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Life Cycle Assessment of Building Materials Using One Click LCA Software: A Case of Shahjahanpur, Uttar Pradesh

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Abstract - The construction sector significantly contributes to environmental degradation through the extensive use of natural resources, high energy consumption, and carbon emissions. This study presents a Life Cycle Assessment (LCA) of Sugarcane Research Institute in Shahjahanpur, Uttar Pradesh, and using One Click LCA software to evaluate the environmental impact of various building materials. The primary objective is to conduct a comprehensive assessment of the building's life cycle stages—from material extraction and transportation to construction, operation, and end-of-life phases. The analysis quantifies the carbon footprint, energy consumption, and resource efficiency associated with different building materials. The results highlight key environmental hotspots, identifying materials with the highest embodied carbon and overall environmental impact. Using One Click LCA, the study also explores potential mitigation strategies, such as material optimization and sustainable construction practices, to reduce the building's ecological footprint. The findings of this research provide valuable insights for architects, engineers, and policymakers by emphasizing the importance of selecting environmentally responsible building materials. The study underscores the need for integrating LCA into the design and planning phases to promote sustainable construction practices in Shahjahanpur and similar regions.

Key Words: Life Cycle Assessment (LCA), Building Materials, Global Warming Potential, Environmental Impact, One Click LCA Software

1. INTRODUCTION *(Size 11, Times New roman)*

The construction industry significantly impacts the environment, particularly through the carbon emissions, energy consumption, and waste generation associated with building materials (Porchelvan & Rajasekharan, 2023). With the growing demand for infrastructure and housing in rapidly developing regions like Shahjahanpur, Uttar Pradesh, the environmental impact of building materials has become a critical concern. The extraction, production, transportation, and disposal of construction materials generate substantial greenhouse gas (GHG) emissions and consume vast amounts of natural resources, making it essential to evaluate their sustainability. The primary aim of this study is to analyze the environmental footprint of commonly used construction materials, thereby supporting green building practices in India (GRIHA Council, 2024).

Life Cycle Assessment (LCA) is a systematic approach (ResearchGate, 2024; Firstgreen Consulting, 2024) used to quantify the environmental impact of products or processes throughout their entire life cycle. When applied to buildings, LCA considers all phases—from material extraction and construction to operation, maintenance, and eventual demolition. This comprehensive analysis provides valuable insights into the embodied carbon, energy consumption, and resource efficiency of various building materials, helping stakeholders make informed decisions about material selection and sustainable construction practices.

In this study, One Click LCA software is used to conduct a Life Cycle Assessment of a building in Shahjahanpur, with a specific focus on analyzing the environmental impact of different building materials. One Click LCA is a widely recognized tool that offers accurate and efficient environmental evaluations by measuring global warming potential (GWP), embodied carbon, and overall resource usage. The software streamlines the process of identifying environmental hotspots, making it easier to develop strategies for impact reduction.

The study aims to analyze the environmental footprint of various construction materials used in the selected building project through a comprehensive Life Cycle Assessment using One Click LCA software. By identifying materials with high embodied carbon and energy consumption, the study aims to propose sustainable alternatives and best practices to reduce the building's overall environmental impact.

2. Methodology

The methodology involved three main steps: building selection, data collection, and life-cycle impact analysis (Figure 1). First, the Sugarcane Research Institute building was selected as a representative public-sector R&D facility. Secondly, detailed material data was gathered from on-site surveys, BOQs, and architectural plans. Finally, a comprehensive life cycle assessment was performed using the One Click LCA platform. The tool followed EN 15978 standards (CECP-EU, 2024) and computed impacts for stages A1–C4, including Global Warming Potential and other categories.

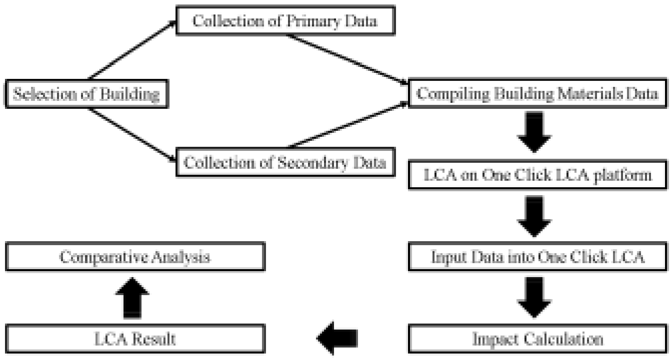

Figure 1: A Graphical Summary of the methodology

3. Study Area

The **Sugarcane Research Institute, Shahjahanpur**, is a premier research institution in Uttar Pradesh, India, dedicated to advancements in sugarcane cultivation and related agricultural practices. Established with the goal of enhancing the productivity and sustainability of sugarcane farming, the institute focuses on developing high-yield and disease-resistant sugarcane varieties, refining cultivation techniques, and promoting efficient pest and disease management practices. It also provides training programs and technical support to farmers to optimize their agricultural output.

