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Green Building: A Sustainable Building Technology to Reduce the Embodied Energy

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Abstract: Climate change, caused by the emission of Green House Gases (GHG) into the atmosphere is considered as one of the major threats in the 21st century. Heavy dependence on energy resources at various stages of manufacturing and distribution of products result in uncontrolled emission of GHG. Total share of the global energy consumption in India and China has also been on the rise due to heavy population explosion, industrialization, urbanization, and intensive growth in Information Technology (IT). If we consider the total energy consumption, building &infrastructure is one of the prime energy consumers up to 40%. This consumption can be reduced through improved efficiency in the building materials and technological advancements. This will result in significant drop down of GHG emissions and control the associated environmental problems within the standards. Hence, sustainable development in building construction becomes an important national agenda for any country to mitigate global environmental problems. Any possibility to reduce the energy consumption in the construction industry local lycan is considered as a potential achievement to meet the challenges of global energy demand and climate change. This research paper discusses about general scenario of energy efficient buildings which are known as green buildings, life cycle energy (embodied energy& operational energy) in buildings and also highlights the importance of sustainable construction.

Keywords: Energy efficiency, Green buildings, Embodied energy, Operational energy, Sustainability.

I. INTRODUCTION

Construction industry is the second largest industry in India and it is one of the largest consumers of natural resources. The demand for infrastructural facilities in the form of different kinds of buildings (residential, commercial and industrial), transportation systems, water resources structures and energy systems are ever increasing due to population explosion, industrialisation, urbanization and widespread growth in Information Technology. The boom in construction industry results in tremendous demand on building materials. The housing sector alone contributes 5-6 percentage of GDP (Gross Domestic Product) in India and it employs more than thirty five million people. This industry consumes more than half of the economic expenditure budget and this sector has been growing at a rapid pace results in many adverse impacts on the environment.

The Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN) [14]by the Intergovernmental Panel on Climate Change (IPCC) reports that renewable energy will be the dominant low carbon energy source by the year 2050. Since building sector alone consumes almost40% of the total energy generated [16], there is an increasing need for alternative methods for controlling the energy consumption. This may be possible by optimum utilization of energy resources and raw materials to produce simple, energy efficient, environment friendly and sustainable building alternatives and techniques[18].This research paper discusses about general scenario of energy efficient buildings which are known as green buildings, life cycle energy (embodied energy & operational energy) in buildings and also highlights the importance of sustainable construction.

II. DEVELOPMENT OF GREEN BUILDINGS FOR SUSTAINABLE CONSTRUCTION IN INDIA

In India, the rate of growth in construction industry is 10 % as compared to the world average of 5.2%. In the recent past, Government of India has initiated many mega infrastructural projects in various parts of the country such as Metro rail projects, Highway projects (Golden Quadrilateral, North-South & East-West Corridors and Delhi-Mumbai Industrial Corridor (DMIC)), River Interlinking Project (Mega network of canals to connect major Indian Rivers) Smart Cities (100 numbers) and Smart Villages (60 numbers).The Ministry of Housing and Urban affairs, Government of India introduced AMRUT (Atal Mission for Rejuvenation and Urban Transformation) to promote urban development and to support economic growth in the country. The main aim of AMRUT is to provide basic infrastructure services such as water supply, sewage connections, green spaces, parks and transportation facilities to 500 cities and towns. These development-enabled structures in the Nation used millions of tonnes of building materials which are directly or indirectly responsible for Green House Gas (GHG)emissions and it has been estimated that 22% of GHG

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emissions is contributed by the construction sector in India. Hence, energy efficiency in the building sector assumes a significant role.In the recent past, energy efficient alternative building technology, which is eco-friendly in nature, known as green buildings have been developed world-wide. Green buildings are designed in such a way that they use optimum energy and water, better indoor air quality and sustainable management of other natural resources. This will be helpful to create less amount of waste and offer healthier built-in environment for the users. These buildings are constructed with eco-friendly designs by using environment-friendly materials. In India, Green building movement started in the year 2000.

