.	Item	Transportation Distance (In KM)
1.	Clay Brick	25-30 km
2.	Fly ash Brick	20-25 km
3.	AAC blocks	8-10 km
4.	OPC	10-15 km
5.	PPC	10-15 km

Comparison of cost and EE

Quantity of construction material has been worked out. Estimated quantity of walling material is 89.5 cum and cement is 32.054 cum i.e. 902 bags. Rates are taken from local manufacturers and suppliers of the respective material.

Various options for walling and cementing material are:-

Sr. No	Item	Designation In paper	Rate Per cum
1.	Clay Brick	CB	2500
2.	Fly ash Brick	FAB	2000
3.	AAC blocks	AAC	3300
4.	Ordinary portland cement	OPC	260 per Bag
5.	Portland Pozzolana cement	PPC	275 per Bag

Data Of the Embodied energy(EE) was taken from the local manifactures of the respective material

Sr. No	Designation In paper	EE per unit MJ
1.	CB	4050
2.	FAB	1100
3.	AAC	1920
4.	OPC	852
5.	PPC	507

Table No. 2 Cost Comparision and Saving.

Sr. no.	Material	Options	Cost in Rupees		
			Conventional Material	Energy efficient material	Saving
1	Brick	CB	223750.00		
		FAB		179000.00	**44750.00**
		AAC		295350.00	-71600.00
2	Cement	OPC	234520.00		
		PPC		248050.00	-13530.00

Table No. 3. Energy comparision and saving.

Sr. no	Material	Options	Energy in MJ		
			Conventional Material	Energy efficient material	Saving
1	Brick	CB	362475.00		
		FAB		98450.00	**264025.00**
		AAC		172600.00	**189875.00**
2	Cement	OPC	27286.00		
		PPC		16236.00	**11050.00**

5. . Discussion

Cost of conventional material is compared to energy efficient material. For masonry three options have been considered. Clay brick is conventional and Fly ash bricks and AAC blocks are energy efficient material. As shown in fig 1. It has been found that cost of clay bricks is 20% more than Fly ash bricks and 30-32% less than AAC blocks. AAC blocks are initially costly but the cost of plastering, finishing which is needed when we use clay or fly ash bricks, is reduced with the use of AAC blocks. AAC block also has the properties such as fire resistant, acid resistant, sound proof which add to its utility.

6. CONCLUSION

1. The overall study suggests that the use of energy efficient materials will considerably reduce the embodied energy.
2. The use of fly ash brick instead of conventional clay brick reduces the cost of bricks by 20% and the energy by 70-72%. Use of Autoclaved Aerated Concrete (AAC) blocks the cost of bricks increases by 32%, but energy wise it is effective as the embodied energy is less as compared to conventional material by 50% to 53%.
3. The use of PPC instead of OPC will lead to increase in cost by only 5-6%, but there the embodied energy is considerably decreased, by about 40-42%
4. The analysis shows that not only material alteration, but also the transportation distance will have significant impact on the cost as well as embodied energy of the building.

7. ACKNOWLEDGEMENT

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Fig. 2 Shows that both energy wise