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ALTERNATIVE BUILDING MATERIALS FOR LOW-CARBON BUILDINGS IN INDIA

Priyanka Mehta[1], Pulkit Gupta[2], Furkan Baig Mirza[3] , Kartik Khokhar[4]

[1]Assistant Professor, Department of Architecture, M.B.M. University, Jodhpur, Rajasthan, India

[2]Assistant Professor, Department of Architecture, M.B.M University, Jodhpur, Rajasthan, India

[3]Assistant Professor, Department of Architecture, M.B.M University, Jodhpur, Rajasthan, India

[4]Student, Department of Architecture, M.B.M University, Jodhpur, Rajasthan, India

Abstract: The Building & Infrastructure sector in India is a prime contributor to the CO_2 emission in the atmosphere. This is because of the developing economic system and because of the boom in construction activity, growing use of energy-intensive materials like cement, brick, steel. The inevitable boom of the population in the the coming decade will bring about big boom in the the use of constructing materials. The simplest feasible way to minimise the CO_2 emission is to evolve to "Sustainable Materials" or "Alternative Building Materials" which might be low energy materials. The Indian construction sector is amongst the largest in ingesting the raw materials/natural assets and the production of construction materials. A giant type of products and materials are being manufactured and eaten up in the construction sector like Cement, Steel, Bricks and many others. Buildings have varieties of carbon emission: Embodied carbon and Operational carbon- Where embodied carbon emission refers to the whole quantity of greenhouse emission precipitated in the course of the existence cycle of the building material while operational carbon emission refers to the whole sum of whole greenhouse emission of the whole construction other than the materials, electricity consumption, heating, cooling and many others. Natural materials along with soil, stones, wood and many others are the precise building materials to reap low carbon footprint, and they possess a great ability of reuse and recycling/ or they may be bio-degradable placing no damage to the environment. Some materials and techniques are- Blended cement, Stabilized mud blocks, Compacted fly ash blocks, Rammed earth wall, Less energy-intensive flooring & roofing system.

Keywords: Carbon Emission, Sustainable Materials, Green Building, Energy Efficient Buildings, Embodied Energy, Alternative Building Materials

1. INTRODUCTION

Energy is the crucial thing to industrial development which ends up in economic boom for the supply of vital offerings that enhance the human condition. Although there's no proof that the sector has started a transition from dependence on fossil fuels, there's a developing subject that their extended use may additionally result in multiplied emissions of greenhouse gases inflicting remarkable greenhouse warming and weather change. India's population that's at present is about 1. three Billion, with an annual boom rate of 1%. With the liberalisation of India's economy, the tempo of improvement might also considerably grow the CO_2 emission from distinctive activities. Although the figures for per capita CO_2 emission won't differ very much from the current figures. The economic boom desires to be completed through a system of sustainable improvement. So that we do not place stress on the assets nor adversely affect the environment. India’s buildings sector debts for around one-fifth of the country’s general annual carbon emissions and, in the absence of pre-emptive mitigation policies, is projected to emit seven instances greater CO_2 by 2050 in comparison with 2005 levels.

According to data of the Climate Watch by the World Resources Institute, India emits 7.1% of worldwide emissions and has per capita emissions of approximately 2.47 Tco2e (tonnes of carbon dioxide equivalent), compared to the global average of 6.45 tco2/per capita. India’s buildings sector accounts for around one-fifth of the country’s overall annual carbon emissions and, in the absence of pre-emptive mitigation policies, is projected to emit seven times of extra CO_2 through 2050 as in comparison with 2005 levels.

The type of material and technologies included for the development of the building has to offer whole satisfaction to the needs of the user, whilst running for the benefit of the society. Environmental awareness has received popularity all through the recent years, which must have been a need rather than a fashion in the building and construction sector. The production of the building materials/products make a contribution to greenhouse gases emission into the surroundings. The emission of greenhouse gases into the surroundings must be decreased with a purpose to manage the unfavourable effect on our environment and surroundings. By analyzing the energy necessities of the manufacturing and processing of building materials/products we can wisely select the best appropriate choice with the intention to preserve our resources. The construction sector of India has one of the most important manpower and production of building materials like cement, steel, brick etc, accordingly making it the largest contributor of CO_2 emissions into the atmosphere. Promoting the use of alternative materials/techniques and strategies in place of the conventional materials can convey down the energy intake along with the CO_2 emissions.

2. OBJECTIVE

To find the Carbon footprint of traditional building materials and analysing their sustainable counterparts. Their importance in creating the architecture of future while emphasising on resource conservation and sustainable development.

