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Estimation of Embedded Energy and CO_2 Emission of an Institutional Building

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***Abstract*- Demand for new buildings are increasing at a higher rate. Buildings are responsible for at least 40% of energy use in most countries. The absolute figure is rising fast, as construction booms, especially in countries such as China and India. It is essential to act now, because buildings can make a major contribution to tackling climate change and energy use.**

Energy efficiency techniques can be applied for all types of buildings.

In the present study, energy efficiency of an academic block with a student capacity of 300, in a technical institution is estimated. The rate analysis of the ordinary building construction cost is compared with the energy efficient building. For the comparison, estimation is done manually.

I. INTRODUCTION

Energy efficiency is a good slogan in the present world. Increase in energy efficiency take place when either energy inputs are reduced for a given level of service or there are increased or enhanced services for a given amount of energy inputs.

This work is focused around some issues pertaining to embodied energy in buildings particularly in the Indian scenario. Energy consumed in the production and usage of basic building materials and a few of their alternatives have been discussed.

A comparison of energy in different types of masonry has been made. Energy in different types of alternative roofing systems has been discussed and compared with the energy of conventional reinforced concrete (RC) slab roof.

II. ENERGY IN BUILDINGS

Energy in buildings can be categorized into two types:

(1) energy for the maintenance/servicing of a building during its useful life, and

(2) energy capital that goes into production of a building (embodied energy) using various building materials.

Study of both the types of energy consumption is required for complete understanding of building energy needs. Embodied energy of buildings can vary over wide limits depending upon the choice of building materials and building techniques. RC frames, RC slabs, burnt clay brick masonry, concrete block masonry, tile roofs represent common conventional systems forming the main structure of buildings in India. Similar building systems can be found in many other developed and developing countries. Alternative building technologies such as stabilized mud blocks (SMB's), prefabricated roofing systems, masonry vaults, filler slab roofs, lime-pozzolana (LP) cements, etc. can be used for minimising the embodied energy of buildings.

III. CONCEPT OF ENERGY EFFICIENT BUILDINGS

To reduce the overall environmental impact, by efficiently using energy, water, and other resources, new technologies refers in making the structures green or sustainable buildings. Energy efficient buildings protect the health of occupants and improve the employee productivity. They are designed to reduce waste, pollution and environmental degradation.

Green buildings often include measures to reduce energy use. To increase the efficiency of the building envelope (the barrier between conditioned and unconditioned space), they may use high-efficiency windows and insulation in walls, ceilings, and floors. Onsite generation of renewable energy through solar power, wind power, hydro power, or biomass and significantly reduce the environmental impact of the building.

A. Water Efficiency

Reducing water consumption and protecting water quality are key objectives in sustainable building. To the maximum extent feasible, facilities should increase their dependence on water that is collected, used, purified, and reused on-site. The protection and conservation of water throughout the life of a building may be accomplished by designing for dual plumbing that recycles water in toilet flushing. Waste-water may be minimized by utilizing water conserving fixtures such as ultra-low flush toilets and low-flow shower heads. The use of non-sewage and grey water for on-site use such as site-irrigation will minimize demands on the local aquifier.

B. Materials Efficiency

Building materials typically considered to be 'green' include rapidly renewable plant materials like bamboo ,recycled stone, recycled metal, and other products that are non-toxic, reusable, renewable, and/or recyclable (e.g. Linoleum, sheep wool, panels made from paper flakes, compressed earth block, clay,etc.)

The EPA (Environmental Protection Agency) also suggests using recycled industrial goods, such as coal combustion products, foundry sand, and demolition debris in construction projects. Building materials should be extracted and manufactured locally to the building site to minimize the energy embedded in their transportation. Where possible, building elements should be manufactured off-site and delivered to site, to maximize benefits of off-site manufacture including minimizing waste, maximizing recycling , high quality elements, less noise and dust.

C. Waste Reduction

Green architecture also seeks to reduce waste of energy, water and materials used during construction. During the construction phase, one goal should be to reduce the amount of material going to landfills [4]. Well-designed buildings also help reduce the amount of waste generated by the occupants as well, by providing on-site solutions such as compost bins to reduce matter going to landfills.

IV. EMBODIED ENERGY AND CARBON EMISSION

In the construction of buildings, a wide range of materials and products are used. They are made by the extraction of raw materials, processed, manufactured, transported to site, and constructed as the finished building. The energy associated with all these steps and processes is what makes up the embodied energy of the building and its materials , and is expressed in terms of the carbon dioxide emissions associated with this embodied energy.

