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Sustainable Construction Technology: Green Building

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ABSTRACT: Green building, also known as sustainable building or green construction, refers to the embracement of resource-efficient and ecologically responsible construction practices to ensure the structure's long-term viability. The term "sustainability" refers to the building's operations, site design, repair, maintenance, and demolition with the minimum amount of environmental impact. The construction engineers, clients, and architects must work closely together throughout the project. With the main focus on the efficient utilization of resources and energy, improved occupational health, water preservation, and reducing wastage and pollution, the goal is to ensure that building and construction methods are cost-effective and durable and reduce overall effects on the environment and human health. Unique cultures and traditions, typical climatic conditions, and a wide range of environmental, social, and economic priorities tend to vary between countries or regions. All of these make improvements to their green construction strategies.

KEYWORDS: Green building, Sustainable building, Green construction, Ecologically responsible construction, Sustainability, Building's operations, Construction engineers, Architects, Occupational health, Environment and human health, Green construction strategies

I. INTRODUCTION

India's population is 1,406,631,776 in 2022 with an increase from 0.95 percent in comparison to 2021. According to the World Bank's collection of development indicators (Zhao, Zuo, Wu, & Huang, 2019) derived from officially recognized sources, India's urban population (percentage of the total population) was 34.93 percent in 2020. India's commercial primary energy consumption has risen by almost 700 percent in the previous four decades. India's current commercial primary energy consumption per capita is around 350 kgoe/year [kgoe means kilogram(s) of oil equivalent], which is significantly lower than that of developed nations.

India's energy consumption is predicted to rise due to its growing population and economy, as well as the desire for a better quality of life. Furthermore, India's large cities are experiencing a scarcity of water, and according to a report published in 2018 by the Niti Aayog (Aayog, 2018), the government of India, 21 major cities, including Delhi, Bengaluru, Chennai, and Hyderabad, are expected to run out of groundwater by 2020, directly affecting 100 million people.

Resultantly, one major remedy to this unsustainable growth (Nadeem, Goh, Hussain, Hussain, & Khan, 2021) is Green Building Construction. A green building, as we all know, is designed, constructed, refurbished, operated, or reused in an ecologically beneficial and resource-efficient manner. Furthermore, these structures are meant to achieve several important goals, including:

- Protecting the health of the occupants
- Improvement in employee Productivity Enhancement
- Preserving water, energy, and other rapidly depleting resources
- Reduce the usage of amount of water, energy, and other quickly depleting resources
- Reduction in carbon footprint
- Decrease in the overall environmental impact
- Better indoor air quality

Green building technologies can greatly assist in attaining these goals in a timely and cost-effective way.

II. GREEN BUILDING TECHNOLOGY ELUCIDATED

Green construction technology (Ding, Fan, Tam, Bian, Li, Illankoon, & Moon, 2018) has become one of the most popular construction ideas. Incorporating green technology into a building has numerous advantages, such as providing major advantages in both new and existing structures.

This technology makes buildings more energy-efficient and long-lasting, resulting in lower carbon emissions (Wu, He, Chen, Xue, & Li, 2021) and fewer environmental effects. It also provides significant benefits to builders, building owners, and renters alike.

Greater energy efficiency is the major method by which green technology benefits are realized. Green building construction plays an important part in the development of new structures at every stage. Every component of the facility, including its location, design, construction materials, and operating and maintenance systems, is selected to be as energy-efficient and sustainable as feasible.

At any given time, 30-40% of a business facility (Chen, Chan, Owusu, Darko, & Gao, 2022) is normally empty. Motion detectors, access card readers, RFID scanners, and other sensors are used in green building technology to track the occupancy status of building sectors. Green technology automatically turns off lights and adjusts HVAC, heating, cooling, and ventilation choices whenever a section of a structure is empty. Building owners can save up to 30% on their energy bills by minimizing wasteful energy use.

In commercial buildings, the "sick building syndrome" (SBS) creates an unpleasant working environment, particularly in older buildings and those in hotter regions where ventilation is an issue; when HVAC systems are left on all the time, condensation forms, allowing hazardous mold spores to grow. When not in use, energy-efficient green building solutions can turn off HVAC systems to maintain the proper temperature and humidity for optimum health. In addition, the installation of sensors (Jain, Siva, Hoppe, & Bressers, 2020) and advanced software can assist with monitoring the ventilation system to avoid carbon dioxide from underground garages from flowing all through the building.