Located in Shahjahanpur district, the institute is positioned (Government of India, Department of Science & Technology) at coordinates 27.8834° N latitude and 79.9097° E longitude. It is situated at an altitude of approximately 155 meters (509 feet) above sea level, making it ideal for conducting research specific to subtropical sugarcane farming. The institute serves as a critical hub for collaboration among researchers, agricultural experts, and farmers in the region, contributing significantly to the state's economy through the advancement of sugarcane agriculture (Figure 2).

Figure 2: Location of Sugarcane Research Institute, Shahjahanpur

The **ground floor** (Figure 3) houses the administrative wing, including the Director's Office, conference hall, and a visitor lobby. It also features laboratories for soil testing, nutrient analysis, plant pathology, and pest control, along with a seed processing unit. Additionally, a library containing resources on sugarcane research and a Farmer's Facilitation Centre for training and outreach programs are located here.

The **first floor** (Figure 3) of the institute is dedicated to advanced research, housing state-of-the-art laboratories specializing in biotechnology, molecular biology, and DNA fingerprinting. It also includes a dedicated data analytics wing supporting GIS-based research and weather modelling, along with well-equipped workspaces for research scientists and support staff. To facilitate academic and training activities, the floor includes seminar rooms for workshops, lecture halls for students and visiting scholars, and a limited number of residential quarters to accommodate visiting researchers and trainees. Additionally, archives are available for the secure storage of research data and historical records. Beyond the main building, the institute is equipped with extensive field research plots used for experimental trials, varietal testing, studies on disease resistance, and irrigation efficiency experiments. This integrated and comprehensive infrastructure positions the institute as a leading centre for sugarcane research and development.

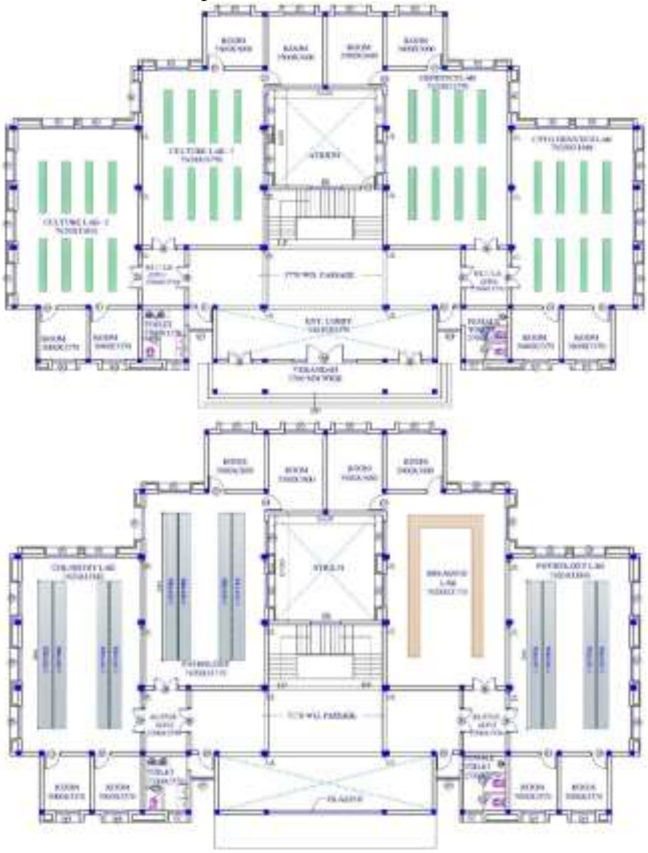

Figure 3: Ground & First Floor plan

The building is primarily constructed using brick masonry (First green Consulting, 2024), which provides robust and durable walls well-suited to the region's climatic conditions (Table 1). Reinforced cement concrete (RCC) is extensively employed in the structural framework, including floors, ceilings, and support elements, ensuring both stability and long-term durability. Large glass-paneled windows are a prominent feature of the institute's design, allowing abundant natural light to illuminate the interiors and thereby enhancing energy efficiency. Interior spaces are finished with plastered walls coated in weather-resistant paint to improve resilience and aesthetic appeal. The flooring consists mainly of ceramic or vitrified tiles, chosen for their smooth surface, ease of maintenance, and suitability for laboratory and research settings. The roofing is typically composed of RCC slabs enhanced with waterproofing layers to effectively handle

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seasonal rainfall. Furthermore, the building integrates modern features such as insulated panels for improved thermal regulation and the use of sustainable materials in select areas to align with environmentally responsible construction practices. Altogether, these architectural and material choices contribute to a functional, resilient, and visually appealing environment conducive to both research and administrative operations.