Generally, buildings are planned for its lifelong serviceability and safety and hence, sustainable construction methods and materials are required. A widely accepted definition for sustainability is “to meet the needs of the present without compromising the needs of the future generations”. Some of the sustainable building options may be written as[17]: (i) Energy conservation i.e., to design the building with minimum energy requirement and maximum utilization of renewable energy, (ii) Minimize the use of energy intensive materials and promote locally available materials, (iii)Adopt environment friendly designs and technologies, (iv) Maximum utilization of industrial and mine wastes to manufacture building materials, (v) Recycling of building wastes, (vi) Proper utilization of surrounding area and roof by making gardens and greenery, (vii) Efficient utilization of natural resources/ raw materials, (viii) Adopt optimal building planning and designs, and (ix) Introduce roof water harvesting techniques in buildings.

In the recent past, awareness on environmental aspects has been grown up in the construction sector. There is a great concern and emphasis on environmental issues which can be controlled by reducing adverse environmental impacts using green materials or energy efficient materials. Ministry of New and Renewable Energy (MNRE) has identified green buildings as one of the aspirational goals of Government of India’s off-grid energy deployment and the plan is to achieve 200 Million Cubic Metre green buildings by the year 2022[15]. The capacity building and awareness generation in green buildings and campuses are considered as one of the strategies of this Ministry during 2011-17.

III. NEED FOR GREEN MATERIALS

The invention of Portland cement and steel caused revolutionary changes in the field of construction. The key material used in construction is reinforced cement concrete and it is actually the final product made from cement and steel. The extensive use of various energy intensive building materials such as steel, cement, glass, aluminium, plastics and other metals provide tremendous pressure on the environment, leading to degradation at various levels. The production and transportation of raw materials and finished products contribute heavily to the increased energy requirements and related environmental problems. Usually, these materials are transported from far-away places and hence, the energy requirement for transportations getting highly intense fied. The production of cement is a major contributor to GHG and it is assessed that the production of one Ton of Ordinary Portland Cement (OPC) releases approximately one Ton of carbon dioxide to the atmosphere [1].Figure 1 and Figure 2 show the details of cement production and corresponding CO_2 emission at global level and Indian level respectively. Globally, cement production and corresponding CO_2 emission had increased almost twice from 1990 to 2005. But in India (during this period), the cement production had increased almost three times and the corresponding CO_2emission was increased more than twice. It has been estimated that around 18.2% of total carbon dioxide (CO_2) emission is resulted because of cement and infrastructure industries only. Hence, it is necessary to reduce the use of the cement which is not possible in today’s context and the viable solution is to make environment friendly concrete. This can be developed by adding green materials (energy efficient materials)such as industrial waste materials like fly ash, silica fume, grounded furnace slag etc., with partial replacement of cement.

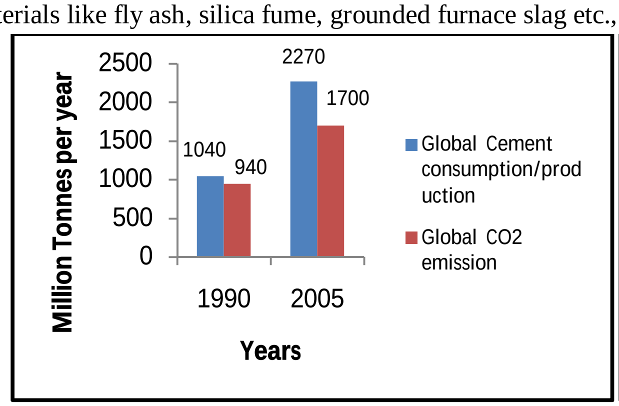

Fig 1: Global Cement Consumption and CO_2 Emission (Source of Data [17])