3. THE INDIAN CONSTRUCTION SECTOR- MATERIALS & RESOURCES

The Indian construction sector is amongst the largest in consuming raw materials/natural resources and the production of construction materials. A vast variety of products and substances are being manufactured and consumed in the construction sector like Cement, Steel, Bricks and so forth. Both energy and raw materials are vital for the production of building materials. Soil, stone, sand, wood/tree products, minerals, ores, chemicals are raw material resources. To process those sources- electricity, coal, oil, gas and so forth are required which are energy resources. The greenhouse gases emission is a by-product of producing and transportation of building materials, these are directly associated with each other. The Indian construction sector is developing at an incredible rate of 11% annually. Table 1 offers the consumption[1-4] and strength of four simple construction materials Burnt clay bricks, Cement, Steel, Aluminium.

Table 1. Construction Materials in India and the energy required

Material	Consumption	Raw materials	Energy
Burnt Clay Bricks	25×10^{15} nos.(75×10^{12} tonnes)	Fertile top soil	5000 KJ/Kg
Cement	379×10^{6} tonnes	Lime stone, Gypsum	4200 KJ/Kg
Steel	75×10^{6} tonnes	Iron ore, Coal	36000 KJ/Kg
Aluminium	1.6×10^{6} tonnes	Alumina, Bauxite	236800 KJ/Kg

3.1 Burnt clay bricks

Burnt clay bricks are the typical type of brick, which is manufactured by pressing wet clay into molds, after that they are dried and fired in kilns. Brick is one of the oldest building materials which was used in many ancient structures. They are hardened clay, with a reddish appearance. When burnt clay bricks are used in walls they are covered with plaster. These bricks can be used in walls, foundations, masonry, and columns.

The burnt clay bricks are classified on basis of average compressive strength.

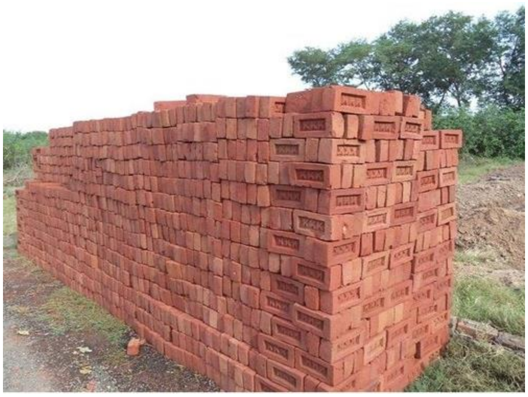

Fig 1. A pile of burnt clay bricks.

3.2 Blended cement

A cement is a binder which in used in construction that sets, hardens and bind materials together. Cement is not usually used alone, but in fact to bind sand and gravel together.

A combination of cement with fine aggregate is known as mortar for masonry, a combination with sand and gravel is known as concrete. Concrete is the most widely used material after water.

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Usually inorganic cement is used for construction, lime or calcium silicate based. It can be termed as non-hydraulic or hydraulic respectively based on its ability to set due to the presence of water.

Chemicals composition of cement- Lime (CaO)- 60 to 67%, Silica (SiO_2)-17 to 25%, Alumina (Al_2O_3)- 03 to 08%, Iron oxide (Fe_2O_3)- 0.5 to 06%, Magnesia (MgO)- 0.1 to 04%, Sulphur (S)- 01 to 03%, Alkalies (K_2O Na_2O)- 0.4 to 1.3%, Gypsum ($CaSO_4$)- 4%

Fig 2. Cement

3.3 Steel

Steel an alloy made up of iron and some percentage of carbon mainly few tenths to improve its strength and fracture resistance as opposed to other forms of iron. Stainless steel which is corrosion and oxidation resistant is manufacture by adding 11% chromium.

Due to the high tensile strength and low cost steel is widely used in buildings & infrastructure, ships, trains, machines etc. Iron is the base of steel. Properties of steel- Strength, Toughness, Ductility, Weld-ability, Durability.

Buildings rely on steel for their strength. Steel is also used in roofs and cladding of the structures. As India is observing the rapid urbanization, the need for infrastructure and buildings continues to grow with the increase in demand for building materials like steel.

Fig 3. Steel reinforcement bars

3.4 Aluminium

Aluminium is a chemical element with the density lower than other common metals, approximately one third of steel. It reacts with oxygen to form a protective layer of oxide when the surface is left exposed to air. It is soft, non-magnetic and ductile.
Aluminium is mostly alloyed, which improves its mechanical properties. Main alloying agents are copper, zinc, magnesium, manganese and silicon with other metals in few percent.

