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ADAPTIVE FACADES AND SMART BUILDING SKINS FOR ENERGY EFFICIENCY: A STUDY FOR MATERIALS PERFORMANCE AND SUSTAINABLE DESIGN PROCESSES

Muhammad Hammad Faiq[1], Haffi Hassan[2], Maham Zainab[2], Syeda Mahwish Zahra[3], Syyed Adnan Raheel Shah[1*]

[1] Department of Civil Engineering, NFC Institute of Engineering and Technology, Multan 66000, Pakistan.
[2] Department of Architecture Design, NFC Institute of Engineering and Technology, Multan 66000, Pakistan.
[3] Laboratory of Materials, Department of Architecture Design, NFC Institute of Engineering and Technology, Multan 66000, Pakistan.

Abstract

The building aesthetic values known as facades which is a material treatment and known as one of the most challenging components of building. It also controls the indoor heating and cooling of building in the tropical climate areas and areas where temperature is below than 0°C. In hot climate areas, during summer season temperature reaches about 40°C-60°C. A well designed exterior of building reduces heat absorption up to 50-60%. This research helps to improve thermal performance and reduce necessity to use artificial light in building during daytime. Natural air circulation in buildings play key role in thermal performance and reduces reliance on artificial cooling at daytime and at night time. Bricks and concrete blocks made with local materials like industrial waste are atmosphere friendly to reduce carbon footprints. With proper texture of bricks and concrete blocks almost reflects 50% of sunlight. The sustainability design of buildings is suitable for tropical regions. Simultaneously, four different parametric building models have been developed in Revit, two for hot and two for cold climates, incorporating other advanced passive design strategies such as optimized orientation, thermal mass integration, and adaptive insulation techniques helps us to analyses the results of better performance. The results of this study offer keen observation for professionals who want to enhance the performance of the sustainable structure design process.

Introduction

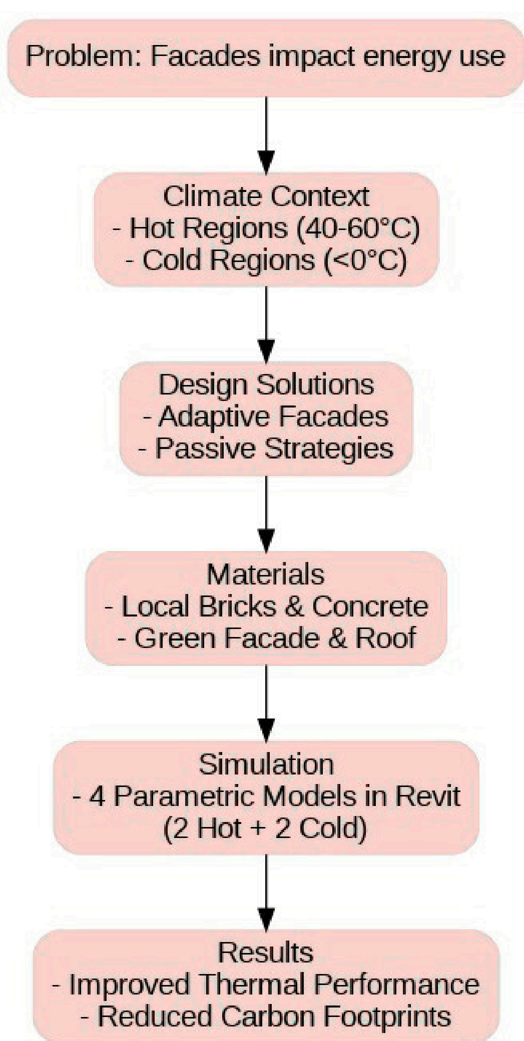
The Thermal envelope, particularly façades and roofs, is a key factor influencing energy efficiency, indoor climate comfort, and collective sustainability performance. In tropical regions, where summer temperatures range from 40 to 60°C, and in cold climates, where temperatures drop below 0°C, inadequately designed façades result in excessive reliance on artificial cooling and heating. This report explains the concept of carbon footprint and then highlights bright building skins as sustainable solutions to reduce energy demand and carbon emissions. By incorporating eco-friendly materials such as locally manufactured bricks and green façades and roofs, the design approach aims to balance thermal performance with aesthetic and environmental goals. Results from energy modeling software show that Material-related carbon emissions account for considerably more (23,875 kg CO_2e; 75.9%) compared to operational carbon (7,598 kg CO_2e; 24.1%), highlighting the importance of material choices and cladding strategies in minimizing lifecycle carbon effects. The use of natural materials and vegetation helps reflect heat from the surroundings, providing an efficient roofing system that reduces heat absorption, which is beneficial in the Summer. This study covers the potential of integrating passive design and optimizing materials to enhance building performance while reducing reliance on non-renewable energy sources.

