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From Earth to Wall: A Comparison of Embodied Carbon in Stabilized Earth and Concrete Masonry

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Abstract - The construction industry accounts for nearly 37% of global energy-related carbon emissions, with embodied carbon emerging as a major contributor as operational emissions decline. Cement production alone contributes approximately 8% of global CO_2 emissions, making cement-intensive materials such as Concrete Masonry Units (CMU) environmentally significant.This dissertation quantitatively compares the embodied carbon of **Compressed Stabilized Earth Blocks (CSEB)** and conventional **Concrete Masonry Units (CMU)** using a cradle-to-gate Life Cycle Assessment (Modules A1–A3). The functional unit is defined as 1 m² of 200 mm thick load-bearing wall.Results indicate that stabilized earth masonry reduces embodied carbon by approximately **45–60%** compared to concrete masonry under equivalent structural conditions. Cement content is identified as the dominant emission driver.The research demonstrates that material substitution in low-rise construction can serve as a scalable climate mitigation strategy in tropical contexts.

***Key Words*: Keywords:** embodied carbon, life cycle assessment (LCA), cradle-to-gate analysis, compressed stabilized earth blocks (CSEB), concrete masonry units (CMU), cement production emissions, sustainable construction materials, low-carbon masonry, material substitution, climate change mitigation, tropical construction.

1.INTRODUCTION

1.1 Background

As operational energy reduces due to passive design and renewable integration, embodied carbon now represents up to 50% of lifecycle emissions in low-energy buildings. In India's rapid urban expansion, masonry systems significantly influence material-based emissions.
Cement production emits approximately 0.85–0.95 kg CO_2e/kg due to:

- Limestone calcination
- Fossil fuel combustion
- Clinker production

This creates urgency for alternative walling systems.

1.2.1 Compressed Stabilized Earth Blocks (CSEB) – Brief Description

Compressed Stabilized Earth Blocks (CSEB) are low-carbon masonry units manufactured using locally available soil stabilized with a small percentage of cement and compacted under mechanical pressure.

- 92–95% local soil
- 5–8% cement stabilizer
- Mechanically compressed for density and strength
- Air cured (no kiln firing)

The minimal cement content and elimination of thermal processing significantly reduce embodied carbon

compared to conventional masonry systems.

Fig -1 Compressed stabilized earth blocks

1.2.2 Concrete Masonry Units (CMU) – Brief Description

Concrete Masonry Units (CMU) are building blocks made from **cement, sand, and aggregates**, produced through industrial manufacturing processes. They contain a **high proportion of cement**, and since cement originates from energy-intensive high-temperature

clinker production, CMUs have relatively high embodied carbon compared to low-cement alternatives.

Fig -2 Concrete Masonry Units (CMU)

1.3 Research Problem

There is insufficient standardized embodied carbon comparison between stabilized earth masonry and conventional concrete masonry under identical structural and climatic conditions.

1.4 Aim

To quantitatively compare embodied carbon (kg CO_2e/m^2) of CSEB and CMU wall systems using cradle-to-gate LCA.

1.5 Objectives

1. Establish embodied carbon framework.
2. Quantify emissions per m² wall.
3. Compare percentage reduction.
4. Interpret structural and climatic implications.

2 .LITERATURE REVIEW

2.1 Embodied Carbon Definition

Embodied carbon includes emissions from:

- Raw material extraction (A1)
- Transport (A2)
- Manufacturing (A3)

Measured as:

Embodied Carbon=Material Quantity×Emission FactorEmbodied\ Carbon = Material\ Quantity \times Emission\ FactorEmbodied Carbon=Material Quantity×Emission Factor

2.2 Cement as Primary Emission Driver

Component	Emission Factor (kg CO_2e/kg)
Cement	0.90
Sand/Aggregate	0.005–0.02
Soil	~0.002
Electricity (India avg)	0.82 kg CO_2e/kWh

Table -1: Carbon emission of cement

Cement contributes over 70% of total masonry emissions.