Table 1: Material Details

CLASS	IFC MATERIAL	QUANTITY	QTY_TYPE	THICKNESS_MM	COMMENT
FOUNDATION	RCC	104.1	M3		Foundation
WALL	Brick	54.1	M3		Foundation
EXTERNAL WALL	Brick	844.5	M2		Brick wall on superstructure
EXTERNAL WALL	Thick gang saw cut stone	541.6	M2	30	Dry cladding upto 10 metre heights on ground floor
INTERNAL WALL	Thick gang saw cut stone	459.8	M2		Dry cladding upto 10 metre heights on First floor
INTERNAL WALL	Thick gang saw cut stone	123.5	M2		Dry cladding upto 10 metre heights on Second floor
EXTERNAL WALL	Parapet	259.7	M2		Dry cladding upto parapet
COLUMN	RCC	53.2	M3		Floors
SLAB	RCC	35.8	M3		Floor
BEAM	RCC	60.9	M3		
STAIRS	RCC	7.0	M3		
OTHER	304 Stainless Steel Balustrade System	34.1	M		Stairs
OTHER	12 mm plaster mix (1:6)	706.6	M2		Ground floor
OTHER	12 mm plaster mix (1:6)	626.7	M2		First floor
OTHER	12 mm plaster mix (1:6)	84.5	M2		Second floor
OTHER	Granite Stone	95.4	M2		Granite stone for Kitchen platforms, vanity counters, window sills
OTHER	Stainless steel ((Grade 304)	230.3	KG		Window railing made of Hollow tubes, channels, plates
HORIZONTAL FINISH	Granite Stone Flooring	387.5	M2		Flooring
HORIZONTAL FINISH	Vitrified floor tiles	939.5	M2		Flooring
VERTICAL FINISH	Ceramic glazed wall tiles	153.2	M2		Ceramic glazed wall tiles on ground and first floor
VERTICAL FINISH	Acrylic emulsion paint	2870.8	M2		Wall painting with premium acrylic emulsion paint on all floor
VERTICAL FINISH	White cement based putty	2870.8	M2	1	White cement based putty on all floor
FINISH	Granite Stone	110.9	M2		Staircase
COVERING	Joint less ceramic tiles	1890.5	M2	18	Laboratory, corridors, toilet, pantry and utility areas for skirting
COVERING	Granite	51.8	M2		Stairs
COVERING	Metal Fall ceiling	724.2	M2		
SITE	Polycarbonate sheet	51.7	M2		Parking

4. LCA ANALYSIS AND RESULT

4.1 Impacts from life-cycle stages

Figure 4 illustrates the distribution of Global Warming Potential (GWP) across various life-cycle stages of a building, highlighting that the product stage demands the most attention for reducing environmental impact. The pie chart presented in the figure breaks down the total GWP in terms of kilograms of CO_2 equivalent (kg CO_2e) and reveals that the majority—93.8%—of emissions stem from the material production phase (A1–A3), which encompasses the extraction, processing, and manufacturing of raw materials. This stage is identified as the most carbon-intensive, underscoring the urgent need for interventions focused on sustainable material selection, low-carbon manufacturing techniques, and increased recycling. Other stages such as transport (A4) and construction (A5) contribute marginally to total GWP, with 0.9% and 4.4% respectively, while waste-related processes such as transport (C2), processing (C3), and disposal (C4) have negligible impacts, collectively contributing less than 1%. Notably, biogenic waste disposal (C4–balancing) shows no significant GWP contribution, indicating either efficient management or minimal carbon emissions during decomposition. These findings suggest that while some gains may be achieved through optimizing transport and construction practices, the most effective strategy for lowering GWP lies in reducing emissions during the early product stage. Emphasis on innovations in sustainable material science, energy-efficient production processes, and the adoption of circular economy

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principles will be critical in minimizing the environmental burden of the construction sector.

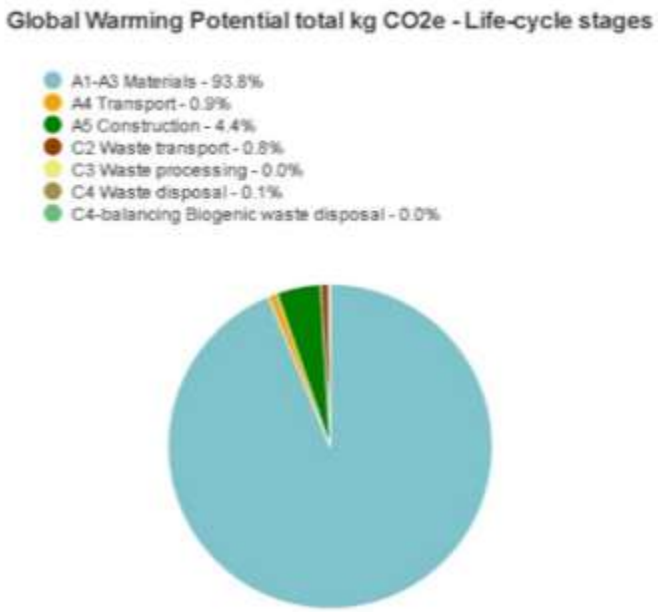

Figure 4: Distribution of GWP total kg CO_2-life-cycle stages
Source: One Click LCA results