Aluminium is widely used in buildings due to its lightness and corrosion resistant properties. Aluminium is used on external facades, roofs, walls, windows, staircases, railings etc

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Fig 4. Aluminium sheets

In 2004, direct emissions from the building sector were about 3 Gt CO2, 0.4 Gt CO2 equivalent in CH4, 0.1 Gt CO2 equivalent in N2O & 1.5 GtCO2 equivalent in halo carbons (CFCs & HFCs). Including the emissions from the use of electricity CO2 emissions related to energy are 8.6 Gt/year which is a quarter of the global total emission.

About 22% of the overall annual CO2 emission is contributed via way of means of the Indian construction sector. Out of the overall emission from the construction sector, 80% are due to the products/industrial processes of building materials, i.e. cement, lime, steel, bricks, aluminium, etc. With the speedy increase in the population, the requirement for those substances has increased, normally in housing. Which is 60% of the intake of substances via way of means of the construction sector annually. Conventional electricity assets nevertheless endure the weight of the manufacturing of construction materials, wherein coal continues to be the dominant fuel for electricity production. High nuclear capability sources and renewable electricity sources substitute coal to a degree in the power generation which reduces the CO2 emissions respectively.

A study performed by Saradhi for the cumulative CO2 emissions in the course of 2005-2035 in numerous scenarios which are indexed withinside Table 2.[5] Enhanced Energy performance of homes because of simple measures of decreasing building-related emissions. Substitution of excessive CO2 emission fuels with low emission fuel, Renewable sources in substitution for fossil fuels. Various techniques for meeting the energy demand and decreasing CO2 emission, enhancing the energy performance of the homes is the most appropriate option.

Table 2. Cumulative carbon dioxide emissions for different scenarios (2005-2035)

Scenario	**Cumulative CO_2 emissions (million tones)**
Business as usual	11151
Low growth	7473
High growth	16409
High nuclear	10135
Aggressive renewable	10755

A few key points to develop sustainable building design are-

i. Energy Conservation
ii. Promoting use of less-energy materials
iii. Promoting the use of local materials and resources
iv. Spreading out material production
v. Maximising the use of local skill-set
vi. Pre and Post construction waste management
vii. Promoting the use of renewable energy sources

4. ENERGY CONSUMPTION IN THE BUILDINGS

Buildings have forms of carbon emission: Embodied carbon and Operational carbon Where embodied carbon emission refers to the full quantity of greenhouse gas emission prompted throughout the existence cycle of the building material while operational carbon emission refers to the full sum of complete greenhouse gas emission of the complete building apart from the materials, electricity consumption, heating, cooling etc. The building materials and techniques affect the embodied energy of the building/structure. The most extensively used sort of structure in India is RC-framed. Aluminium and glass is the most common material used for the openings in the structure, embodied energy varies between 5 x 10^6 KJ/m2 to 10 x 10^6 KJ/m2. Table 3 offers the strength of four exclusive forms of masonry, Energy/m3 in addition to its per cent equal of brick masonry.[6]

Table 3. Energy in different type of masonry

S.No.	Type of Masonry	Energy/m^3 of Masonry (MJ)	Equivalent of Brick Masonry (%)
1	**Burnt clay brick**	2141	100
2	**Hollow concrete block**	819 (7% cement block) 971 (10% cement block)	38.3 45.4
3	**Soil-Cement block**	646 (6% cement block) 810 (8% cement block)	30.2 37.8
4	**Steam cured mud block**	1396 (10% lime)	65.2

Environmental issues and energy consumption is vital and a matter of concern across the world. The buildings play a crucial function in this matter. The building's existence cycle contains"embodied energy" & operational energy". The embodied energy of a building contains all of the energy consumed. Which may be further divided into three segments-

- Initial embodied energy (IEE)- energy consumed from the production/extraction of raw materials, processing to manufacturing, and transport of products to the site. It additionally consists of the energy directly related to construction activities. Pre-use phase
- Recurrent embodied energy (REE)- Energy required for repairing, maintenance, or refurbishment of the building at some point of the utilization period.
- Demolition embodied energy (DEE)- Energy consumed at some point of the demolition of the building at the end of its utilization period. We can recycle, reuse a few components and take away unimportant debris & waste with the aid of using transportation to landfills or incinerators.[7]

The operational energy of a building is the energy that is required majorly for heating, cooling, lighting, and different operational purposes. Studies display that embodied energy and CO_2 emissions are growing as compared with operational energy. Embodied energy is stimulated with the aid of using many variables from extraordinary geographical places to specific production processes, transportation mode, distance from the development site.

