

STUDY ON OPTIMIZING THE SUSTAINABLE MATERIALS FOR SRI LANKAN HIGH RISE BUILDING IN CONSTRUCTION INDUSTRY

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Abstract

As the demand for high-rise buildings in Sri Lanka increases, its construction industry is evolving rapidly. Therefore, there is a very urgent need to enhance high-rise building construction using sustainable materials. The study focused on enhancing the use of sustainable materials for the construction of high-rise buildings in Sri Lanka, which would address the environmental, economic, and social issues. Green building practices are necessary to ensure carbon emission reduction, natural resource preservation, and energy efficiency, which all take great steps toward addressing global and regional environmental concerns. It compares various sustainable material options like fly ash concrete, recycled steel, bamboo, and locally made bricks with respect to lifecycle cost, environment impact, and social acceptability. The research investigates the enablers and barriers to such material uptake, in terms of cost, availability of materials, and knowledge among stakeholders. For long-term financial benefit through sustainable construction, reduced energy and maintenance costs are being considered, along with the generation of jobs locally, improved well-being among local communities, and other similar factors. It is aimed at delivering in-depth advice on optimizing sustainable material usage in high-rise building construction projects by utilizing quantitative data and qualitative insight. These guidelines integrate the many sustainability targets and pragmatic perceptions and therefore ensure that this industry plays its rightful role in fulfilling Sri Lanka's sustainable development targets. This study emphasizes the importance of collaboration between policymakers, construction professionals, and material providers in efforts to mainstream sustainable practice in the construction industry.

Key words: Energy-efficient buildings, Environmental impact, Life cycle assessment (LCA), Local construction materials

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Introduction

Literature review

Sustainability is becoming imperative across all industries as businesses attempt to reduce the environmental impact of economic development. In property, sustainability activities focus on managing and developing properties such that they will not cause or reduce adverse environmental effects. This current study follows a qualitative framework, with an eight mega development case study employed to investigate the practice of sustainability in eight mega developments in Colombo, Sri Lanka. Data was collected through interviews with permitted officers in every project and assessed in radar and heat map format to ascertain performance in five major areas of sustainability: energy efficiency, water efficiency, recycling, chlorine-free paper, and non-toxic cleaning

Background Study

The findings revealed that energy and water efficiency and conservation were the most frequently implemented practices, while recycling and composting were less prioritized. Chlorine-free paper products were rarely used. (Madushan MJ Pereraa, BHN Mendisb, HT Wickramasinghec); Construction is an emerging technology in many countries used to develop the construction industry through its value-added benefits. The adoption of these novel technologies in the Sri Lankan construction industry has been relatively slow compared with other developing countries, delaying the development of the construction industry and the attainment of the added benefits of these technologies. Therefore, this study aims to identify the suitability of modular construction for the Sri Lankan construction industry via a survey and case study. A questionnaire survey was developed and distributed to assess and identify the benefits of implementing the concepts and constraints in Sri Lanka. (Thisari Munmulla, Hasitha Damruwan Hidallana-Gamage, Satheskumar Navaratnam, Thusiyanthan Ponnampalam, Guomin Zhang, Thishan Jayasinghe, 2023); Construction companies have been busy picking up slack during a pandemic, grappling with the complexities of keeping workers safe and financing construction. The economy has bounced back faster than expected. The challenges of the past year have sharpened the business practices of contractors and finance professionals across the United States, proving that if contractors are committed to seeing through the boom and taking adequate steps to streamline their bidding, contracting and financial practices, consistent success can be achieved. Resisting bidding on unprofitable work, careful record keeping through automation, and paying attention to new tax laws are some of the ways a contractor can ensure that they are profitable for years to come. (TAMULONIS, 2021)

Objectives

- a) To identify the most sustainable building materials available for high-rise construction in Sri Lanka
- b) To evaluate the environmental, economic, and social impacts of using these materials.
- c) To propose guidelines and recommendations for the use of sustainable materials in future high-rise projects in Sri Lanka.

Problem Statement

The rapid rate of urbanization and construction of high-rise buildings in Sri Lanka has led to major environmental challenges, including excessive resource consumption, excessive carbon emissions, and wastage. The traditional materials like steel and concrete, while widely utilized, are the leading cause of these environmental challenges due to their high energy consumption and resource extraction mechanisms.