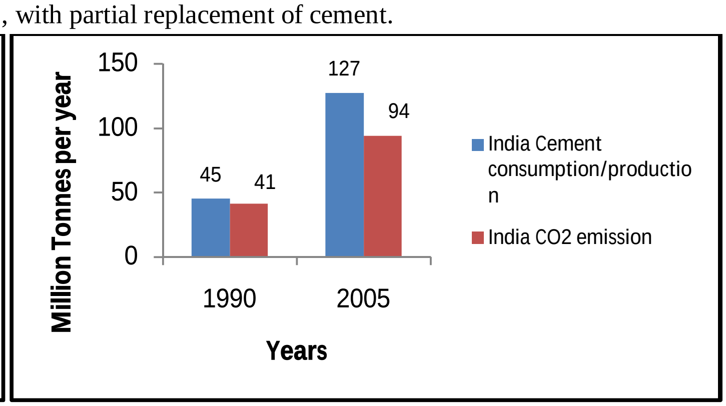

Fig 2: Indian Cement Consumption and CO_2 Emission(Source of Data [17])

The roads and highways in India which is the second largest road network across the world comprises of 97,991 km (1.29%) National Highways, 1, 67,109km (3.05%) State highways, 11, 01,178 km(20.12%) other district roads, 33, 37,255 km (61%) rural roads and 4, 67,106 km (8.54%) urban roads. The Indian roads carry almost 90 per cent of the country's passenger traffic and around 65 per cent of freight[13]. In India, sale of automobiles and movement of freight by roads is growing at a rapid rate. To generate an adequate road network to cater the demand of increased passenger traffic and movement of goods, Government of India has setup an earmarked 20 % of the investment of US $ 1 Trillion reserved for infrastructure during the 12th Five-Year Plan (2012–17)[12].The construction of a new road has a number of implications for the environment, consuming large amount of materials and energy. Also, the price of crude oil, which is the major source of bituminous binder, has significantly increased in the recent years. This has led to an increase in the total price of asphalt mixtures. Figure 3 shows the consumption of the constituent materials i.e. bitumen and aggregate during 2007 -2015.

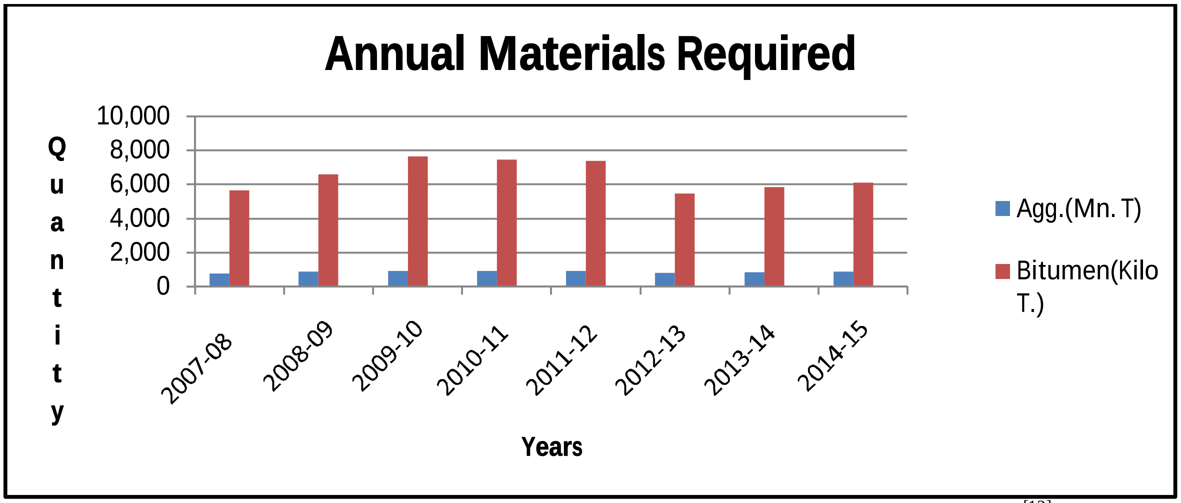

Figure3: Annual Requirement of Building Materials from Year 2007-08 to 2014-15[12]

In order to promote sustainable practices and to combat price increase, measures with sound sustainability credentials need to be widely implemented. Developing novel materials and technologies to integrate greener materials, waste and recycled materials into the production cycle of asphalt mixtures is a methodology that improves both sustainability and cost-efficiency of the asphalt pavement industry[9]. There are eco-innovative asphalt pavements designed through partial substitution of greener materials into asphalt mixtures such as reclaimed asphalt pavement (RAP), construction and demolition waste (C&DW), lignin (by-product of 2nd generation bio-ethanol processing) and bio-binder from vegetable oil. There are some initiatives of utilizing waste materials in roads and transportation to reduce the use of virgin materials so that the CO_2 emission can be reduced. Waste plastics, littered both by domestic and industrial sectors were found to be suitable as alternative raw materials for the flexible pavement[9].

