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Life Cycle Assessment of Residential Building Using Building Information Modelling

V. Karthikeya[1], M. Anil Kumar[2], P. Vandhana[3], P. Keerthi[4], T. Rohit Kumar[5]

[1,2,3,4,5] GMR Institute of Technology

A B S T R A C T

This study presents a comprehensive life cycle assessment (LCA) of g+9 buildings using Building Information Modelling (BIM) to analyze their environmental impacts from construction to demolition. The research integrates environmental considerations with structural analysis to provide a holistic evaluation of sustainability in mid-rise building construction. Through a multidisciplinary approach, the study examines the embodied energy, greenhouse gas emissions, resource consumption, and other environmental indicators associated with different building materials, construction processes, and end-of-life scenarios. The analysis utilizes BIM technology to model and simulate the life cycle of g+9 buildings, enabling the assessment of various design alternatives and construction strategies. The findings highlight the significance of early design decisions and material selection in minimizing environmental footprints and improving overall building performance. Furthermore, the study identifies key areas for improvement and proposes recommendations for enhancing the sustainability of g+9 buildings through optimized design, construction practices, and material choices. Overall, this research contributes to advancing sustainable building practices by providing valuable insights into the environmental impacts of mid-rise construction and demonstrating the potential of BIM-enabled LCA for informing decision-making processes in the building industry.

Keywords: LCA, Building Information Modelling, Sustainability, Buildings.

1. Introduction

Background of LCA:

Life Cycle Assessment (LCA) emerged in response to growing concerns about the environmental impacts of human activities. It originated in the late 1960s and early 1970s as a methodology to comprehensively evaluate the environmental footprint of products and processes. Recognizing the need for a holistic approach, researchers and environmentalists began exploring ways to assess the entire life cycle of products, from raw material extraction to production, use, and disposal. This shift in perspective marked a significant departure from traditional environmental assessments, which focused primarily on individual stages or endpoints. As environmental awareness increased, LCA gained traction as a valuable tool for decision-making in industry, policymaking, and academia. Over time, it evolved into a standardized methodology, with guidelines and standards developed by organizations such as the International Organization for Standardization (ISO). Today, LCA plays a crucial role in sustainability assessment, helping stakeholders identify opportunities for improvement and make informed choices to minimize environmental impacts.

Importance of LCA:

Life Cycle Assessment (LCA) is of paramount importance in understanding the environmental impacts of products, processes, and systems across their entire life cycle. By considering all stages from resource extraction to production, use, and disposal, LCA provides a comprehensive view of the environmental footprint associated with various activities. This holistic approach is crucial for making informed decisions and designing sustainable solutions. LCA helps identify hotspots where interventions can be most effective in reducing environmental burdens, guiding efforts towards more resource-efficient and environmentally friendly practices. Moreover, LCA promotes transparency and accountability by enabling stakeholders to evaluate alternatives, compare different options, and assess trade-offs. In today's world, where environmental sustainability is a pressing concern, LCA serves as a valuable tool for achieving more sustainable development patterns and ensuring a healthier planet for future generations.

Out Line:

This stage involves clearly defining the objectives of the LCA study and establishing the boundaries and scope of the assessment, including the functional unit, system boundaries, and life cycle stages to be considered. Life Cycle Inventory (LCI): In this stage, data on the inputs (e.g., materials, energy) and outputs (e.g., emissions, waste) associated with each life cycle stage are collected and compiled. This includes gathering information on raw material extraction, production, transportation, use, and end-of-life disposal. Life Cycle Inventory (LCI): In this stage, data on the inputs (e.g., materials, energy) and outputs (e.g., emissions, waste) associated with each life cycle stage are collected and compiled. This includes gathering information on raw material extraction, production, transportation, use, and end-of-life disposal. In interpretation stage, the results of the LCA are interpreted and communicated to stakeholders. This involves analyzing the findings, identifying key findings and areas of improvement, and drawing conclusions based on the assessment. Recommendations for mitigating environmental impacts and improving sustainability may also be provided.

Review of Literature:

Paper 1: Kjaer Zimmermann R, Kanafani K, Nygaard Rasmussen F, Birgisdottir H, "Early Design Stage Building LCA using the LCAbyg tool: Comparing Cases for Early Stage and Detailed LCA Approaches", Danish Buildiong Research Institute, Alborg University, A.C. Meyers Vaenge 15,2450 Copenhagen, Denmark, 10.1088/1755-1315/323/1/012118.