TABLE 1: EMBODIED ENERGY AND CARBON EMISSION OF BUILDING MATERIALS

MATERIAL	UNIT	ENERGY/UNIT, MJ	CO_2 / UNIT, KG
BRICK	ONE BRICK	3.75 – 4.50	0.33
CEMENT	Kg	5.20	0.80
LIME	Kg	5.40	0.40
LIME+FLY ASH	Kg	2.33	0.15
STEEL	Kg	42.00	2.2 – 2.8
ALUMINUM	Kg	240.00	11 – 13
GLASS	Kg	14 – 17	0.7 – 1.0
SAND	Cu.m	206.00	15.9
MARBLE (RAJASTHAN)	Sq.m	200.00	15.4
POLYESTER	Kg	84 – 93	2.7 – 3.0
GFRP	Kg	107 – 118	7.5 – 8.3
POLYCARBONATE	Kg	105 – 116	5.4 – 5.9

Typically, embodied energy is measured as a quantity of non-renewable energy per unit of building material, component or system. For example, it may be expressed as Mega joules (MJ) or Giga joules (GJ) per unit of weight (kg or tonne) or area (square metre).

The production of building materials invariably entails utilization of thermal energy, very often based on fossil fuels. Based on studies by Prof. K.S Jagadish [1-3] the basic embodied energy of a number of building materials is listed in table 1. In this table the energy due to transport of materials that go into the production of materials like bricks, cement and steel has not been considered. However, the embodied energy of materials like sand and marble is essentially the transportation energy. This shows the importance of using local materials to bring down energy expenditure.

The carbon emission values generally follow the energy values except for cement and lime. Cement and lime generate additional carbon emissions since limestone loses its CO_2 during burning. The energy in cement is roughly one eighth of the energy in steel but the CO_2 emission value is about one third of steel. Burnt brick has a reasonably low value of 0.33 Kg of CO_2 per brick. However, a building needs large number of bricks and hence carbon emission from a building due to bricks is not small.

Alternative to bricks hence become important. Table.2 shows the energy and emissions due to three alternatives to burnt brick.

The hollow concrete block shows better energy reduction but it has an unacceptably low strength. Higher strength may be achieved by using more cement, but the energy expenditure could go up to some extent. The hollow clay block has higher energy content but is significantly superior to burnt brick due to its lighter weight. It is also the strongest of the four materials.

V. TOTAL EMBODIED ENERGY IN BUILDINGS

It is now possible to integrate the basic information on building materials to calculate the total embodied energy in a building.

Various technological options are available for buildings and it is useful to evaluate the effect of different building technologies[5]. Primarily, a building can be built either as a framed structure involving a large number of storeys or a load bearing masonry structure going upto 4 or 5 storeys. Table.3 shows the implications of different technologies by considering 5 typologies of buildings.

The table 3 clearly shows the advantage of load bearing masonry using SMB over RC framed construction. Even use of hollow concrete block for load bearing masonry can lead to energy efficiency provided the concrete blocks have strength of 6.0 – 7.0 MPa. The energy requirements can be further reduced using stabilized mud blocks for walls and roofs. The energy reduction is of the order of 80% when compared to RC frame with brick infill (8 storeys). Reduction of carbon emissions is also similar.

The maintenance energy and the corresponding carbon emission are however much higher than the embodied energy and carbon emissions. This is due to the preponderant use of electrical energy for lighting, thermal comfort, water pumping and so on. Proper utilization of day light for indoor illumination also becomes important.

VI. ENERGY CONTENT OF MASONRY

Masonry walls constitute one of the major energy consuming components of the building, especially in case of load bearing masonry structures. Varieties of materials are used for the construction of masonry walls. Different types of building blocks viz. stone, burnt clay brick, soil–cement block, hollow concrete block and steam cured mud block are considered. Energy content of masonry should include energy content of masonry units as well as mortar.

TABLE 2: ENERGY AND EMISSIONS FROM BUILDING BLOCKS

Material	Unit Size cm	Energy/ unit MJ	Energy for brick equivalent volume MJ	CO_2 Emission for brick equivalent Kg	Strength MPa
Brick	23x10.5 x7.5	3.75 – 4.50	3.75 – 4.50	0.33	3.0 – 7.0
Stabilised Mud Block (SMB)	23x19x 10	2.87	1.19	0.185	3.0 – 4.0
Hollow Concrete Block	40x20x 20	7.85 – 10.4	0.89 – 1.18	0.136 – 0.181	2.0
Hollow clay block	30x20x 15	9.00	1.81	0.177	10.0

Energy/m³ of masonry as well as equivalent of brick masonry energy has been reported. Cement mortar (1:6) for brick masonry and hollow concrete block masonry and cement–soil mortar (1:2:6) for soil–cement block masonry and steam cured mud block masonry, have been considered for calculating the energy content of masonry.

