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Sustainable Construction with Energy-Efficient Materials

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Abstract

Due to the overuse of energy, water, land, and other resources as a result of urbanisation and industrialization, the natural ecosystem has become unbalanced. Rapid industrialization has resulted in the accumulation of millions of tonnes of varied industrial wastes at numerous locations, which has severely harmed the ecosystem. In India, demolition wastes from built-up areas also produce a sizable amount of debris, including sand, gravel, concrete, stone, and bricks. The demand-supply gap can be partially filled by recycling aggregate materials from construction and demolition debris and using industrial wastes for the production of valuable building materials. This essay focuses on the concepts of recycling and reusing, creating income from trash, and the proper use of waste in the production of building materials.

Keywords: Energy-efficient construction, green building, fly ash, slag and stone dust.

I.INTRODUCTION

Humans have three basic needs that are particularly important: food, shelter, and clothing. In the past, construction was done with materials with no embodied energy, such as clay, stone, sand, leaves or thatch, and untreated wood. With the exception of stone, natural materials have generally very poor levels of weather resistance, strength, and durability. Modern construction materials including bricks, cement, metal, and plastic are a result of efforts to find enduring materials. These materials must be manufactured and transported from the manufacturing location to the building site using a lot of energy. As a result, the Indian building sector gradually switched from using low-energy materials to high-energy ones. Rapid urbanisation and population growth have increased the already explosive demand for contemporary materials, which has led to a rise in the price of energy, a finite resource. The manufacturing of contemporary materials and sustaining the comfort level of occupants within desired levels require 33% of the electrical energy used by the construction industry (i.e., residential sector 25% and commercial sector 8%). Green house gas emissions from contemporary building materials contribute to global warming. There must be a coordinated effort to employ sustainable materials in the construction industry to reduce energy use and greenhouse gas emissions. In view of the Indian construction sector, this study discusses a few topics relating to energy, carbon emissions, and sustainable building materials.

1.1 NEED FOR SUSTAINABLE MATERIALS

Sustainability refers to minimising energy and resource use, which lowers waste production and pollution caused by building. Consequently, engineers Environmentalists and architects have been focusing their efforts on figuring out how to use any industrial process' waste as an input or source material for producing other things. For instance, fly ash, a byproduct of thermal power plants, can be utilised as a raw material to create fly ash bricks and concrete. Through better planning, designing, construction, operation, maintenance, and removal throughout the entire life cycle, sustainable buildings maximise energy efficiency while using sustainable materials and construction technology to reduce GHG emissions and the production of industrial waste byproducts. By using up nearly 340 billion tonnes of resources, our nation uses 180 billion tonnes of bricks.Table 1 includes energy use and advances in the building materials industry; Table 2 highlights some of the energy- and bulk-produced building materials in India; Table 3 describes cement production and CO2 emissions (million tonnes annually). It is clear that making some common building materials requires about 3155x106 GJ of energy, and CO2 emissions are rising at an alarming rate. Overuse of resources such as energy and raw materials can deplete them and have a negative impact on the environment. To satisfy the ever-increasing demand, sustainable eco-friendly alternatives are needed. These alternatives should include: 1) energy efficiency; 2) less use of high-energy materials; 3) use of local materials by minimising transportation; 4) utilisation of industrial wastes for producing building materials; 5) recycling of building wastes; 6) use of renewable energy materials; 7) rainwater harvesting; and 8) use of biogas.

1.2 GREEN BUILDING MATERIALS

Sustainable building materials are those that have a low carbon footprint, low greenhouse gas emissions, and can be recycled and reused. A few sustainable materials are mentioned along with their usage, etc.