- Comparison of GWP Impact: The study found that the Environmental Design (ED) tool resulted in a higher Global Warming Potential (GWP) impact overall compared to the detailed Life Cycle Assessment (LCA). This disparity can be attributed to the early design approach's more conservative estimation of materials and its higher completeness in material use.
- Factors Contributing to Higher Impact: The early design approach included a broader range of building elements, such as building systems, finishes, membranes, fastenings, and structural components for floors and ceilings. These additional elements significantly contributed to the increased GWP impact, despite their relatively lower mass contribution.
- Importance of Comprehensive Material Consideration: The findings underscore the importance of including diverse building elements in the assessment for a comprehensive understanding of the environmental impacts of buildings. Neglecting certain components, such as finishes and structural elements, can lead to underestimation of the overall environmental impact.

Paper 2: Joao de Lassio, Josue Franca, Karida Espirito Santo, AssedHaddad, "LCA Methodology Applied to Materials Management in a Brazilian Residential Construction Site", 10.1155/2016/8513293.

- Importance of LCA Methodology: The study underscores the significance of employing Life Cycle Assessment (LCA) methodology to evaluate the environmental impacts of essential building materials used in residential construction.
- Critical Environmental Concerns: The analysis reveals alarming levels of fossil fuel consumption and nonrenewable energy use in the production of building materials, contributing to global warming and posing risks to human health.
- Need for Action: There is a pressing need for intervention in the production chain of steel, cement, and ceramic materials to mitigate their adverse environmental effects. Complementary research is required to explore alternative materials and systems, particularly in ceramic usage.
- Promotion of Sustainability: The study aims to promote sustainability and environmental protection in all stages of construction. Recommendations are made for building designers to reconsider the usage of ceramic materials and explore alternative options to minimize environmental impacts.

Paper 3: Aashish Sharma, Abhishek Saxena, Muneesh Sethi, Venu Shree, and Varun, "Life Cycle Assessment of Buildings", 10.1016/j.rser.2010.09.008.

- Energy Consumption in Buildings: Buildings are significant contributors to energy consumption, particularly in the residential and commercial sectors. This high energy consumption results in the emission of hazardous gases, leading to global environmental issues such as ozone depletion, greenhouse effect, and acidification.
- Environmental Impact Throughout Life Cycle: The study highlights that all phases of a building's life cycle have notable environmental impacts. However, the operational phase stands out as the most significant, accounting for approximately 80-85% of energy consumption. This finding is consistent with similar studies conducted in various countries.
- Importance of Construction Phase: Implementing alternative construction methods and materials can significantly reduce the environmental impact of buildings. Constructing buildings with a focus on minimizing energy consumption during the operational phase can lead to the development of performance-based structures that benefit both the environment and the economy.
- Potential for Performance-Based Buildings: By prioritizing energy-efficient construction practices, it is possible to create buildings that not only reduce energy consumption but also contribute positively to the economy. Performance-based building design can play a crucial role in achieving sustainability goals and mitigating environmental harm.

Paper 4: Silvia Dimova, Gervasio H, Dimova S, "Model for Life Cycle Assessment (LCA) of buildings", European Commission, Joint Research Centre, Directorate E, Unit E.4, 10.2760/10016.

- Project Goal: The EFI Resources project aims to develop a performance-based approach for sustainable design, focusing on assessing resource efficiency in the early stages of building design. This aligns with European policies aimed at promoting the efficient use of resources in construction.
- Harmonization of Criteria: The proposed approach seeks to harmonize environmental and structural criteria in building design, resulting in designs that meet safety requirements while reducing environmental impact and resource consumption. This integration allows structural engineers to consider environmental factors in decision-making, promoting resource efficiency throughout the building's life cycle.

- Development of LCA Model: The report focuses on developing a model for life cycle analysis (LCA) and integrating it into a software tool. The standardized LCA procedure ensures comparability and clear communication of results, facilitating benchmarking of the life cycle performance of building structural systems.

Conclusions or results

The research gap for the life cycle assessment of G+9 buildings lies in the lack of comprehensive studies that integrate both environmental considerations and structural analysis throughout the entire life cycle of such buildings. While there are existing studies focusing solely on the environmental impacts of building materials and construction processes, there is a need for more holistic assessments that also consider the structural performance and resilience of buildings, particularly in the context of seismic analysis. Additionally, there is limited research that explores the use of Building Information Modelling (BIM) in facilitating life cycle assessments for mid-rise buildings like g+9 structures. Bridging this gap requires conducting interdisciplinary research that combines expertise in environmental science, civil engineering, and architectural design to develop robust methodologies for assessing the sustainability of g+9 buildings from construction to demolition. Furthermore, there is a need for empirical data and case studies that validate the effectiveness of these methodologies in real-world applications, providing practical insights for policymakers, architects, engineers, and developers to make informed decisions towards more sustainable building practices.

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