Many organizations such as The Centre for Sustainable Technologies (CST) earlier known as Application of Science and Technology for Rural Area at Indian Institute of Science, Bangalore has been working since 1974 to develop environment friendly, energy efficient, simple and sustainable building technologies utilizing maximum local resources and skills. Some of the alternative building materials identified as stabilized mud blocks, steam cured blocks, fine concrete blocks, rammed earth blocks, mud-concrete blocks, lime-pozzolona cements, soil-lime plaster and composite mortars for masonry. Various precast structural components may be used such as composite beam and panel roofs, reinforced brickwork/tile-work roof, ferro-cement and ferro-concrete roofing systems, un-reinforced masonry vaults and domes, ribbed slab construction, filler slab roofs, rammed earth foundations, reinforced block-work lintels and precast chajjas. Other alternative techniques are solar passive cooling techniques and containment reinforcement for earthquake resistant masonry[18].

A. Green Rating Systems

To promote the design and construction of green buildings in the Country, The Energy and Resources Institute (TERI), New Delhi with the support of Ministry of New and Renewable Energy Resources has developed a national rating system known as Green Rating for Integrated Habitat Assessment (GRIHA) for the interaction on scientific and administrative issues related to sustainable habitats in the Indian context, considering the conditions of all climatic zones. The Ministry wants to pursue the promotion of green buildings in a mission mode and expects a huge capacity building using GRIHA rating [16].

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Confederation of Indian Industry (CII) has created Indian Green Business Centre to promote energy efficiency. Indian Green Building Council (IGBC)[7]under CII provides awareness and latest trends on green buildings to Architects, Designers and other people involved in construction industry. They organize conferences, training programs and other discussions to delegates to get the opportunity to network with national and international experts. It provides a platform to launch new building products and thus get the opportunity to explore new business opportunities. Apart from promoting the technology, they are popularizing the green building rating system also. According to IGBC, if a building has 48 to 59 credits without interiors or 45 to 55 credits with interiors, the building may be certified as a gold building. Many buildings have been constructed in various parts of the Country with alternative building technologies. The awareness and adoption of the technology for a positive impact on the environment is possible only if all aspects of the technology are studied. Green buildings are constructed in Gujarat also. The Infrastructures Ltd at Ahmedabad is designed as the first green building in the state. It is a gold-certified green building by Indian Green Building Council (IGBC) with 69 credits. GIFT CITY Gandhinagar and L&T Knowledge City, Vadodara are examples for green rated buildings in Gujarat.

B. Embodied Energy in Buildings

The demand supply gap for residential buildings is increasing every year (20 million units in 1980 to 40 million units in 2000) which consumes major building materials such as cement (more than 75 million tonnes per annum), steel (more than 10 million tonnes per annum) and bricks (more than 70 billion per annum) are the largest and bulk consumption items in the Indian construction industry[1]. The energy consumption in the manufacturing and transportation of building materials is directly related to Green House Gas (GHG) emissions. Traditional materials like mud, thatch, timber etc., consume zero energy but the ever increasing demand of building materials cannot be met by these traditional materials. Energy is consumed by a building from construction to operation till demolition. Embodied energy is the total energy consumed for all the processes associated at the time of construction to convert raw materials from the nature to appropriate building materials and its transportation to the construction site with suitable construction techniques. The operational energy during the service period (life span)till demolition is known as Life Cycle Assessment. The embodied energy depends upon the choices of the materials and the construction methods and it considers the energy requirement at the time of construction only. Energy content of doors and windows are not considered for the calculation of embodied energy because they are made from wood and timber (zero energy products)[17]. Renovation and maintenance of the buildings will also contribute to the embodied energy. But the energy requirement during the service period (operational energy) and the energy required for demolition will not be considered for the calculation of embodied energy. However, a faulty building plan / design/ construction technique may consume more embodied energy and results in more operational energy. Hence, the planning and design aspects should also be addressed properly to reduce the embodied energy. The following Table shows the thermal energy consumed by different types of conventional building materials for their manufacturing processes.