TABLE 3: ENERGY AND EMISSIONS FROM DIFFERENT BUILDINGS

Building type	Total embodied energy/m^2 GJ	Equivalent coal, T	Carbon emissions. T/m^2	Maintenance energy 25 years, GJ/m^2	CO_2 emissions 25 years T /m^2
8 Storey RC frame wi th brick-in-fill	4.20	0.21	0.41	9.3	0.91
4 Storey RC frame wi th brick-in-fill	2.70	0.135	0.25	9.3	0.91
2 storey brick masonry RC floors	2.65	0.133	0.25	9.3	0.91
4 storey SMB masonry RC floors	1.33	0.067	0.13	9.3	0.91
2 storey SMB masonry SMB floors	0.62	0.03	0.06	9.3	0.91

Energy content of brick masonry is the highest with a value of 2141 MJ/m³. Soil–cement block masonry consumes only about one-third of brick masonry energy. Hollow concrete block masonry requires about 38–45% of the brick masonry energy. Steam cured mud block masonry consumes about two-thirds of that needed for brick masonry. Soil – cement block masonry is the most energy efficient among the alternatives listed in table 4.

TABLE 4: ENERGY IN MASONRY MATERIALS

Type of masonry	Energy/m³ of masonry (MJ)	Equivalent of brick masonry energy (%)
Burnt clay brick masonry	2141	100
Hollow concrete block masonry	819 (7% cement blocks) 971 (10% cement blocks)	38.3 45.4
Soil–cement block masonry	646 (6% cement blocks) 810 (8% cement blocks)	30.2 37.8
Steam cured mud block masonry	1396 (10% lime blocks)	65.2

VII. ENERGY CONTENT OF FLOOR/ROOFING SYSTEMS

Varieties of alternatives are available for the construction of roof/floor of a building. Energy in different roofs/floor systems are listed in Table 5.

TABLE 5: ENERGY IN DIFFERENT ROOFS/FLOOR SYSTEMS

Sl no:	Type of roof/floor (span 3.6m)	Energy/m² of plan area (MJ)	Equivalent of RC solid slab (%)
1	RC Slab	730	100.0
2	SMB filler slab roof	590	80.8
3	RC ribbed slab roof	491	67.3
4	Composite brick panel roof	560	76.7
5	Burnt clay brick masonry vault roof	575	78.8
6	SMB masonry vault roof	418	57.3

7	Mangalore tile roof	227	31.1
8	Ferroconcrete roof	158	21.6

VIII. ESTIMATION OF TOTAL ENERGY AND CO_2 EMISSION

Detailed estimate of the proposed building was done manually and the total embedded energy and CO_2 emission are calculated. The results are shown in Table 6. The energy and CO_2 emission calculated for alternate building materials are shown in Table 7.

TABLE 6: ESTIMATE OF ENERGY USING CONVENTIONAL MATERIALS

SL NO	DESCRIPTION	QTY	UNIT	ENERGY RATE	UNIT	TOTAL ENERGY(MJ)	CO2/UNIT, KG	TOTAL CO2 EMISSION
1	CEMENT	1179156.608	Kg	5.2	Kg	6131614.362	0.8	943325.2864
2	SAND	2331.036	m³	206	m³	480193.416	15.9	37063.4724
3	AGGREGATE	3773.83	Kg	87.5	kg	330210.125	Negligible	Negligible
4	BRICK	471956.78	No	4	No	1887827.12	0.33	155745.7374
5	STEEL	3059.887	Quintal	42	Kg	128515.254	2.4	7343.7288
6	GLASS	333.2	m²	25.8	m²	8596.56	0.8	266.56
7	MARBLE	2997.483	m²	200	m²	599496.6	15.4	46161.2382
8	RC ROOF	3202.498	m²	730	m²	2337823.54		0
	TOTAL					**11904276.98**		**1189906.023**

TABLE 7: ESTIMATE OF ENERGY USING ALTERNATE MATERIALS

SL NO	DESCRIPTION	QTY	UNIT	ENERGY RATE	UNIT	TOTAL ENERGY(MJ)	CO2/UNIT, KG	TOTAL CO2 EMISSION
1	LOW POZZOLANA CEMENT	1179156.608	Kg	2.33	Kg	2747434.897	0.15	176873.491
2	SAND	2331.036	m³	206	m³	480193.416	15.9	37063.472
3	AGGREGATE	3773.83	kg	87.5	kg	330210.125	Negligible	Negligible
4	STABILIZED MUD BLOCK	471956.78	No	2.87	No	1354515.959	0.185	87312.004
5	STEEL	3059.887	Quintal	42	Kg	128515.254	2.4	7343.729
6	GLASS	333.2	m²	25.8	m²	8596.56	0.8	266.56
7	MARBLE	2997.483	m²	200	m²	599496.6	15.4	46161.238
8	STABILIZED MUD BLOCK ROOF	3202.498	m²	590	m²	1889473.82		
	TOTAL					**7538436.63**		**355020.495**

IX CONCLUSION

Embodied energy in basic building materials, the energy emission and their carbon dioxide emission has been studied. Here an academic block in a technical institution was studied and estimated the energy release from the conventional building. After using few alternative materials, a detailed comparison has been made. It was found that there was a net decrease of 37% in energy emitted and almost 70% in carbon dioxide emitted to the atmosphere. Thus we concluded that by selecting energy efficient building technology, it would lead to considerable reduction in embodied energy and carbon dioxide emission of the building as a whole.

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