E-BOOK OF EXTENDED ABSTRACT

THE 14TH INTERNATIONAL INVENTION, INNOVATION & DESIGN COMPETITION 2025

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BAMBOO ZERO: MODELLING BAMBOO AS A CARBON SINK FOR NET-ZERO CARBON CONSTRUCTION

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ABSTRACT

The construction industry is one of the largest contributors to global greenhouse gas emissions, primarily due to its dependence on carbon-intensive materials such as concrete and steel. In Malaysia, addressing these emissions is critical to meeting the national target of achieving net-zero carbon emissions by 2050. Despite policy frameworks like the Low Carbon Cities Framework (LCCF) and the Low Carbon Cities 2030 Challenge (LCC2030C), practical, scalable solutions remain limited, particularly those that integrate both environmental and socioeconomic sustainability. Bamboo Zero responds to this urgent need by modelling bamboo as a carbon sink within the construction sector. Known for its rapid growth and high carbon sequestration capacity, bamboo presents a locally available, renewable alternative. Scientific modelling from results shows that every 1m³ of bamboo can sequester up to 0.54 tons of Carbon, reducing the embodied carbon of building materials significantly. By replacing or complementing conventional materials, Bamboo Zero contributes directly to carbon reduction in the built environment. Beyond environmental benefits, the innovation also promotes eco-entrepreneurship by empowering local bamboo farmers, builders, and green businesses, supporting the circular economy and creating green jobs. This dual-impact model aligns with Malaysia's sustainable development goals, integrating low-carbon design, urban resilience, and community empowerment. Ultimately, Bamboo Zero is more than a material solution. It is a transformative framework that demonstrates how nature-based materials can be leveraged to create a net-zero carbon construction future while uplifting local economies and reinforcing climate resilience strategies.

Keyword: Carbon Sink, Carbon Embodied and Carbon Operation, Bamboo, Sustainable Urban Planning, Carbon Sequestration

1. INTRODUCTION

The construction industry is a major contributor to global carbon emissions, with buildings and construction accounting for around 40% of total emissions worldwide (UNEP, 2019). Traditional materials like concrete and steel are particularly carbon-intensive, due to energy-demanding production and construction processes. As the world faces growing climate challenges, there is an urgent need for greener, low-carbon alternatives in the built environment.

Bamboo has emerged as a promising solution. It is a fast-growing, renewable material with a high strength-to-weight ratio and strong carbon sequestration capacity. Studies such as Lobovikov et al. (2009) highlight bamboo's ability to absorb large amounts of CO_2 during its growth, making it a viable alternative to more carbon-intensive materials. Unlike slow-growing hardwoods and manufactured materials, bamboo offers environmental benefits across its lifecycle.

Despite these advantages, the practical use of bamboo in carbon-negative construction is still limited. While its sequestration potential is well-documented (Cai et al., 2017), there is a lack of standardized methods to measure its carbon storage capacity in buildings. In addition, emissions from harvesting, transporting, and processing bamboo are often overlooked in existing research (Brahma et al., 2018). These stages can significantly affect the overall carbon balance of bamboo construction.

Design factors, such as how much bamboo is used and how it is arranged in a structure, also influence its carbon performance. Zhao et al. (2019) found that design integration can impact total carbon sequestration, yet this area remains underexplored. Furthermore, many life cycle assessments (LCA) do not fully consider the benefits of using locally sourced bamboo, which can reduce emissions from transport and support regional sustainability.

This innovation aims to fill these gaps by developing a carbon model for bamboo used in buildings, focusing on a real-life bamboo hall in Ipoh, Malaysia. The study has three main objectives:

a) To create standard methods for measuring bamboo's carbon sequestration in buildings.
b) To assess the environmental impact of bamboo production and processing.
c) To evaluate how bamboo quantity and arrangement in structures affect carbon storage.

By analysing the full lifecycle of bamboo—from cultivation to construction—this study will offer insights to support bamboo as a low-carbon material for sustainable buildings. The findings will help advance Malaysia's climate goals and promote carbon-conscious design in urban development.

2. METHODOLOGY

This study uses a three-phase approach to evaluate the potential of locally sourced bamboo for carbon-negative construction, focusing on carbon sequestration, environmental impact, and its role in sustainable urban planning.