Table 1: Thermal Energy Utilised for Production of Conventional Building Materials[1]

Type of material	Thermal energy (MJ/kg)
Cement	5.85
Lime	5.63
Steel	42.0
Aluminium	236.8
Glass	25.8
Burnt clay bricks	3.75– 4.75
Hollow concrete block	12.3–15.0

Aluminium has the highest value and hence, the usage of this metal can be minimised in the building construction. Reinforced Cement Concrete (RCC) also gives high embodied energy due to high thermal energy of its constituents. Green materials are selected using two main criteria [6]; (i) less embodied energy and (ii) reduction in the operational energy. The first criterion can be met by the usage of recycled materials, flyash based cement, and locally available materials etc. The following Table shows the energy consumed by different green materials and the energy consumption of these materials is very low compared to the energy consumption of conventional materials.

Table 2: Embodied Energy in Various Walling, Floor / Roofing Systems [17]

Type of Building Element	Energy per Unit (GJ)
Burnt clay brick masonry (m^3)	2.00-3.40
SMB Masonry (m^3)	0.50-0.60
Fly ash block masonry (m^3)	1.00-1.35
Stabilized rammed earth wall (m^3)	0.45-0.60
Unstabilized rammed earth wall (m^3)	0.00-0.18
Reinforced concrete slab (m^2)	0.80-0.85
Composite SMB masonry jack-arch (m^2)	0.45-0.55
SMB filler slab (m^2)	0.60-0.70
Unreinforced masonry vault roof (m^2)	0.45-060

The embodied energy of a two storied load bearing building with conventional materials is estimated as 2.95 GJ/m^2 whereas the same with alternative building materials such as stabilized mud blocks (SMB) for masonry walls, SMB filler slab roof etc. is 1.53 GJ/m^2[17]. This shows that the embodied energy is reduced to almost 50% if alternative building materials are used. Hence, minimizing the consumption of the conventional materials with alternative materials, methods and techniques can result in considerable energy savings as well as reduction of CO_2 emission. Latest study reveals that many gaps exist in the sustainability assessment and needs to be addressed [15].

When highly processed building materials transported from far-away places are used in buildings consume very high embodied energy. These energy intensive materials cause high carbon emissions. It is estimated that the total energy expenditure of conventional building materials considering the annual consumptions is 3155 x 10^6GJ [17].Table 3 shows the energy used for production and transportation of some of the building materials for hauling distance of 50 km and 100 km.

Table 3: Energy required for transportation of building materials [1]

Sr No.	Type of material	Energy (MJ)		
		Production	Transportation	
			50 km	100 km
1.	Sand (m^3)	0.0	87.5	175
2.	Crushed aggregate (m^3)	20.5	87.5	175
3.	Burnt clay bricks (m^3)	2550	100	200
4.	Portland cement (tonnes)	5850	50	100
5.	Steel (tonnes)	42000	50	100

IV. CONCLUSION

The use of green materials (energy efficient materials) and green evolutionary technology ensure healthy built-in environment, comfort and safe living for the inhabitants. Green concept ensures energy efficiency for building's full life cycle (life span during construction to operation till demolition) process to achieve efficient use of resources (energy, water and building materials) with minimum impact on the environment for sustainable building envelope. Green construction techniques and materials reduce the embodied energy which results in the reduction of greenhouse gas emission, resource depletion and other negative environmental impacts to achieve carbon footprints. The embodied energy can be minimised significantly if energy efficient alternate building materials which are locally developed are used. Since there exists a huge gap in the sustainability assessment, there is an urge to promote research in this area for sustainable and economic development of better tomorrow. To popularize green building technology is a critical requisite for energy conservation in building sector to espouse eco-friendly constructions which will be indispensable to save the environment, ultimately the planet Earth.

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