Table 4. Embodied energy of building materials Canadian Architect and Centre for building performance research.[8]

S.No.	Material	Embodied energy MJ/Kg
1	**Aggregate 0.10**	0.10
2	**Concrete block 0.94**	0.94
3	**Concrete precast 2.00**	2.00
4	**Brick 2.50**	2.50
5	**Steel 32.00**	32.00
6	**Glass 15.90**	15.90
7	**Paint 93.30**	93.30
8	**Aluminium 227.00**	227.00

5. THE WAY FORWARD WITH LOW CARBON FOOTPRINT BUILDING MATERIALS & TECHNIQUES

Building materials/products with a minimal intake of energy sources will put us on the path to minimise the carbon footprint of the building/infrastructure. Natural materials including soil, stones, wood and so on are the

right building materials to attain a low carbon footprint, and they possess an exceptional ability of reuse and recycling/ or they can be bio-degradable putting no damage to the environment. Natural materials have barriers to their power and durability, processing and transporting the natural material effects in carbon emission.

A few materials & techniques-

i. Rammed earth walls
ii. Stabilised mud blocks (SMB)
iii. Fly ash blocks

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iv. AAC blocks
v. Blended cement
vi. Solar tiles
vii. Ashcrete

6. LOW CARBON FOOTPRINT BUILDING MATERIALS

Building materials that have low carbon emission with the least carbon footprint and an excellent ability for reusing and recycling are majorly natural materials like soil, stones, timber/biomass. These materials have limitations of their power and sturdiness whilst they're unprocessed or least processed. As visible above the processing and transportation of the consequences of the substance in carbon emission. To minimise this technology need to be developed to provide building materials and products with a minimal quantity of energy. Some materials and techniques are mentioned in the following part.

6.1 Blended cement

A form of cement that carries an excessive quantity of one or extra varieties of complementary cementing materials, like coal fly ash, granulated slag, silica fume, or reactive rice-husk ash. A big quantity of CO_2 is emitted for the duration of the production of the cement (0.9 tonnes/tonne of clinker). With the substitution of clinker with CCM, we reduce the quantity of CO_2 emitted for the duration of the process. There are ongoing studies for the use of CCM in Portland cement, research proposes 40% substitution is possible. CO_2 emissions contributed through the cement enterprise may be decreased extensively through 2030. It may be 940x106 tonnes through 2030 which can be almost identical to the year 1990, but the consumed concrete quantity is extensively excessive.

Advantages of blended cement are-

- It offers a finer texture than OPC whilst blended and placed. So it could be used for finishing and elevation works.
- Water intake is much less which makes it easy to work with and shape.
- The strength gained after 28 days is substantially more potent than OPC, in each compressive and flexural stress.

Disadvantages of blended cement are-

- The quality of fly ash can have an effect on the quality and strength of Cement concrete.
- Poor quality fly ash can grow the permeability of the concrete and cause harm to the building.

6.2 Stabilized mud blocks for masonry

The burning of processed clay produces burnt clay bricks. The strength of the brick is achieved with the aid of using the irreversible adjustments that the clay minerals experience because of high-energy input. Energy and clay mineral resources can be conserved and they are crucial for the environment. Stabilized mud blocks (SMB) are alternatives to burnt bricks, those are energy efficient, eco-friendly. These are manufactured by compacting soil combined with sand stabilizer (cement/lime) and water, a solid block is achieved. These may be used for wall construction after 28 days. The soil composition, density of the block, and per cent of stabilizer are a few elements on which the compressive strength of the block depends.

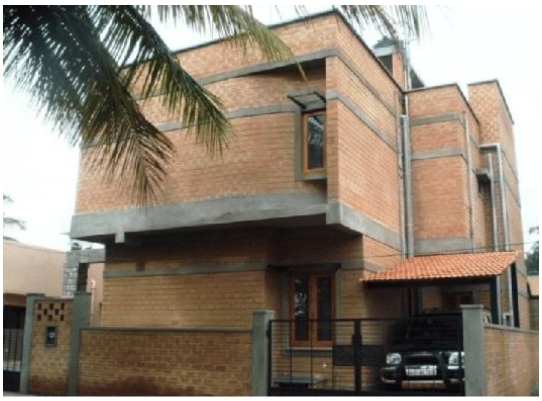

Fig 5. Residence constructed with Stabilised Mud Block.

