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Evaluating the Environmental Impact of Bio brick and Natural Beton: A Comprehensive Life Cycle Assessment from Cradle to Gate

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Abstract

This study employs a Life Cycle Assessment (LCA) to evaluate the environmental impacts associated with the production of biobrick and Natural Beton (N.B.), innovative building materials made from lime and hemp. Adhering to the ISO 14040 and 14044 standards, the research focuses on the 'cradle to gate' stages, incorporating both primary data from the production processes and secondary data for raw materials and transportation impacts.The assessment, executed using the SimaPro software and the ReCiPe Midpoint method, establishes a functional unit of one kilogram of each product at the factory gate. The study identifies significant energy reductions in the 'cold' manufacturing processes used for both materials compared to conventional methods. Study analyses that transportation, particularly of lime, significantly influences the total environmental footprint. Scenarios utilizing local sourcing for lime reduced transport-related emissions by over 90%, emphasizing the benefits of local material procurement strategies.The LCA also shows the potential for nearly zero waste in production, with effective reuse of production offcuts and minimal packaging waste. The results advocate for policy shifts towards sustainable manufacturing practices and local sourcing within the building materials industry.

Keywords: Sustainable Building Materials, Life Cycle Assessment (LCA), Environmental Impact, Bio-composite Materials, Waste Minimization.

Introduction

In the evolving landscape of construction materials, the pursuit of sustainability has led to innovative approaches that promise reduced environmental footprints without compromising functional integrity. Among these, biobrick and Natural Beton emerge as frontrunners due to their biocomposite nature, utilizing hemp and lime in their composition. This research is prompted by the increasing recognition of the need for environmental stewardship and the pursuit of greener building solutions. However, a gap remains in systematically understanding how these strategies can be optimized during the manufacturing phases of innovative materials such as biobrick and Natural Beton. Therefore, this paper extends the body of knowledge by quantifying the environmental impacts of these materials, analyzing the pivotal role of transportation and local sourcing, and exploring potential waste minimization techniques in their production processes.By potentially lowering lifecycle environmental impacts, these materials contribute to the United Nations Sustainable Development Goals, particularly those targeting responsible production and consumption. Future studies and industry practices must align with these global benchmarks to ensure that the environmental benefits of biobricks and Beton are realized on a global scale. This alignment also promotes the international transfer of best practices and technologies, fostering global collaboration in sustainable construction (Morero B et al., 2015).

The environmental impacts of biobricks and natural Beton, gaps remain that need to be addressed through ongoing research. These include the long-term durability and maintenance requirements of biobricks, the development of new composite materials that could further reduce the environmental impact of Beton, and the full lifecycle analyses that incorporate the end-of-life scenarios for these materials. Additionally, research should also focus on the socio-economic impacts of adopting these materials in different geographic and economic contexts, ensuring that environmental gains do not come at the cost of social or economic downsides (Ramesh et al., 2022).The urgency to adopt environmentally sustainable practices within the construction industry is further amplified by the escalating impacts of global climate change and the increasing scarcity of natural resources. This study draws on the principles of green chemistry and sustainable engineering to provide a detailed examination of biobrick and Natural Beton. These materials are not only innovative due to their composition but also for their potential to revolutionize the building sector through environmentally benign production processes.

The objectives of this research are twofold: first, to conduct a rigorous Life Cycle Assessment (LCA) to quantify the environmental impacts associated with the production of biobrick and Natural Beton, from the extraction of raw materials to the delivery at the factory gate. Second, to dissect the influence of local sourcing and transportation distances on their overall environmental footprints, offering a comparative analysis that could serve as a benchmark for future material innovations in the industry.

Background

The evaluation of environmental impacts within the construction industry has increasingly focused on sustainable building materials, pushing forward the development of innovative composites like Biobrick and Natural Beton. This section reviews existing studies that align with our assessment, framing our research within the broader discourse on sustainable building practices and Life Cycle Assessments (LCA).Biobricks and natural Beton (concrete) are pivotal in sustainable building practices, offering different ecological footprints, which necessitate thorough evaluations through life cycle assessments (LCAs). Biobricks, often part of bio-composite materials, rely heavily on agricultural byproducts and natural binders. An LCA perspective highlights the importance of raw material sourcing and processing. Biobricks exhibit lower energy consumption and carbon emissions when compared to traditional bricks due to less energy-intensive production processes and the carbon sequestration capabilities of the biological materials used in them (Morero, Rodriguez, & Campanella, 2015). Traditional concrete or Beton's environmental assessment involves evaluating the extraction and processing of its primary components: cement, aggregates, and water. Cement production is energy and carbon-intensive, significantly impacting its LCA. Modern approaches aim to integrate recycled materials and alternative cements to mitigate these impacts (Rusdianasari et al., 2022). Comparative LCAs provide insights into how biobricks and Beton stack against one another. Studies focusing on comprehensive environmental impacts, including CO2 emissions, energy use, and water footprint, suggest that while biobricks offer lower immediate impacts, their long-term performance and durability need further exploration. Beton, meanwhile, benefits from extensive research backing its structural integrity but struggles with high initial environmental costs (Curaqueo et al., 2017).