A.Bricks and concrete made of fly ash

Fly-ash is produced as a waste product in thermal power plants, and Portland cement-like in appearance. Fly ash is utilised as a lightweight aggregate in masonry and structural concrete. It is also employed in the creation of cellular concrete. Fly ash bricks, which are significantly lighter in weight and stronger than typical clay bricks, can be made using fly ash, lime, gypsum, and sand or stone crusher dust. Depending on the grade of the raw materials used or accessible, the proportion of the raw materials is typically in the range of 60-80% fly ash, 10-20% lime, 10% gypsum, and 10% sand or stone dust. After mixing, it undergoes hydraulic/mechanical press compression, drying, and a 21-day water curing process. Pavements, dams, tanks, under-water works, canal lining, irrigation projects, etc. are all built with fly ash bricks. Thermal power plants in India have access to enormous amounts of fly ash, which can be used effectively to create materials that are useful rather than polluting the environment. Brick need might be satisfied by building small factories adjacent to thermal power plants already in operation. This would reduce the cost of transportation while also meeting local demand.

B. Blast furnace cement

Slag is a waste product in the manufacturing process of pig-iron and it contains the basic elements of cement namely alumina, lime and silica. Hence, it is used for manufacturing cement and the properties of the above cement are more or less the same as those of ordinary Portland cement (OPC). Its strength in early days is less and hence it requires generally a longer curing period. It proves to be economical as slag which is a waste product, used in the manufacture of cement. Coal fly ash, silica fume and
reactive rice-husk ash (RHAs) are also used as supplementary cementing materials (SCMs). The cement industry's CO2 emissions can be significantly decreased by substituting SCMs up to 40%. Concrete is primarily made from air cooled blast furnace slag (BFS), which is created when molten slag is allowed to gently harden. It is also used as a filler in road and railway embankments as well as a raw material for

cement blocks, pavement blocks and other building materials. It lessens heat hydration and corrosion risk while enhancing the mechanical strength, durability, and workability of concrete.

C. Stabilized mud block for masonry

The ingredients for stabilised mud blocks are soil, sand, cement or lime, and water. Following mixing, it is mechanically compressed in a hydraulic press, dried, and cured for 28 days. These energy-efficient blocks offer a 60–70% energy savings over burned clay bricks and don't require burning. Other industrial by products that clean up the environment can also be employed, such as stone dust and fly ash.

Fig**1: Stabilized mud block masonry**

D. Earthen rammed wall

It is a wall made of compacted earth, sand, and gravel. The two varieties of rammed earth buildings are: 1) Rammed earth that is not stabilised 2) stabilised earth rammed. A rammed earth wall that is not stable comprised of soil, sand, and gravel; stabilised rammed earth walls also contain additives like lime or cement. The un stabilized rammed earth wall falls within the zero carbon option because it is built of natural resources. However, strength decreases with saturation and erodes as a result of wind-driven rain. These walls need to be well protected because they are thicker (400mm or more). The US, the EU, and Australia are all big markets for these stabilised earth walls. These walls have three advantages: 1) minimal energy consumption; 2) material recycling; and 3) easily changeable wall strength.

Fig**2: Earthen rammed wall**

E. Recycling aggregate made from construction and demolition trash

The idea of recycling and reusing building and demolition trash is practised in many developed and developing countries in order to attain sustainability countries. In 2003, almost 86% of demolition waste in Germany was recycled, compared to 52% in the UK in 2005. The overall quantity of garbage produced by the building industry in India is thought to be between 12 and 14.7 million tonnes per year (MTPA). The expected amount of each sort of building debris is shown in Table 1. In the majority of countries, recycled aggregate is utilised in non-structural applications like highways, embankments, etc. Using recycled coarse aggregate in place of natural coarse aggregate in the preparation of concrete has been proven to have no discernible impact on the concrete's compressive strength after 28 days.

Fig**3: Recycling aggregate made from construction and demolition trash**

Constituent	Quantity generated in million tonnes per annum
Soil, sand and gravel	4.20 to 5.14
Bricks and masonry	3.60 to 4.40
Concrete	2.40 to 3.67
Metals	0.60 to 0.73
Bitumen	0.25 to 0.30
Wood	0.25 to 0.30
Others	0.10 to 0.15

F. Self-Compacting Concrete (SCC)

Self-compacting concrete (SCC) is prepared using fly ash and stone dust. The capacity of fresh concrete to flow under its own weight over a large distance without segregating and achieve correct compaction without the use of vibrators is known as self-compaction. The substantially reinforced parts may be filled with this concrete more effectively and without applying any vibration. It has been proven that self-compacting concrete can reach the typical strength of M30 grade concrete by replacing 30% of the cement content with stone dust. It is also known that adding fly ash to cement in varying amounts—from 20% to 40%—will make it more workable and deformable. However, based on specific investigations, compressive strength diminishes as fly ash percentage rises and can be increased by mixing in an admixture.