III. TYPES OF SUSTAINABLE TECHNOLOGIES APPLIED IN GREEN CONSTRUCTION

The top sustainable construction technologies utilized (Zhang, Wang, Gao, Wang, Zhou, Kammen, & Ying, 2019) in green construction are listed below:

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Solar power

In green buildings, solar power is used in two ways: active solar power and passive solar power. Active solar power employs functioning solar systems that absorb the sun's rays to provide warmth and energy. It minimizes the requirement for electricity or natural gas.

Although the initial installation costs are greater, it saves money on energy bills in the long run and helps reduce greenhouse gas emissions from non-renewable energy sources such as fossil fuels. Passive solar power, on the other hand, is a design that makes use of the sun's rays to warm homes by strategically placing windows and using heat-absorbing materials. The windows allow energy to enter the house, and the heat absorbed minimizes the need to heat the house during colder months.

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Biodegradable materials

Using biodegradable materials is an environmentally beneficial way to ensure that the building is long-lasting. The majority of traditional construction methods lead to a buildup of waste products and harmful chemicals, which take decades to degrade. Even if they decay, they pollute and destroy the environment. Biodegradable materials, such as organic paints, help to prevent negative environmental consequences by breaking down quickly and without releasing toxins. Sustainable construction technologies also include the use of biodegradable materials for building foundations, insulators, and walls.

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Green insulation

Insulation is one of the most important considerations when it comes to constructing buildings and residences. Most people are unaware, however, that insulators are just wall filters that do not require the usage of pricey or highly finished materials. Green insulation is a sustainable construction method since it reduces the need for high-end finishes made of non-renewable resources. Green insulation uses old and discarded materials like denim and newspaper to provide a solution, or it also implies that the walls are lined with recycled materials.

- **Employing**

Commercial buildings and homes consume the world's energy significantly, so the use of smart appliances as part of sustainable construction technologies (Gao, Yang, & Xie, 2020) is necessitated for this reason. Sustainable construction technologies emphasize the installation of energy-saving and self-sufficient appliances. SmartGrid dishwashers, refrigerators as well as washing machines are examples of such sustainable technologies. The technology is oriented towards establishing low-energy commercial buildings as well as homes.

- **Smart**

- **Appliances**

- **Cool roofs**

Because homes and commercial buildings utilize most of the world's energy, smart appliances must be included as part of sustainable construction technology. Therefore, the installation of energy-saving and self-sufficient appliances is emphasized in sustainable construction methods. SmartGrid dishwashers, washing machines, and refrigerators are examples of such environmentally friendly products. The technology is geared toward creating zero-energy residences and commercial structures.

- **Sustainable resource sourcing**

As the name implies, sustainable resource sourcing is a good example of sustainable construction technology because it ensures the use of ecologically friendly construction materials that are designed and constructed from recycled resources. Agricultural wastes or by-products are commonly used to make construction materials. The materials are remanufactured, recyclable, recycled, and sourced from eco-friendly sources.

- **Low-energy house and zero-energy building design**

Mechanisms to reduce energy usage are common in sustainable construction technology. Buildings made of wood, for example, have a lower embodied energy than those made of steel or concrete, making them a more sustainable construction method. In addition to using high-performance windows and insulation measures, sustainable green construction uses designs that reduce air leakage and allow for the free movement of air.

These strategies aim to lessen reliance on air conditioning and indoor heating. Another strategy that increases daylighting is the reduction of the demand for electric lighting for an entire day is the strategic placement of windows.

A low-energy building design includes energy sources. Although the initial expenditures of constructing such buildings are considerable, they pay out in the long run.

- **Electrochromic Smart Glass**

Electronic Smart Glass is a paradigm of technology used in ecologically responsible construction. Electronic smart glass is a new technology that helps to block off the severe heat of solar radiation, especially during the summer. The smart glass modifies the amount of solar energy reflected by the windows by sending out tiny electric signals.