Existing studies on sustainable building materials largely neglect the comprehensive environmental impacts of production processes, particularly the effects of local sourcing and transportation distances. Additionally, there is a limited understanding of waste minimization strategies in the lifecycle of newer biocomposite materials like biobrick and Natural Beton, which this study aims to address by exploring various production and sourcing scenarios.

In this study, we aim to conduct a thorough Life Cycle Assessment (LCA) of biobrick and Natural Beton, tracking their environmental impact from cradle to gate. This analysis will enable us to measure the footprint of these sustainable building materials while considering the full spectrum of their production processes. Additionally, we will examine the influence of local sourcing and varying transportation distances on the overall environmental costs associated with these materials. A critical component of our investigation involves exploring and evaluating waste minimization strategies and alternative production scenarios. Our goal is to identify enhancements in the manufacturing process that could further bolster the sustainability of biobrick and Natural Beton production. This comprehensive evaluation will provide valuable insights into making the production of building materials more environmentally friendly and sustainable.

Methodology

This research employed a comprehensive Life Cycle Assessment (LCA) to evaluate the environmental impacts of biobrick and Natural Beton (N.B.), focusing on their production, transportation, and end-of-life stages. The study adopted the ISO 14040 and 14044 standards for LCA, ensuring a systematic approach to data collection, impact assessment, and interpretation.

Data Collection:

Primary data were collected directly from Equilibrium, the company producing the materials, covering all direct inputs and outputs of the production processes, including raw material consumption, energy use, and waste generation. Secondary data, relating to upstream and downstream processes like raw material extraction and transport emissions, were sourced from the Ecoinvent database. This hybrid approach ensured comprehensive coverage of all life cycle stages.

Functional Unit and System Boundaries:

The functional unit defined for this LCA was 'one kilogram of finished product at the factory gate.' The system boundaries extended from cradle to gate, including raw material extraction, material processing, and transportation to the manufacturing site, but excluding installation and disposal processes.

Impact Assessment:

The SimaPro software tool was used to model the environmental impacts across multiple categories, including global warming potential, energy use, and waste generation. The study utilized the ReCiPe Midpoint method to quantify and aggregate environmental impacts into a single score, facilitating comparison between the two products and identification of key impact drivers.

Scenario Analysis

To explore the effects of different production and logistical strategies on the environmental footprint, several scenarios were evaluated. These included variations in raw material sourcing distances and alternative production techniques aimed at reducing energy consumption.

Data Quality and Validation:

Data quality was assessed based on representativeness, consistency, and temporal alignment with the study's goals. The LCA results were validated through peer reviews and sensitivity analyses to ensure reliability and robustness of the conclusions drawn.

Results

Environmental Impact of Production

The LCA conducted on the production of biobrick and Natural Beton (N.B.) revealed distinct environmental footprints for each product. For biobrick, the production process, which incorporates a "cold" technique to mix hemp and lime, showed a lower total energy consumption compared to traditional methods. The analysis recorded that biobrick production consumes approximately 0.776 kWh per cubic meter during the mixing phase, attributed to the efficient use of energy in the specialized equipment.

In contrast, the production of Natural Beton in both 1:1 and 2:1 mixture indicated slightly higher energy requirements due to the varying ratios of lime to hemp. Specifically, the N.B. 1:1 mixture required 0.776 kWh per cubic meter, similar to biobrick, whereas N.B. 2:1 needed 0.776 kWh but with increased lime content, impacting the overall energy consumption of the mixing process.

Transportation and Inbound Logistics

The environmental impact of transportation was notably significant, especially for the lime component. Lime sourced from the quarry near Narni (530 km distance) resulted in a substantial carbon footprint, calculated at approximately 15990 ton-km per shipment. An alternative scenario utilizing lime from a closer site at Brembilla (40 km distance) suggested a potential reduction in transport-related emissions by over 90%, highlighting the importance of local sourcing for reducing environmental impacts.