4.2 Environmental impacts across different life-cycle stages

Figure 5 presents life-cycle impacts across various environmental metrics using stacked column graphs, where each environmental category—such as GWP fossil, GWP biogenic, water use, and others—is divided into individual life-cycle stages represented by distinct colors. The data shows that the A1–A3 material production phase dominates nearly all impact categories, particularly in Global Warming Potential (GWP) from fossil fuels, land use change (LUC), and overall GWP totals, emphasizing that material extraction and manufacturing are the primary sources of environmental burden. Interestingly, in the GWP biogenic category, A1–A3 stages exhibit negative values, reflecting the carbon sequestration properties of biogenic materials like wood, though this benefit is partially offset by positive emissions from the construction phase (A5). Other life-cycle stages such as C4 (waste disposal) and B6 (energy use) contribute modestly to environmental metrics like abiotic depletion of fossil resources (ADPF) and water consumption. Transport (A4) shows a moderate impact on ADPF and water use, indicating the environmental cost of moving construction materials. Waste transport (C2) and processing (C3) contribute negligibly across most impact categories. Notably, B6 energy use makes a significant contribution to water use, likely due to water-intensive energy production processes. Metrics such as ozone depletion potential (ODP-A2) and terrestrial eutrophication potential (EP-T) register relatively low impacts across all stages. From this analysis, it is clear that material production (A1–A3) is the most critical stage for intervention, and targeted efforts should focus on reducing emissions, energy usage, and resource depletion at this early phase. Utilizing biogenic materials can offer carbon-offsetting benefits if downstream emissions are controlled. Additionally, improving transportation efficiency, switching to cleaner energy sources, and optimizing waste disposal practices can contribute to lower overall environmental impact. Finally, integrating circular economy principles such as reuse and recycling will enhance sustainability throughout the life cycle of building materials.

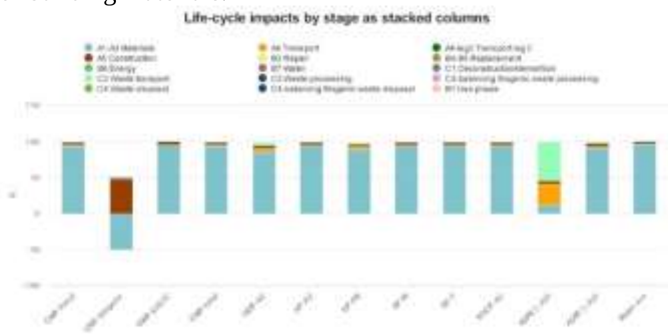

Figure 5: Distribution of environmental impacts across different life-cycle stages
Source: One Click LCA results

4.3 Distribution of GWP total kg CO_2e–Resource type

Figure 6 illustrates the Global Warming Potential (GWP) contributions, measured in total kilograms of CO_2 equivalent (kg CO_2e), by various resource types through a pie chart with percentage shares labelled in the legend. Cement emerges as the dominant contributor, accounting for 52.9% (Porchelvan & Rajasekharan, 2023) of total emissions, which is attributed to the highly carbon-intensive production process involving substantial energy consumption and CO_2 release during limestone calcination. Structural steel and steel profiles follow as the second-largest source at 28.6%, largely due to the energy demands of smelting and processing operations. Ready-mix concrete used in structural components and foundations collectively contributes around 10.5% to GWP, reflecting its extensive application in construction. Aluminium, despite its smaller volume, contributes 3.2% owing to the energy-intensive electrolysis process involved in its production. Other materials such as wall and floor tiles (1.9%), common clay bricks (1.4%), and renewable energy systems (0.7%) make relatively minor contributions, while gypsum board (0.3%) and miscellaneous resources (0.5%) account for negligible emissions.

The analysis underscores that cement and steel together are responsible for over 80% of the total GWP, signalling that decarbonization efforts must prioritize these materials. Innovations such as low-carbon cement alternatives, the adoption of recycled steel, and carbon capture technologies offer potential pathways for significant emission reductions. Although concrete and aluminium contribute less individually, their cumulative impact warrants attention, with strategies focusing on energy-efficient production and circular economy models. While minor resource types have limited GWP contributions, the adoption of eco-friendly substitutes can still support broader emission mitigation efforts. A comprehensive approach that prioritizes high-impact materials while promoting sustainability across all resource types will be essential for achieving meaningful reductions in the construction sector's environmental footprint.