It is integrated into the building's control system, enabling users to select how much solar radiation they want to block. Using this technology, homes and business buildings can save money on heating, ventilation, and air conditioning. Smart glass is still being improved, but it is on its way to becoming a widely utilized energy-saving solution in sustainable construction.

- **Water efficiency technologies**

Several water-saving solutions are part of sustainable construction technology. The technologies essentially cover the reuse of water and the implementation of efficient water delivery systems. Dual plumbing, greywater reuse, rainwater harvesting, and water-saving fixtures are just a few instances. These techniques ensure that water is properly managed and recycled for non-portable functions like car washing and toilet flushing.

For example, dual plumbing reduces sewer traffic and increases the possibility of reusing water on-site. Rainwater harvesting, on the other hand, supplies water for multiple uses and can even be stored for later use. Water efficiency sustainable construction solutions, on the whole, reduce water usage expenses and aid in water conservation. The technologies aim to reduce water waste by 15% to solve freshwater shortages in urban areas.

- **Sustainable indoor environment technologies**

The health and safety of the building's residents are crucial, and they must be ensured during the construction of any structure or residence. As a result, for green construction, sustainable indoor technologies are required.

Additionally, the materials used must meet green safety criteria, which include the absence of dangerous elements, the use of non-toxic materials, the reduction of volatile emissions, and moisture resistance.

Cork, wood, and bamboo, for example, are all naturally sourced and have no harmful, inflammatory, or carcinogenic ingredients. Also, the use of low-VOC materials improves IAQ and reduces exposure to health-hazardous substances like vinyl, lead, and phenol-formaldehyde.

- **Self-powered buildings**

The progress of self-powered building construction (Franco, Pawar, & Wu, 2021) is a sustainable construction technology art. The rationale for this is that self-powered structures allow for zero-energy construction to be realized. The structures (Kim, & Kim, 2020) are designed to generate enough energy to meet their own energy needs and even feed excess energy back into the power system. Wind power is employed in a myriad of situations, and it is very popular in skyscrapers with wind turbines erected on the rooftops. The turbine blades are propelled by steady and heavy air currents at higher altitudes, which produce the building's power needs.

- **Rammed earth brick**

Rammed earth brick is an ancient construction technique that has recently been reintroduced to meet environmental sustainability requirements. Raw materials are sourced sustainably. Technological advancements have eased the building of a rammed-earth structure, but it still follows the ancient preparation process.

Building a rammed-earth construction has become easier as a result of technical improvements, but it still follows the old preparation method. A moist earth combination and hard material, such as gravel or clay, are mixed with stabilizing ingredients like concrete and compressed to make dense, hard walls. Rammed-earth bricks are appropriate for sustainable construction because of their sourcing and production process, reducing environmental consequences while stabilizing a building's temperature. Consequently, rammed-earth construction reduces emissions while keeping buildings cool in the summer and warm in the winter.

IV. THE OBSTACLES TO INDIA'S QUICK ADOPTION OF GREEN BUILDING PRACTICES

Although green building approaches (Sharma, 2020) are gaining traction in the construction sector as a feasible solution for satisfying the growing demand for environmentally friendly or healthy structures. On the other hand, green building technologies are not being adopted as quickly as they should be. The following are the major roadblocks to the widespread implementation of green building technologies:

- **Lack of awareness**

A major segment of Indian people is unaware of green buildings and their long-term benefits. Furthermore, users who are unfamiliar with green buildings believe it is a costly and financially unattainable choice.

- **Insufficient policies and procedures of the government**

Given that India has set big goals for its green building program (Darko, Chan, Yang, Shan, He, & Gou, 2018), most of it is still lacking in necessary government guidelines and regulations to help it thrive. There are insufficient government rules and regulations to ensure that green building standards are implemented on a large scale.

- **Additional clearances and approvals**

Builders and developers must go through a lengthy approval procedure, which is made even more difficult by the long list of permissions required for green building compliance. This could be one factor slowing down the adoption of green buildings.

- **Minimal incentives to foster adoption**

There are now just a few incentive programs available in India to stimulate green construction uptake. Furthermore, the ones that exist are not uniform, as they differ between states and localities, owing to the many regulatory organizations (Hou & Wu, 2021). Green building incentives are typically in the form of increased FAR, followed by a property tax rebate and other similar programs. However, these incentives have historically failed to induce widespread adoption of green building principles in the United States.