Advantages of SMB are-
- Do not require burning
- On-site production is possible
- Utilization of industrial solid waste like stone quarry dust, fly ash, etc
- Easy to adjust the block strength

Disadvantages of SMB are-
- Not suitable for high-rise buildings and wide-spans
- Proper soil identification required
- Skilled labour required

6.3 Compacted fly ash blocks

A high-density block is crafted from an aggregate of lime, fly ash, and stone crusher dust. Water-insoluble bonds are formed whilst lime reacts with fly ash offering strength. Reactions are gradual at ambient temperatures and may be multiplied by both low-temperature and steam curing, or with components like phosphogypsum (industrial waste). The strength of the block relies upon the composition of the mix, density & per cent of stabilizer/additives.

Fig 6. Compacted fly ash blocks

Advantages of fly ash blocks-
- Tiny scale industry production
- Reuse of industrial waste products
- Environment friendly

Disadvantages of fly ash blocks-
- Poor quality blocks may have negative effect on the cement, can increase permeability.
- Only modular brick size can be manufactured, the large size will suffer more breakages.

6.4 Rammed earth wall

An approach of creating strong partitions by compacting processed soil in a brief framework in layers. Two kinds of rammed earth construction are there- Stabilised rammed earth and unstabilized rammed earth. Unstabilized rammed earth includes soil, sand, and gravel. On the alternative hand, stabilized rammed earth includes extra components like cement and lime. Unstabilised rammed earth partitions are zero-carbon, with sure risks like lack of strength, erosion. They are usually 400mm or greater in thickness and need safety from moisture. Inorganic components like cement for rammed earth partitions had been around for the remaining 5-6 decades. Examples of rammed earth cement-stabilized may be visible in the USA, Europe, Asia

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Fig 7. Rammed earth wall.

Advantages of rammed earth construction-

- Low energy-intensive
- Recyclable materials and locally available
- Strength and thickness can be adjusted easily

Disadvantages of rammed earth construction-

- The cost of rammed earth can get considerably high.
- It is hard to correct issues after a wall gets built.
- Rammed earth gets confined to low-rise buildings and rectangular shapes.

6.5 Less energy-intensive flooring & roofing systems

Two or more building materials/products make up the roofing and floors system. For example, a reinforced concrete slab is made from materials like reinforcing steel, concrete, and different elements like ground finishes, paints, and many others. The energy intensity of an RC slab is made from the energy intensity of its component. Composite masonry jack-arch roof or floors system, filler RC slabs, unreinforced masonry vaults, and many others are a few examples of low energy-intensive options for floors and roofing systems.[9]

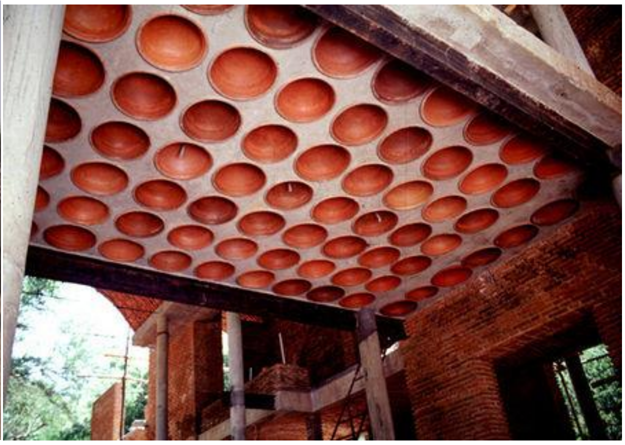

Fig 8. (Left)- Composite masonry jack arch roof system **Fig 9. (Right) - Filler slab**

Advantages of filler slab (less energy-intensive system)-

- Consumes much less concrete and steel because of decreased weight of slab through the introduction of a less heavy, low price filler material like layers of burnt clay tiles.
- Enhances thermal comfort within the building because of heat-resistant features of filler substances and the space among burnt clay tiles.

Disadvantages of filler slab (less energy-intensive system)-

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- Skilled labour required for the construction
- The rebars can corrode if it comes in touch with clay products which are used as fillers.

CONCLUSION

This study attempts to understand the topic carbon emission resulting from the production and consumption of building materials/products, embodied energy in buildings and sustainable materials. Current used materials for construction have been studied in detail, energy consumption in the construction sector in the present scenario which reflect the need to conserve the natural resources.

With the growth in the demand of housing, infrastructure, buildings, construction sector requires more resources. On the contrary the natural resources are depleting fast, therefore materials that have low carbon footprint, low embodied energy will help reducing the carbon emission thus saving our resources and environment. Several of the examples have been discussed in the above sections.

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