Material Utilization and Waste Management

Material efficiency was observed in the use of hemp, where the LCA data indicated minimal waste due to the biodegradable and recyclable nature of the materials. For biobrick, the reintegration of production waste into the initial stages of the mixing process demonstrated an innovative approach to achieving near-zero waste production. Similarly, for Natural Beton, the water used in the mixture, sourced directly from the aqueduct, carried no transport-related environmental impact, emphasizing the sustainability of local resource utilization.

Discussion

Implications of Energy Consumption in Production

The findings highlight the critical role of production methods in the overall environmental footprint of building materials like biobrick and Natural Beton. The energy efficiency of the "cold" production process used for these materials, particularly for biobrick, suggests that adopting such methods can significantly lower the energy demand and associated emissions compared to more energy-intensive traditional manufacturing processes. This supports the notion that sustainable production technologies are not only feasible but also beneficial in reducing the environmental impact of construction materials.

Importance of Local Sourcing for Materials

The substantial environmental impact associated with transporting lime over long distances underscores the importance of local sourcing. By switching lime sourcing from Narni to Brembilla, the potential reduction in CO_2 emissions and other transport-related impacts presents a compelling case for regional sourcing strategies. This strategy not only minimizes the carbon footprint but also supports local economies and reduces transportation costs, making it a multifaceted solution.

Zero-Waste Strategies in Material Production

The integration of production waste back into the production cycle of biobrick and the minimal waste associated with Natural Beton production illustrate the potential for achieving zero-waste in the building materials sector. These practices not only help in reducing the amount of waste sent to landfills but also optimize resource use, which is crucial in the context of sustainable materials management. Future research could explore further innovative waste reduction and reuse strategies to enhance sustainability in the industry.

Recommendations for Policy and Industry Practice

Given the findings, it is recommended that policymakers and industry stakeholders consider incentives for the adoption of sustainable production technologies and local sourcing strategies. Additionally, regulations could be strengthened to encourage the construction industry to adopt practices that reduce environmental impacts, such as mandatory recycling of production waste and utilization of local material sources.

Future Research Directions

Further studies are needed to explore the long-term durability and performance of biobrick and Natural Beton in various climatic conditions to validate their applicability as sustainable building materials. Additionally, research into alternative natural materials that could be used in similar production processes may uncover new opportunities for reducing the environmental impacts of the construction sector.

Conclusion

This study's life cycle assessment of biobrick and Natural Beton (N.B.) underscores the significant potential for reducing the environmental impacts associated with building materials through the adoption of sustainable production techniques and the strategic sourcing of raw materials. The findings demonstrate that the "cold" production processes utilized for these biocomposite materials not only minimize energy consumption but also facilitate a near-zero waste output by reintegrating production waste back into the cycle. Moreover, the critical impact of transportation logistics on the overall environmental footprint reveals the substantial benefits of local sourcing, particularly in reducing greenhouse gas emissions. The research highlights the feasibility and environmental advantages of biobrick and N.B. in sustainable construction, advocating for policy changes and industry practices that prioritize local sourcing and sustainable manufacturing methods. Future research should continue to explore alternative sustainable materials and innovative production techniques to further the development of the construction industry towards greater ecological responsibility.

References

[1] Morero, B., Rodriguez, M. B., & Campanella, E. A. (2015). Environmental impact assessment as a complement of life cycle assessment. Case study: Upgrading of biogas. *Bioresource Technology*, *190*, 402-407.

[2] Ramesh, M., Deepa, C., Kumar, L. R., Sanjay, M. R., &Siengchin, S. (2022). Life- cycle and environmental impact assessments on processing of plant fibres and its bio- composites: A critical review. *Journal of Industrial Textiles*, *51*(4_suppl), 5518S- 5542S.

[3] Weiss, M., Haufe, J., Carus, M., Brandão, M., Bringezu, S., Hermann, B., & Patel, M.

[4] K. (2012). A review of the environmental impacts of biobased materials. *Journal of Industrial Ecology*, *16*, S169-S181.

[5] Morero, B., Rodriguez, M. B., & Campanella, E. A. (2015). Environmental impact assessment as a complement of life cycle assessment. Case study: Upgrading of biogas. *Bioresource Technology*, *190*, 402-407.

[6] Agrawal, M. S., Vanarotti, M. B., & Yashwant, K. M. (2022). Research on Emotion in Artificial Life and Artificial Intelligence: Dealing with Issues. *Telematique*, 860-864.