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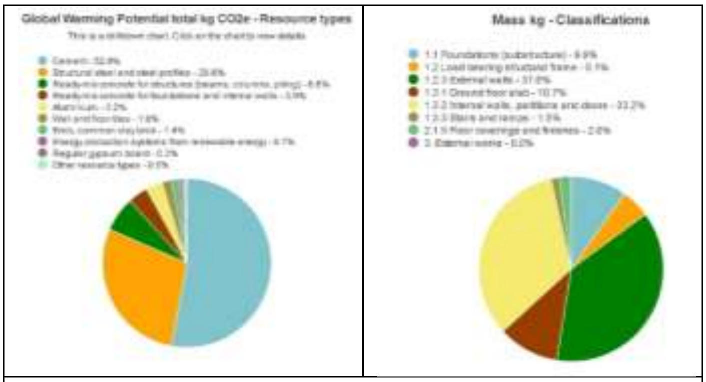

Figure 6: Distribution of GWP total kg CO_2e–Resource type and Mass kg-Classification
Source: One Click LCA results

4.4 Impacts from building elements

Figure 7 presents the Global Warming Potential (GWP), expressed in total kilograms of CO_2 equivalent, for various building classifications based on their contribution to environmental impact. The analysis reveals that internal walls, partitions, and doors are the most significant contributors, accounting for 44.5% of the total GWP, closely followed by external walls at 43.2%. Collectively, these two elements dominate the environmental burden, comprising 87.7% of the overall emissions. Other components such as foundations (2.6%), floor coverings and finishes (3.7%), and the ground floor slab (3.2%) contribute modestly, while load-bearing structural frames (1.4%), stairs and ramps (0.7%), and external works (0.7%) register minimal impacts.

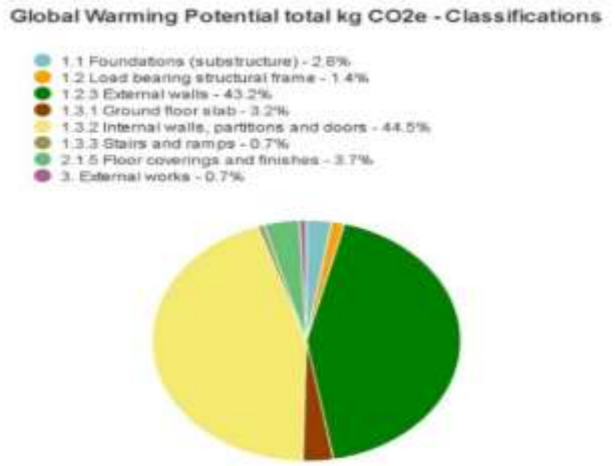

Figure 7: Distribution of GWP total kg CO_2e–classifications
Source: One Click LCA results

This uneven distribution clearly indicates that internal and external walls are the most carbon-intensive components within building construction. The relatively negligible contributions from elements like stairs and external works suggest that targeted emission reduction strategies should focus primarily on the major contributors. Consequently, implementing low-carbon alternatives and sustainable construction practices for internal and external wall systems presents a significant opportunity to reduce the environmental footprint of buildings and achieve meaningful progress toward climate-resilient construction.

4.5 Sankey diagram

The Sankey diagram visualizes the Global Warming Potential (GWP) contributions across various building components, material types, and life-cycle stages, effectively illustrating how emissions flow from material production (A1–A3), construction (A5), and transport (A4) into different building classifications such as internal walls, external walls, and foundations. Among these, internal walls, partitions, and doors emerge as the largest contributors to GWP, primarily due to the extensive use of cement—a material known for its high carbon footprint. External walls follow closely, with their emissions largely driven by structural steel, steel products, and ready-mix concrete. While cement dominates the emissions profile for internal partitions, steel and concrete are the primary culprits for external walls and foundations. Contributions from other materials and processes are comparatively minor, and categories such as floor finishes and substructure foundations exhibit relatively low impacts. Furthermore, the transport (A4) and construction (A5) phases play a lesser role in overall emissions when compared to material production, reinforcing the critical importance of the A1–A3 stage in the life cycle (Figure 8).

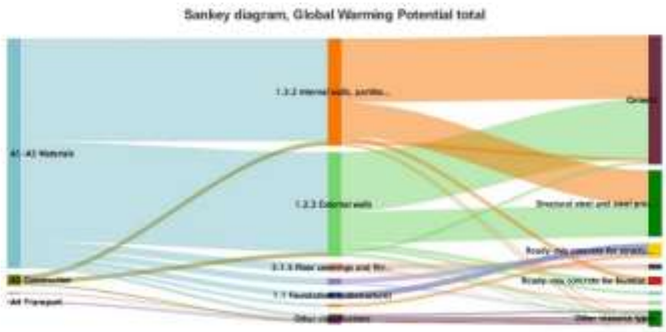

Figure 8: Embodied carbon breakdown by key building elements (Sankey diagram)
Source: One Click LCA results

The analysis underscores that meaningful reductions in GWP can be achieved by focusing on the largest impact areas—namely internal and external walls—through the adoption of low-carbon materials, improved design choices, and sustainable construction practices. Although emissions from transport and construction are modest, optimizing these phases can further enhance sustainability outcomes in the built environment.