Research Methodology

Research Design

Off-site construction (OSC) methods have received significant attention for the last decade for a sequence of advantages bestowed, ranging from less time and expense in construction to higher efficiency and environmental gains. OSC has been demonstrated to have superior environmental performance in areas such as waste generation and carbon emission. However, with clearly documented benefits, no major market until 2018 has reached more than 20% of OSC penetration. Hence, it is appropriate to recognize the factors that advanced and enhanced the environmental performance of OSC from current research to learn about the learnings and approaches. Research design: quantitative method approaches. It aligns precisely with the aim to learn how to measure the environmental, economic, and societal impacts of using these materials

The research will employ a self-administered questionnaire. The advantages of this are:

- Time-saving: The respondents will complete the questionnaire in their own time, thereby eliminating scheduling and interviewing.
- Economical: Online questionnaires eliminate printing and distribution costs.
- Anonymity: The respondents are more likely to answer sensitive questions, thereby providing more accurate and honest responses.

The questionnaire will be designed to collect data on the following key areas:

- **Use of sustainable material:** Sustainable materials are used for reducing environmental impact, increasing energy efficiency, and creating durable structures. They can replace traditional materials in structural elements, insulation, finishes, and non-structural components.
- **Waste minimization:** Use of materials like recycled aggregates and by-products (i.e., fly ash) minimizes construction waste, landfill load, and strengthens the circular economy through recycling of resources.
- **Environmental advantage:** Eco-friendly materials significantly lower carbon emissions, reduce resource depletion, and increase energy efficiency, resulting in an improved environment and the prevention of climate change.
- **Barriers to Using Sustainable Materials:** High initial cost, low domestic production, lack of awareness and technical expertise, and supply chain challenges hinder the extensive application of sustainable materials in construction.
- **Employment generation:** Manufacturing, processing, and use of sustainable materials create jobs in manufacturing, green construction, research, and development, boosting local economies.
- **Economic benefit:** Long-term economic benefits include reduced maintenance, energy efficiency, durability of buildings, and appreciation in property value, which make sustainable materials cost-effective in the long term.

Sustainable materials ensure a promising solution to the environmental challenges facing the construction industry. Through the use of renewable materials, recycled content, and energy-efficient products, these materials minimize carbon emissions, conserve resources, and limit waste. Though their upfront costs are slightly higher, long-term savings in the form of reduced maintenance costs, energy use, and increased property value that make sustainable materials affordable. However, at the current time, several issues regarding their limited availability, insufficient knowledge, and technical expertise encroach upon their wider spread. Disintegrating such types of barriers through more research work, governmental support, and industrial coordination would be required for the facilitation of sustainable materials' utilization and to create a genuinely sustainable built environment.

Research Process

Research involves a systematic procedure that strives to be objective and gather much information to analyze so that the research can be completed. The process is used in all research and evaluation projects, regardless of research methodology. The process seeks to explore ideas through a systematic procedure. Throughout the process, the study is documented in such a way that another person can replicate it. Any research that is carried out without documentation of the study is not a test using the research process to enable others to study the process and get outcomes.

The process of research is a step-by-step process and every step is interconnected with other steps in the process. If any changes are introduced in one step of the process, the researcher has to go through all the other steps to implement the change throughout the process. According to (Blankenship, 2010), there has to be a nine-point study in order to carry out the research to make the research successful.

Step 1: Identify the Problem

Step 2: Review the Literature

Step 3: Research Design

Step 4: Data Collection

Step 5: Sampling

Step 6: Data Analysis

Step 7: Material Collection

Step 8: Development of Guidelines

Step 9: Validation of Findings

Population and Sample Selection

Population - The population of sustainable materials that are under consideration for high-rise buildings in Sri Lanka can be divided into environmental, economic, and social effects. These are measured by the amount of carbon footprint reduction that the material can offer, cost savings, and improvement of the welfare of people.

Defining the Sampling Frame - Due to the possibility that there might not be an easily accessible and up-to-date list of all relevant professionals, more than one step can be required in order to form a robust sampling frame. In one such research on sustainable materials used in the construction of high-rise buildings in Sri Lanka, the sampling frame can be as follows.

- Construction professionals - Construction professionals play a significant role in designing, planning, implementing, and administering high-rise construction projects. Their contribution is seriously important in allowing proper integration of sustainable materials in the construction process of buildings.
- Academics and researchers - Researchers studying sustainable construction materials and their application in Sri Lankan high-rise construction projects.
- Developers and Building owners - Real estate developers who make use of sustainable solutions to raise property value as well as marketability.

Sample Selection - Once the sampling frame is established, a probability sampling technique will be employed to procure a representative sample. Two of the possible techniques are outlined below,

1. Stratified Random Sampling - The population can be stratified according to profession (e.g., consultant, contractor) or type of project (e.g., residential, commercial). Proportional allocation can then be used to choose a random sample within each stratum, thus having a representative distribution in the total sample.
2. Simple Random Sampling - Given that the sampling frame is an accurate representation of the population, one can employ a simple random sampling technique. Each member in the frame would have an equal chance of being selected, hence ensuring unbiased representation.