Fig**4: Self compacting concrete**

G. Rubber chips

Embankment fill, rubber chips for concrete and road material can all be made from tyre scraps that have been shredded. It won't rot or be washed or blown away. The addition of rubber chips to concrete improves its resistance to abrasion, lowers vibration, and serves as a sound insulator. In order to reduce noise, rubber chips are used to build noise-reducing wall cladding and to underlay road pavements. Rubber chips are utilised as a fill material beneath structures in earthquake-prone areas because they could shield the structure from ground vibrations. The use of rubber chips in building and construction materials, however, raises questions about safety, health, and the environment.

Fig**5: Rubber chips**

H. Low energy intensity floor and roofing systems

The low energy intensity choices for floor and roof slabs include re-filler slabs, composite masonry jack-arch roof or floor systems, unreinforced vaults, etc.

Fig**6: Low energy intensity floor and roofing systems**

1.3 EMBODIED ENERGY

There are two categories of energy utilised or consumed in buildings: 1) Embodied energy, or the energy used in the production, preparation, and construction of buildings; and 2) Energy consumed in maintenance and servicing during a building's useful life. The first one is subject to change based on the choice of building materials and methods, whilst the second one is determined by the climate zone in which the building is situated. The embodied energy in various walling, flooring, and roofing systems is displayed in Table 5. According to the above table, energy is used less by sustainable building materials than by contemporary ones. The embodied energy of the composite masonry jack-arch roofing is lower than that of the traditional structure (RC slab).

Table 2 shows energy use and advancements in construction materials

Prior to 4000 BC	4000 BC-1800AD	1800AD-to date
Soils, stones, reeds/thatch Sun dried bricks/ adobe, unprocessed timber	Burnt clay bricks, lime, cast iron products, lime-pozzolana cement	Aluminium, steel, glass Portland cement, plastic, other smart materials, Nano-materials, etc
Zero-energy materials	Medium-energy materials	High-energy materials

Table 3 shows the volume of construction materials produced in India.

Type of materials	Annual con-sumption	Raw materials	Energy
Burnt clay bricks	150 x 109 nos	Fertile soil (500 x 106 tonnes)	600 x106GJ
Cement	187 x 106 tonnes	Lime stone, Gypsum, Oxides	650x106GJ
Structural steel	45 x 106 tonnes	Iron ore, Lime	1800x106GJ

		stone	
Coarse Aggregate	250 x 106 m3	Granite/ Basalt rock	30x106 GJ
Fine Aggregates	350 x 106 m3	River sand/ Rocks	75x106 GJ

Table 4 shows annual CO2 emissions from cement production in million tonnes.

	1990	2005	2010 (projected)
Global Cement consumption/ Production	1040	2270	2800
CO2 released	940	1700	2070
India Cement consumption/ Production	45	127	200
CO_2 released	41	94	148

Table 5: Solid waste generated by inorganic industries and mines in India.

Type of solid waste	x106 tonnes/year
Fly ash	112
Coal mine waste	60
Lime stone waste	18
Construction waste	15
Blast furnace slag	11
Iron ore tailings	11
Copper mine tailings	4
Marble dust	6
Red mud, lime sludge, phospho-gypsum, zinc tailings, kiln dust, Gold mine tailings etc	20

Inorganic industrial/mine solid waste (total)	257

1.4 FINAL COMMENTS

In the last few decades, the combined effects of population growth, industrialization, and globalisation have produced enormous amounts of industrial waste, which contribute to environmental pollution and global warming. The idea of creating money out of trash has been described, and the method utilised to create a variety of building materials from industrial wastes has been highlighted. It has been noted that further research is required to fully utilise wastes in the creation of better and more valuable building materials. Our nation would prosper with a green environment in the coming decades if the industrial wastes are fully and effectively utilised in the construction sector through recycling and reuse.

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