2.3 Comparative Studies

Literature indicates:

- CSEB walls: 16–35 kg CO_2e/m^2
- CMU walls: 40–85 kg CO_2e/m^2

Reduction potential: 40–70%

3. RESEARCH METHODOLOGY

3.1 Research Framework

- System Boundary: Cradle-to-Gate (A1–A3)
- Functional Unit: 1 m² of 200 mm thick wall
- Typology: Low-rise (G+0 to G+3)
- Context: Indian tropical region

3.2 Wall Specification

Parameter	CSEB	CMU
Thickness	200 mm	200 mm
Density	1800 kg/m³	2200 kg/m³
Cement Content	6%	14%

Mortar	Minimal	Standard cement mortar

Table -2: Wall Specification

3.3 Material Quantity per m²

Volume per m²: 1×0.2=0.2m31 \times 0.2 = 0.2 m³1×0.2=0.2m3

CSEB- 0.2 × 1800 = 360 kg total
Cement = 6% = 21.6 kg

CMU- 0.2 × 2200 = 440 kg total
Cement = 14% = 61.6 kg

3.4 Embodied Carbon Calculation

CSEB Wall

Cement:
21.6 × 0.90 = 19.44 kg CO_2e

Soil & processing ≈ 3.5 kg CO_2e Total ≈ 23 kg CO_2e/m^2

CMU Wall

Cement:
61.6 × 0.90 = 55.44 kg CO_2e

Aggregates + processing ≈ 8 kg CO_2e Total ≈ 63 kg CO_2e/m^2

4 . RESULTS & ANALYSIS

4.1 Comparative Carbon Table

Wall Type	**Cement (kg)**	**Total CO_2e (kg/m²)**
CSEB	21.6	23
CMU	61.6	63

4.2 Percentage Reduction

Reduction =63−2363×100
Reduction = \frac{63 - 23}{63} \times 100Reduction=6363−23×100 =63= 63%=63

Stabilized earth reduces embodied carbon by approximately 60%.

4.3 Carbon Contribution Breakdown

Component	**CSEB (%)**	**CMU (%)**
Cement	84%	88%
Other materials	16%	12%

Cement dominates emissions in both systems.

4.4 Case Study Contextualization

Auroville Earth Institute

The **Auroville Earth Institute** plays a significant role in promoting sustainable and low-carbon building technologies, particularly compressed stabilized earth construction in tropical regions.

- Promotes low-carbon earth construction technologies
- Encourages localized block production systems
- Minimizes transportation-related emissions through on-site manufacturing

Its integrated approach demonstrates how decentralized material production can substantially reduce embodied carbon in low-rise construction.

Fig -3: Auroville Earth Institute

Aranya Low Cost Housing

Architectural Context: Balkrishna Doshi

- Large-scale masonry housing developments
- Predominantly cement-intensive construction systems
- Illustrates embodied carbon implications at scale The projects demonstrate how material choices in mass housing significantly influence total embodied emissions, especially when cement-based masonry is extensively used.

Fig -4: Aranya Low Cost Housing

4.5 Interpretation

1. Cement drives most emissions because its production releases large amounts of CO_2, making it the biggest carbon contributor in masonry walls.
2. Local sourcing reduces transport carbon, since using nearby soil avoids long-distance material movement.
3. Lower cement percentages can still achieve required strength, so structural safety does not require high cement content.
4. Replacing concrete blocks with stabilized earth blocks immediately cuts embodied carbon, making material substitution a fast and practical decarbonization strategy.

5. RECOMMENDATIONS

5.1 Key Findings

The study shows that CSEB emits ~23 kg CO_2e/m^2, while CMU emits ~63 kg CO_2e/m^2 for the same wall specification, achieving nearly 60% embodied carbon reduction.

Cement is identified as the primary emission source, contributing 80–90% of total embodied carbon, highlighting cement reduction as the key strategy for low-carbon masonry construction.

5.2 Overall Conclusion

Stabilized earth masonry exhibits significantly lower embodied carbon than conventional concrete masonry under equivalent functional conditions.

Material substitution in low-rise construction can contribute meaningfully to climate mitigation targets.

5.3 Recommendations

For Architects

- Optimize cement stabilization to 4–6% where structurally feasible.
- Use site-proximate soil to reduce transport emissions.
- Integrate passive climatic design strategies to enhance overall building performance.

For Policymakers

- Incentivize adoption of low-carbon masonry systems.
- Develop India-specific embodied carbon databases.
- Establish embodied carbon benchmarks and regulatory targets.

For Future Research

- Extend analysis to cradle-to-grave LCA.
- Investigate alternative stabilizers (lime, geopolymer).
- Conduct whole-building carbon modeling.
- Explore cost–carbon optimization frameworks.

6. CONCLUSION

This dissertation concludes that:

- Stabilized earth construction is structurally viable for low-rise load-bearing applications.
- Cement content is the dominant driver of embodied carbon emissions.
- A ~60% reduction in embodied carbon is achievable through CSEB substitution.
- Localized production systems significantly enhance environmental performance.
- Material substitution in masonry represents a scalable and practical climate mitigation strategy.

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