4.6 Life cycle Stage

The tree map and life-cycle stage analysis clearly indicate that the A1–A3 materials production phase is the dominant contributor to Global Warming Potential (GWP) and other environmental impacts, accounting for nearly the entirety of emissions across various indicators. Cement emerges as the largest single contributor within this phase, followed by structural steel and steel profiles, both of which involve carbon-intensive manufacturing processes. Ready-mix concrete also contributes significantly—particularly for structural and foundational elements—though to a lesser extent than cement and steel. Other materials such as aluminum, gypsum board, natural stone, and wall and floor tiles play a relatively minor role in GWP (Figure 9).

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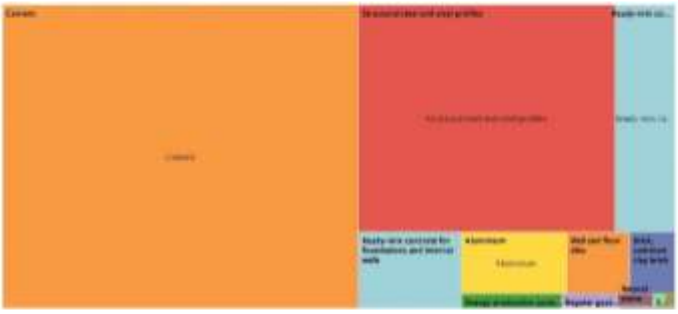

Figure 9: Resource type- Subtype (Over whole life cycle)
Source: One Click LCA results

The A4 transport and A5 construction phases, contribute far less to total emissions, reinforcing the need to focus intervention efforts on the earlier production stages. Waste-related phases like C2 transport and C3/C4 processing and disposal also register minimal environmental impact, although C2 transport shows a noteworthy contribution to ADPF (Abiotic Depletion of Fossil Fuels), suggesting high energy use. The C3-balancing and C4-balancing phases are negligible in their influence. Given these findings, the most effective strategies for environmental impact reduction in the construction sector involve targeting the A1–A3 material production phase—specifically through the adoption of low-carbon cement alternatives, increased recycling and reuse of steel, and the promotion of sustainable building materials (Figure 10). While optimizing transport, construction, and waste management phases may offer additional gains, focusing on material choice and production methods will yield the greatest reduction in overall environmental burdens.

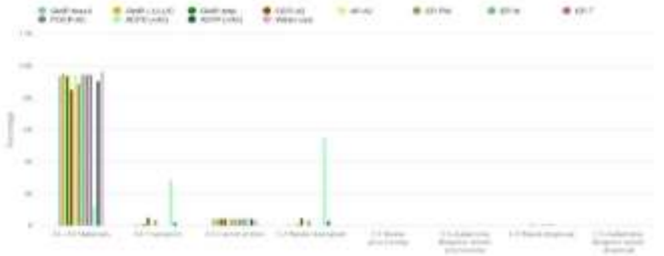

Figure 10: Result by Life –Cycle Stage
Source: One Click LCA results

4.7 Spider gram grouped by Building Parts breakdown

The radar chart highlights the environmental impacts across different building components, with **Load bearing structural frame (1.2)** showing the highest contributions across most impact categories such as **GWP-fossil, GWP-total,** and **ADPF (+A2).** This indicates that structural frames are a major source of energy and resource consumption. Other elements like **External walls (1.2.3)** and **Floor coverings and finishes (2.1.5)** also show notable impacts, particularly in specific categories like **GWP-biogenic** and **POCP-A2.** Comparatively, **Foundations (1.1)** and **External works (3)** contribute less across all indicators. Overall, the chart emphasizes the need to focus on reducing environmental impacts from load-bearing structural frames and external walls to achieve significant improvements in building sustainability (Figure 11).

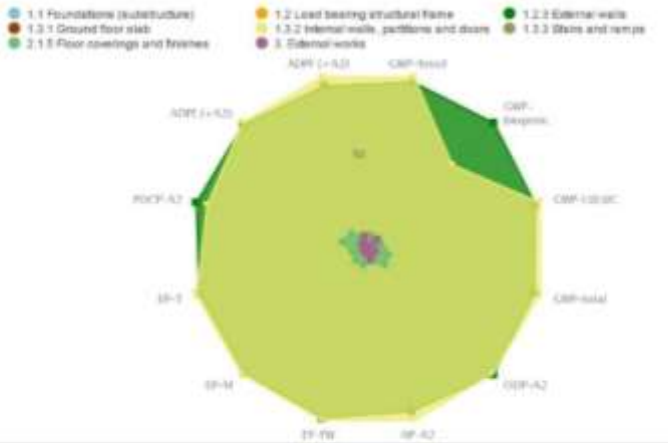

Figure 11: Spider gram grouped by Building Parts breakdown
Source: One Click LCA results

4.8 Life- Cycle impacts by martial as Stacked Columns

The bar chart (Figure 12) highlights that Portland cement and structural steel profiles are the leading contributors to environmental impacts across categories like GWP-fossil, GWP-total, ADPF (+A2), and EP-M, due to their high energy and resource demands. Materials such as ready-mix concrete, fiber-reinforced cement plaster, and ceramic glazed tiles show moderate impacts, while photovoltaic panels notably contribute to GWP-biogenic, indicating carbon offset benefits. The negative values for GWP-biogenic reflect carbon sequestration from renewable or biogenic materials. Overall, the chart underscores the need to reduce reliance on high-impact materials and enhance the use of sustainable alternatives.