Sample Size Calculation - Statistical formulas taking into consideration the confidence level desired, population size (where known), and acceptable margin of error will be used to determine the minimum sample size. Normal distribution or finite population formulas are routine equations. Standard practice for construction research can also be utilized to set an appropriate sample size.

Pilot Testing - Pilot testing will be conducted before the ultimate survey administration on a small sample to assess the ease of comprehension, clarity, and response time of the questionnaire. This allows the survey instrument to be calibrated before large-scale data collection.

By clearly defining the population, constructing an adequate sample frame, and using a probability sampling method with an appropriate sample size, this research attempts to maximize the sustainable materials of high-rise buildings in construction in Sri Lanka.

Research Approach

Research method is a process and design from general hypotheses to particular research methodology of data collection, analysis, and interpretation. Thus, it adheres to the nature of the problem to be investigated. Quantitative research approach is a technique for testing empirical hypotheses through objective theory to explore relationships between variables. The variables usually measured on an instrument can be analyzed numerically by statistical analysis. The final written report has a structure consisting of introduction, literature and theory, methods, results, and discussion. It attempts to document, analyze, and uncover the underlying meaning and significance of human experience and behavior, e.g., conflicting beliefs, behaviors, and feelings. (Alheimer, 2009). Researchers are keen.

Questionnaire Design

My survey was done online and asked people in the Sri Lankan construction sector how to optimize sustainable material in high-rise buildings in the Sri Lankan construction sector. It asked basic questions like what are the most sustainable material, reducing waste while using sustainable material, environmental impact of sustainable material, cost-effectiveness of using sustainable material, problems they face when using sustainable material (using checklists or taking advice from experts). They also measured those risks (such as scoring systems or taking into account different scenarios) and how they prevent problems (such as saving). These will be extremely useful in understanding how to use sustainable materials for their high-rise buildings.

Data Analysis Techniques

Data analysis for the study employed a quantitative method approach. Frequency of risk mitigation measures used, for example, was examined using descriptive statistics (e.g., percentage, means).

Results and Discussion

- Sustainable Materials to be Utilized for High-Rise Building

Literature sources indicate a list of sustainable materials that can be utilized for high-rise building in Sri Lanka, varying as locally available and imported materials. Locally available materials include fly ash concrete, bamboo, and compressed stabilized earth blocks (CSEB). Fly ash concrete, using waste industrial products, conserves cement usage by 30%, reducing carbon emissions without compromising durability (Nayak et al., 2022). Green product bamboo offers good tensile strength but is treated to offer durability where wet conditions prevail

(Akinlabi et al., 2017). CSEB, made from stabilized soil, offers affordability and is green and has low energy requirements in manufacturing (Waziri & Lawan, 2013).

Foreign materials such as recycled steel and cross-laminated timber (CLT) are less common due to cost and availability constraints. Recycled steel conserves embodied carbon by utilizing waste from building demolition, though its high initial expense discourages uptake (Qin & Kaewunruen, 2022). CLT, being structurally robust, is not taken up in Sri Lanka due to costs of importation and unavailability of local expertise (Brandner et al., 2016). Of these, CSEB and fly ash concrete are most appropriate for Sri Lanka since they are locally available and taken up with economic constraints.

Environmental, Economic, and Social Impacts

Environmental Impacts: Sustainable building materials have a significantly reduced environmental footprint in the construction of high-rise buildings. Fly ash concrete and CSEB reduce carbon emissions by reducing cement production, which accounts for 8% of world CO₂ emissions (Singh et al., 2024). Bamboo and recycled aggregates increase resource efficiency through reduced virgin material use (Chen et al., 2003). The materials also increase waste minimization, with recycled aggregates reducing landfills waste from construction, in line with circular economy.

Economic Impacts: Sustainable materials are more expensive in the short term but yield tremendous lifecycle benefits. Fly ash concrete and CSEB are low maintenance because of their long lifespan, with one report estimating 21–30% reduction in operating expenses in green buildings (Abou Hamad & Abu-Hamd, 2019). CSEB made locally reduces transportation costs, and cost efficiency is enhanced. Recycled steel materials imported, on the other hand, are cost-constrained and difficult to scale within Sri Lanka's price-sensitive economy.

Social Impacts: Social welfare is achieved through sustainable materials in employment and healthier occupants. Rural job opportunities and rural economy empowerment are offered by CSEB and bamboo manufacturing in rural areas (Walker et al., 2019). Thermal comfort and indoor air quality are enhanced by materials like CSEB and bamboo, hence reduced health risk to the occupants (Khoudja et al., 2021). Culturally, the materials fit within the tradition of building culture in Sri Lanka and become socially acceptable.