METHODOLOGY, RESULTS & ANALYSIS

THEME

This research work aligns with SDG 7 (Affordable and Clean Energy), SDG 11 (Sustainable Cities and Communities), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 13 (Climate Action). By innovating energy-efficient design, encouraging the use of sustainable local materials, reducing carbon emissions, and supporting climate resilience, one can develop nature-integrated structures that foster sustainable growth.

METHODOLOGY



RESULTS & ANALYSIS

Table 1. Carbon breakdown of the building model

Category	Value(kgCO₂e)	Percentage(%)
Total Carbon	31473.81	100.0
Embodied Carbon	23875.26	75.9
Operational Carbon	7598.56	24.1

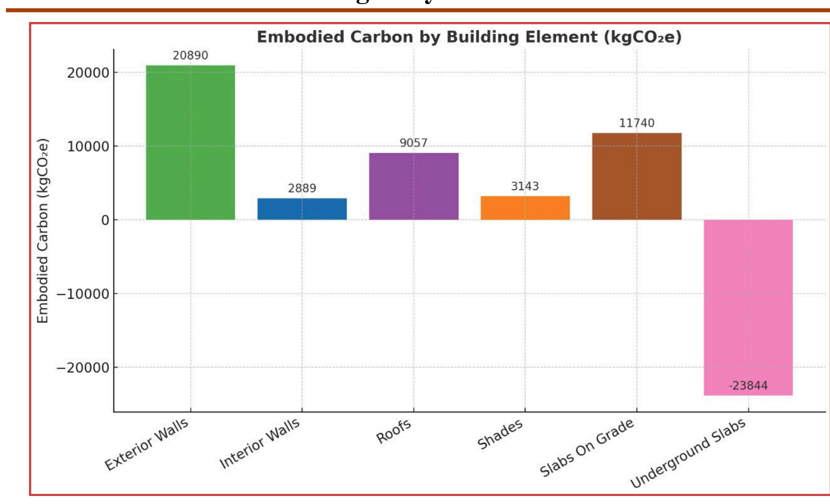
Presents a comprehensive breakdown of carbon, showing that embodied carbon is the dominant share, approximating operational emissions.

Presents

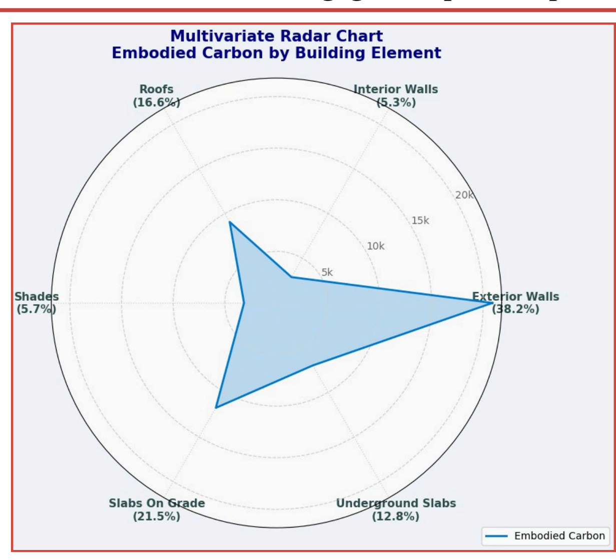
Table 2. Carbon breakdown by building elements

BuildingElement	Value(kgCO₂e)
Exterior Walls	20889.94
Interior Walls	2889.04
Roofs	9057.24
Shades	3143.23
Slabs on Grade	11740.11
Underground Slabs	7000.0

Displays the distribution of embodied carbon across different building components. Exterior walls and slabs on grade are identified as the highest contributors, highlighting the vital role of material choices in reducing lifecycle emissions.



The chart illustrates the distribution of embodied carbon across distinct building elements, with exterior walls and slabs on grade emerging as the most effective contributors. In contrast, interior walls and shades show the most negligible impact comparatively.



Exterior walls (38.2%) and slabs on grade (21.5%) = highest carbon share.
Interior walls (5.3%) and shades (5.7%) = lowest carbon share.

CONCLUSION

- Façades and roofs play an important role in structural energy efficiency and overall sustainability.
- Material-related carbon emissions exceed functional carbon emissions, underscoring the importance of making informed material selections.
- The use of luminous façades, reflective exteriors, eco-friendly local materials, and sustainable design processes (e.g., insulation, green exteriors) enhances indoor environmental quality and reduces energy demand.
- By using this combination, The Structure is environmentally friendly and fulfills all Sustainability Goals

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