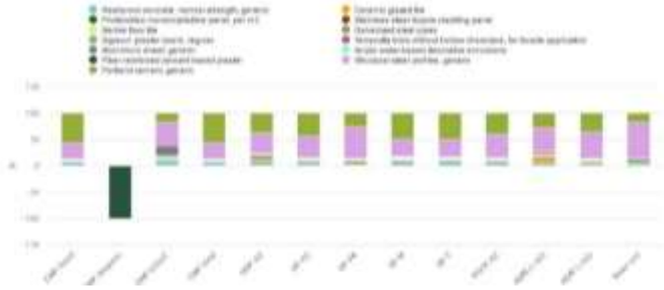

Figure 12: Life- Cycle impacts by martial as Stacked Columns
Source: One Click LCA results

4.9 Global Warming Potential (GWP-total) grouped by building parts breakdown.

The bar graph (Figure 13) illustrates the CO_2 emissions (kg CO_2e) across various construction components, categorized by stages like materials (A1-A3), construction (A5), transport (A4), repair (B3), replacement (B4-B5), waste processes (C2, C3, C4), and biogenic balancing (C4-balancing, C3-balancing). External walls (1.2.3) and internal walls, partitions, and doors (1.3.2) are the largest contributors, each emitting over 800,000 kg CO_2e, predominantly from materials (A1-A3). Other components, including foundations, structural frames, floor slabs, stairs, floor coverings, and external works, exhibit comparatively lower emissions. The green sections (A5 Construction) and minor contributions from repair and waste stages indicate their marginal role in total emissions compared to material usage. This suggests that

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material production plays the most significant role in the overall carbon footprint of construction activities.

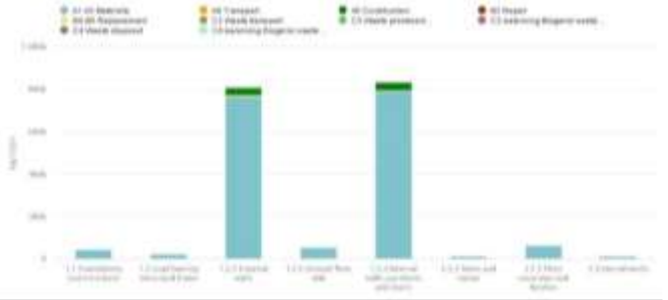

Figure 3: Global Warming Potential (GWP-total) grouped by building parts breakdown
Source: One Click LCA results

4.10 Environmental Impact of Building Elements on Abiotic Depletion and Energy Consumption

Figure 14 analyzing abiotic depletion potential (ADP) and fossil fuel energy consumption (ADPF) across various building elements reveal that external walls (1.2.3) and internal walls, partitions, and doors (1.3.2) are the most environmentally impactful components. In terms of acidification potential (measured in kg SO_2 equivalent), these two categories show the highest values—approximately 80 kg SO_2 eq. and 70 kg SO_2 eq., respectively—driven largely by C2 Waste Transport and A4 Transport stages, with additional but lesser contributions from material production (A1–A3) and construction (A5).

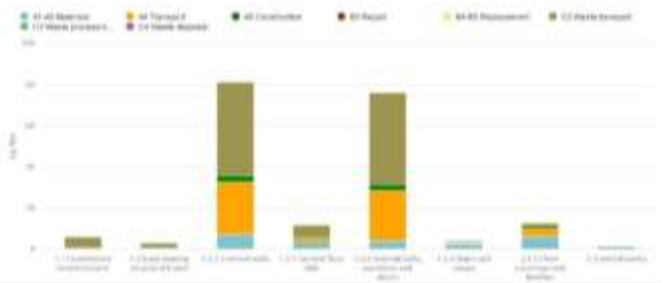

Figure 14: Abiotic depletion potential (ADP-elements) for non-fossil resources (+A2) (AFPE(+A2)) grouped by building parts breakdown
Source: One Click LCA results

Similarly, in terms of fossil fuel depletion (measured in mega joules), both elements exceed 6 million MJ, with the bulk of the energy demand stemming from the A1–A3 materials stage. Other building components, such as foundations, load-bearing frames, ground floor slabs, and floor finishes, exhibit comparatively lower environmental burdens, though they still rely heavily on material production for their energy input. These findings underscore the urgent need to minimize emissions from transportation stages and to adopt low-energy, sustainable materials for walls—interventions that can significantly reduce the overall environmental footprint of buildings (Figure 15).