Adoption Challenges

Despite the benefits that they possess, sustainable materials have a challenging time being adopted in Sri Lanka. High initial costs, particularly for imported materials, deter developers in a cost-sensitive market (Kulatunga et al., 2013). Unavailability of specialized materials and lack of availability of skilled labor deter adoption, as does poor awareness among stakeholders. Regulatory frameworks are also lagging, with unclear standards for sustainable construction practices in the form of approvals (Munmulla et al., 2023). All these point to the need for targeted interventions towards mainstreaming sustainable materials.

Conclusion and Recommendation

Summary of Key Findings

For promoting the transition towards sustainable construction, a multi-faceted process is required. This involves the support of government policies, sectoral cooperation, and technological advances. Through cost challenges resolution, investment in capacity building, and awareness creation, Sri Lanka is able to reap the maximum potential of sustainable construction practices.

Growing awareness and interest

Sri Lankan industry professionals are progressively aware of and interested in the use of sustainable construction materials.

- **CSEB's popularity**
Compressed Stabilized Earth Blocks (CSEB) are nowadays a green favorite, demonstrating the potential of utilizing locally sourced, environmentally friendly substitutes.
- **Moderate uptake**
The take-up of environmental-friendly materials is still moderate in general despite the growth in demand.
- **High upfront cost**
The high initial cost is one of the key barriers to higher take-up of environmental-friendly materials.
- **Multi-faceted solution**

To accelerate the transition to sustainable construction, a combination of government incentives, cooperation by the industry, and technology advances is necessary.

- **Addressing cost barriers**
Strategies to cross the initial high cost, such as government incentives and financing arrangements, need to be implemented.
- **Development of human resources**
Investing money in training workshops to build a skilled workforce can facilitate the adoption of sustainable construction techniques.
- **Raising awareness**
Repeated efforts need to be undertaken to make stakeholders aware of the benefits of sustainable construction.

The survey reports growing demand for sustainable construction and CSEB as a chosen alternative. The primary hindrance to wider applications is the excessive initial cost. To reduce it, government subsidies, industry cooperation, human skill development, and technology assume important roles in accelerating the move towards sustainable building practices in Sri Lanka.

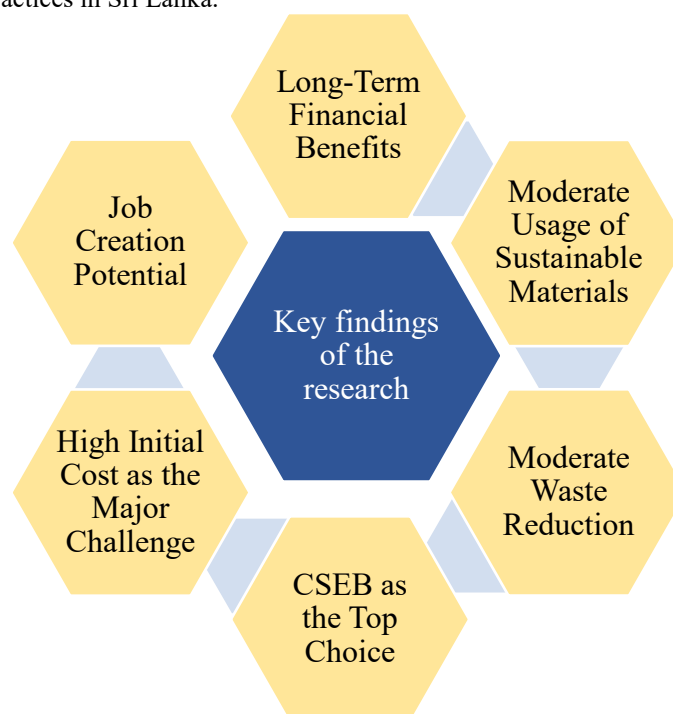


Figure 011: Key Findings of the Research Industry Professionals' and Policymakers' Recommendations

1. Policy Support:

Implement tax subsidies and incentives to reduce the initial cost of sustainable material.
 Institute clear and facilitative policies to ease the process of green building project approvals.
 Invest in R&D to foster innovation in green construction technology.

2. Industry Collaboration:

Foster cooperation among government agencies, industry specialists, and academia to share knowledge and best practices.
 Establish industry standards and certifications for green construction materials and practices.
 Create platforms for networking and collaboration among stakeholders.

3. Skill Development:

Invest in training courses to create an efficient workforce to design, construct, and maintain green buildings.
 Collaborate with schools to integrate sustainable building principles into school curricula.

4. Technology Adoption:

Encourage the use of latest technologies, such as Building Information Modeling (BIM) and digital fabrication, to advance the utilization of green materials and boost construction efficiency. Offer incentives for research and development of new green materials and building techniques.

5. Public Awareness:

Organize public awareness campaigns to inform people of the advantages of sustainable building, such as less environmental footprint, better health and well-being, and cost savings in the long run.

Use media and social media to inform and raise awareness on sustainable activities.

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