- **Expensive equipment and products**

Compared to conventional buildings, the equipment and products utilized in the construction of green buildings are far more expensive. So, many developers and builders are apprehensive that incorporating green features into their structures will incur significant upfront expenditures; hence they are unable to do so.

•Shortage of subject matter experts and adept manpower

The shortage of experienced professionals and people (Dwaikat, & Ali, 2018) is one of the most significant barriers to green building adoption in India. None of the organizations involved in the development of green buildings, from politicians to architects, engineers, contractors, and laborers, have the necessary knowledge and abilities.

V. MODEL FORMULATION

Mathematical modeling is one of the best tools for illustrating the lifespan behavior of any real-life issue. A mathematical model has been developed by taking into account four state variables, such as the number of green buildings, the energetic ingredients produced from green buildings, the amount of greenhouse gases, and the human communities of a certain area, in order to analyze the impact of global warming due to extreme greenhouse gas

emissions on sustainable cities. The suggested model explains how using green buildings might reduce greenhouse gas emissions.

To establish the green building model, let us consider the green building variable $G(t)$ where $\frac{dG}{dt}$ defines the rate of change of $G(t)$ at any time t . In the model, $\frac{dC}{dt}$ represent the rate of change of greenhouse gases at any time t . Also, the green building since produced a number of energetic ingredients $I(t)$ so at any certain time the rate of $G(t)G(t)I(t)C(t)$

change of $I(t)$ is denoted by $\frac{dI}{dt}$. Again let $\frac{dH}{dt}$ identifies the rate of change of the human community at any certain time t . Here $G(t)$ and $H(t)$ be the quantity of green building, greenhouse gases and human community $H(t)$ at any certain time respectively. A mathematical model with four state variables is formulated in the following form according to the schematic diagram described in Figure 4: $H(t), \Lambda, \Omega, \Psi, G(t), C(t), I(t)$

$$\begin{aligned} (1) \quad \frac{dG}{dt} &= \Lambda + a_1 GC - a_2 G \\ (2) \quad G(0) &= G_0 \geq 0; C(0) = C_0 > 0; I(0) = I_0 \geq 0; H(0) = H_0 \geq 0 \\ (3) \quad \frac{dH}{dt} &= \Psi + a_6 HI - a_8 H \frac{dC}{dt} = \Omega - a_1 GC + a_3 HC - a_4 C \frac{dI}{dt} = a_5 GI - a_6 HI - a_7 I \end{aligned}$$

with the initial conditions,

The parameters used in the suggested model are described in Table 1. If green buildings interact with greenhouse gases, it reduces 20% of greenhouse gases by consumption (Biswas, Dey, Islam, & Mandal, 2022), so we use to define the a_1, a_3, a_6

absorption rate of greenhouse gases by green buildings. In the model and $\frac{dC}{dt}$ defines the producing coefficient of greenhouse gases and the absorption coefficient of ingredients by human communities respectively. Also, in the



model, indicates the number of ingredients produced by the green building. $a_5 a_2 \Omega$

Parameters	Parametric statement
Λ	Amount of green building.
a_1	Absorption rate greenhouse gases by green buildings.
	The reduction rate of green building.
	Amount of greenhouse gases.
a_3	Rate of human originated greenhouse gases.

a_4	The reduction rate of greenhouse gases.
a_5	Production rate of ingredients by green buildings.
a_6	The adoption rate of ingredients by human communities.
a_7	The reduction rate of ingredients.
Ψ	Amount of human community.
a_8	The reduction rate of human communities.

Table 1. Descriptions of the model parameters with their corresponding values.

VI. CONCLUSION

Green construction has obvious environmental advantages, but there are additional compelling reasons to use green building technology that may not immediately come to mind. Additional commercial prospects, for example, might be gained by appealing to an ever-growing pool of environmentally conscientious consumers.

Green buildings make strong commercial sense since they pay off quickly, with a fair return on investment in 3-4 years. Employing new technology may require additional labor and expenditure, but the benefits are significantly greater and more fulfilling.

Green building technology supports green efforts, helping both the workforce and society as a whole while also lowering operational expenses and increasing the value of your brand.

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