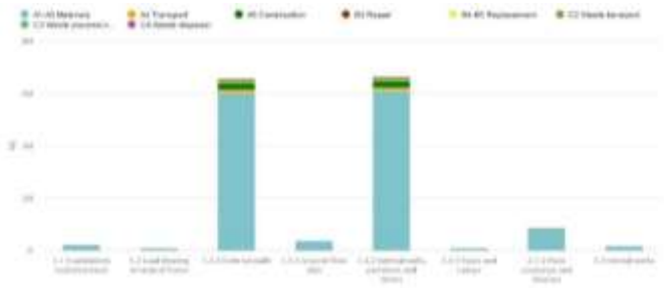

Figure 15: Abiotic depletion potential (ADP-fossil fuels) for fossil resources (+A2) (ADPF(+A2)) grouped by building parts breakdown
Source: One Click LCA results

4.11 Water use (water use) grouped by Building Parts breakdown

Figure 16 illustrates the water consumption of various building components, measured in cubic meters deprived (m^3 deprived), across multiple lifecycle stages. The analysis shows that external walls (1.2.3) and internal walls, partitions, and doors (1.3.2) are the highest consumers of water, each exceeding 200,000 m^3 deprived. This substantial impact is primarily attributed to the A1–A3 materials production stage, with minimal additional contributions from A5 construction and other lifecycle stages such as transport, repair, and disposal. In contrast, other building elements—including foundations, load-bearing structural frames, ground floor slabs, and floor coverings—display significantly lower water usage, though the materials stage still accounts for the majority of their impact. These findings emphasize the critical role that material selection plays in water depletion, particularly for high-volume components like walls. To reduce the overall water footprint of building construction, it is essential to adopt water-efficient manufacturing practices and explore alternative, less water-intensive materials.

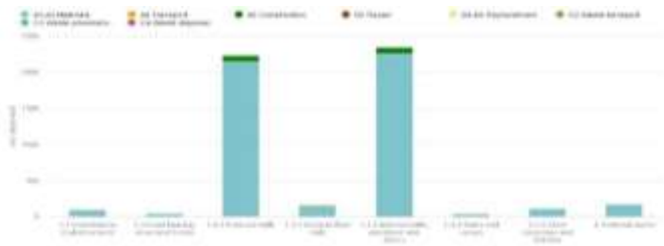

Figure 16: water use (water use) grouped by Building Parts breakdown
Source: One Click LCA results

5. CONCLUSIONS

The results emphasize the importance of material choice in reducing building-related emissions. Low-carbon cement alternatives, recycled steel, and sustainable material innovations (Kansal et al., 2021) can significantly lower impacts. Circular economy strategies like design for disassembly and recycling (Alliance for an Energy Efficient Economy, 2021) are also essential. Indian green building policies like GRIHA can be strengthened with LCA-based guidelines for material use (GRIHA Council, 2024).. For example, GRIHA ratings could give additional credit for using low-embodied-carbon materials or for demonstrating material reuse.

The Life-Cycle Assessment (LCA) results emphasize the paramount importance of the material production stage (A1–A3) in contributing to the overall environmental impacts of buildings, particularly in terms of Global Warming Potential (GWP). Cement and structural steel stand out as the most carbon-intensive materials, accounting for 52.9% and 28.6% of total GWP, respectively (Porchelvan & Rajasekharan, 2023) — together responsible for over 80% of a building's embodied carbon

The analysis also identifies internal and external wall systems as the primary emission hotspots, contributing 44.5% and 43.2% of the building's GWP, respectively. These components dominate the environmental footprint, signalling a need for interventions in material selection, construction methods, and design strategies (e.g., using alternative wall materials, optimizing wall thickness, incorporating insulation). In contrast, the construction (A5) and transport (A4) stages have comparatively smaller impacts on GWP — 4.4% and 0.9% respectively — though they still influence fossil fuel depletion and water consumption. Therefore, while the greatest gains come from material-level improvements, incremental benefits can be achieved by optimizing logistics (shorter transport distances, efficient vehicles), adopting cleaner construction practices (electric or biodiesel equipment), and improving on-site waste management.

Additionally, biogenic materials such as sustainably sourced timber offer potential carbon sequestration benefits during the production stage, but downstream processes like construction and demolition can offset these advantages. Careful life-cycle accounting is necessary to ensure that purported carbon storage is not double-counted or negated (e.g., by land-use impacts or disposal practices). Waste-related stages (C2–C4) contribute minimally to GWP, yet should not be neglected; increasing the recycling and reuse of construction and demolition waste will conserve resources and avoid landfill emissions.

Overall, a holistic, multi-faceted approach is essential for transforming the construction sector. This includes material innovation (developing and using low-embodied-carbon alternatives), circular economy principles (recycling, reuse, and design for deconstruction), and life-cycle optimization (improving efficiency at every stage). Collaborative efforts among government, industry, and research institutions will be needed to implement these strategies effectively. By prioritizing high-impact materials and integrating LCA insights into policy and design, India can significantly reduce the environmental footprint of its building stock and advance toward its sustainability and climate goals.

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