[7] Pandey, P., Lamba, A., & Agrawal, S. (2021). A Review on Study of Multilevel Car Parking. *International Research Journal of Modernization in Engineering Technology and Science. https://www. irjmets. com/uploadedfiles/paper/volume_3/issue_12_december_2021/17422/final/fin_irjmets1638433809. pdf*.

[8] Mahant, M. V., Agrawal, M. S., & Lamba, M. A. (2021). Experimental Study on Dolomite Bricks with Positive Permanent Linear Change.

[9] Agrawal, M. S. (2022). IMPACT OF HEAVY METAL ACCUMULATION IN GROUND WATER DUE TO LEACHATE & ASSESSMENT OF RHEOLOGICAL PROPERTIES. *Journal of East China University of Science and Technology*, *65*(2), 318-326.

[10] Agrawal, M. S. (2022). A STUDY ON SEWAGE TREATMENT & GROUND WATER CONTAMINATION IN RAIPUR CITY. *Harbin Gongye Daxue Xuebao/Journal of Harbin Institute of Technology*, *54*(5), 187-191.

[11] Sinha, M. A. K., Verma, M. D. K., & Agrawal, M. S. (2020). Intelligent Transport System In India. *Solid State Technology*, *63*(6), 13123-13126.

[12] Pathak, A., Singh, V., Darjee, M. A., & Agrawal, M. S. (2017). A Seismic Behavior of Building in Earthquake Zone in Nepal.

[13] Lamba, M. A., Agrawal, M. S., & Dubey, M. A. (2021). ANALYSIS OF USE OF SUGARCANE BAGASSE ASH FOR THE PRODUCTION OF GEO POLYMER CONCRETE. *International Research Journal of Modernization in Engineering Technology and Science*, *3*.

[14] Agrawal, M. A., & Lamba, M. A. (2023) ANALYSIS AND DESIGN OF G+ 3 BUILDING IN DIFFERENT SEISMIC ZONES USING E-TABS.

[15] Shori, A., & Lamba, A. (2019). Performance of Concrete using Red Mud as Replacement Material with Basalt Fiber.

[16] Padhy, M. A. P., Lamba, M. A., & Tamrakar, M. G. (2022). Impact of Process Limits on Cable and Curve Additive Production Process. *Telematique*, 512-522.

[17] Lamba, M. A., Tamrakar, M. G., & Gaur, M. H. (2022). A comparative analysis on CI turbine act and emissions resorting to a novel antioxidant preservative. *Telematique*, 523-535.

[18] Sahu, M. K., Padhy, M. A. P., & Lamba, M. A. (2022). Preliminary Study on Interpretation Motion Traits of Moored Well-proportioned Wheeled vehicle for hauling-substitute in Common Waves. *Telematique*, 497-511.

[19] Lamba, A. (2022). FORMATIVE DESIGN OF HIGH-RISE SYSTEM IN STEEL STRUCTURE. *Harbin Gongye Daxue Xuebao/Journal of Harbin Institute of Technology*, *54*(6), 49-56.

[20] Lamba, M. A. (2022). In-Structure Response Spectra Considering Nonlinearity Of RCC Structures: Experiments And Analysis. *Yantu Gongcheng Xuebao/Chinese Journal of Geotechnical Engineering*, *44*(5), 97-103.

[21] Lamba, A. (2020). A Study On Geo Polymer Concrete Using Sugarcane Bagasse Ash. *Solid State Technology*, *63*(6), 13127-13134.

[22] Jaiswal, S., & Agrawal, S. (2021). Design of Horizontal and vertical alignment of Expressway for the speed of 150kmph–'A Review'.

[23] Rusdianasari, Utarina, L., Kalsum, L., Wulandari, D., & Bow, Y. (2022). Environmental Potential Impact on Biofuel Production from Thermal Cracking of Palm Shell using Life Cycle Assessment. *Journal of Ecological Engineering*, *23*(12).

[24] Curaqueo, G., Cea, M., Vera, L., & Navia, R. (2017). Environmental hotspots in the life cycle of a biochar-soil system. *Journal of Cleaner Production*, 158, 1-7. https://doi.org/10.1016/J.JCLEPRO.2017.04.163.

[25] Singh, B., Strømman, A. H., & Hertwich, E. G. (2011). Comparative life cycle environmental assessment of CCS technologies. *International Journal of Greenhouse Gas Control*, *5*(4), 911-921.