In Phase 1, carbon sequestration measurement, measures the carbon sequestration potential of four (4) bamboo species (*Dendrocalamus asper* or Betung*, Gigantochloa scortechinii* or Semantan*, Gigantochloa albociliata* or Madu*, and Schizostachyum brachycladum* or Lemang) using a LICOR 6400XT system. Key environmental factors, including light intensity, CO_2 concentration, relative humidity, and temperature, are adjusted to assess photosynthetic efficiency. The photosynthesis rate, which reflects carbon sequestration, is measured with a 20% data sampling method to ensure statistical accuracy. This phase provides standardized metrics for bamboo's carbon storage potential in construction.

In Phase 2, embodied carbon and environmental impact, evaluates the embodied carbon of bamboo construction by assessing the lifecycle emissions from harvesting, processing, transportation, and installation. A Life Cycle Assessment (LCA) is used, alongside insights from experienced workers on the environmental effects of bamboo sourcing. This phase aims to identify strategies for reducing the embodied carbon in bamboo-based buildings.

In Phase 3, operational carbon evaluation, examines operational carbon emissions from bamboo buildings, focusing on energy use and efficiency. Expert interviews guide the analysis of energy consumption, offering insights into reducing operational carbon footprints in bamboo construction.

3. FINDINGS

The study evaluates bamboo's potential for low-carbon construction by assessing carbon sequestration, embodied carbon, and operational carbon at Bamboo Hall. In Phase 1, photosynthetic assimilation rates were measured across four bamboo species, with Semantan showing the highest Net Primary Production (NPP) and carbon sequestration potential, followed by Madu, Lemang, and Betung. Semantan sequestered 61,684.96 kg C per clump annually, while Betung sequestered the least at 2,138.62 kg C.

Phase 2 examined the embodied carbon of bamboo used in the hall's construction, revealing a total carbon sequestration of 48,694.84 kg C and total embodied emissions of 122.21 kg C. Emissions from harvesting, manufacturing, transportation, and installation were considered, with transportation emerging as a significant contributor.

In Phase 3, operational carbon was assessed, with ceiling fans contributing the most emissions (974.75 kg annually), while solar-powered LED lights had zero emissions. The total volume of the bamboo hall is 90 m^3, corresponding to 48,673 kg C, which translates to 540.8 kg C per cubic meter or 0.54 tons C/m^3. This data provides a valuable tool for architects, landscape architects, environmental consultants, and developers to estimate embodied carbon on a larger scale. Understanding this helps make informed decisions on sustainable construction practices and supports broader sustainability goals.

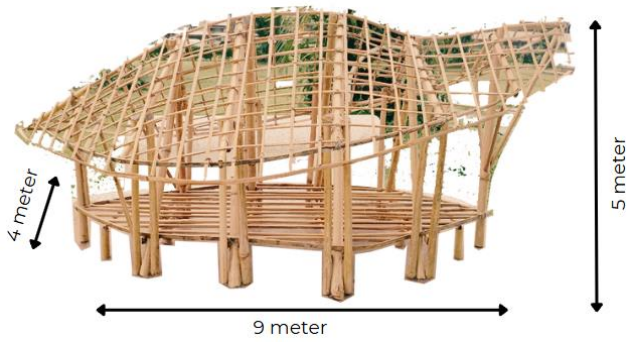

Figure 1 The Bamboo Hall constructed using four different bamboo species.

4. CONCLUSION

Bamboo Zero delivers a science-based, scalable carbon modelling tool that positions bamboo as a viable carbon sink in the construction sector. By quantifying sequestration capacity per cubic meter and evaluating embodied and operational emissions, this innovation offers a comprehensive, service-oriented solution to support carbon accounting in the built environment. The results empower developers, landscape architects, and environmental consultants to estimate and offset carbon footprints accurately, paving the way for data-driven decisions in achieving net-zero goals. More than a material alternative, Bamboo Zero is a practical service model that bridges ecological science with urban development—catalyzing low-carbon design, promoting local bamboo economies, and aligning with national and global sustainability agendas. Its adoption could significantly accelerate Malaysia's journey toward a climate-resilient and carbon-conscious future.

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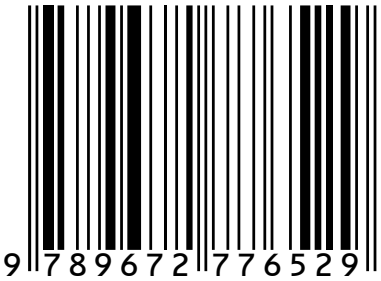

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