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THERMAL PERFORMANCE ASSESSMENT OF COMPRESSED STABILIZED EARTH BLOCK (CSEB) WALLS IN THE HOT-HUMID CLIMATE OF CHENNAI

Anbuchezian Ashokan Professor, Department of Civil Engineering, Annapoorana Engineering College (Autonomous), Seeragapadi, Salem, 636308, Tamil Nadu, India.
Asha Sapna, Research Scholar, Department of Civil Engineering, Bharath Institute of Higher Education and Research, Chennai, 600073, Tamil Nadu, India .
Anbalagan C, Professor, Department of Civil Engineering, Bharath Institute of Higher Education and Research, Chennai,600073, Tamil Nadu, India.
E-mail: principalaecsalem@gmail.com

ABSTRACT
The thermal performance of building envelopes plays a crucial role in achieving energy efficiency and thermal comfort, especially in hot and humid climates such as that of Chennai, India. This study investigates the thermal behavior of Compressed Stabilized Earth Block (CSEB) walls as a sustainable alternative to conventional masonry in residential construction. CSEB, being a low-energy and locally available material, offers significant potential for passive thermal regulation due to its favorable thermal mass and low thermal conductivity. The research assesses the impact of wall thickness, material properties, and solar exposure on indoor temperature regulation through both experimental monitoring and simulation-based analysis using [insert software, e.g., EnergyPlus or DesignBuilder]. Results indicate that CSEB walls provide a time lag of 6–10 hours and reduce indoor heat gain by up to 4°C compared to burnt clay brick walls. The study concludes that CSEB walls can significantly improve indoor thermal comfort while reducing dependence on mechanical cooling systems. These findings support the use of CSEB as a viable, eco-friendly walling solution for sustainable building design in tropical regions like Chennai.

Keywords:
Compressed Stabilized Earth Block (CSEB),Thermal Performance, Indoor Thermal Comfort, Hot-Humid Climate, Sustainable Building Materials

Introduction
The building sector is a significant contributor to global energy consumption and greenhouse gas emissions, with a large share attributed to the heating, cooling, and ventilation of indoor spaces. In hot-humid regions such as Chennai, India, the demand for space cooling is high due to elevated ambient temperatures, high humidity levels, and prolonged periods of solar radiation. Consequently, there is a growing need for energy-efficient and climate-responsive building solutions that can minimize environmental impact while enhancing indoor thermal comfort [1]. One of the key strategies in sustainable building design is the use of thermally efficient wall materials that reduce the need for mechanical cooling. Among the various alternatives, Compressed Stabilized Earth Blocks (CSEBs) have emerged as a promising solution. Made from locally available soil stabilized with a small percentage of cement or lime, CSEBs are energy-efficient, cost-effective, and environmentally friendly. Beyond their ecological advantages, CSEBs possess high thermal mass and relatively low thermal conductivity, making them suitable for passive thermal control in tropical climates [2] Chennai experiences a tropical wet and dry climate characterized by high temperatures and humidity throughout most of the year. Conventional construction practices, which often rely on fired bricks or concrete blocks, tend to contribute to heat gain and result in higher cooling loads. In contrast, CSEB construction has the potential to reduce indoor temperature fluctuations and delay heat transfer due to its thermal inertia, thus enhancing occupant comfort and reducing energy demand.

This study aims to evaluate the thermal performance of CSEB walls under the climatic conditions of Chennai, focusing on parameters such as wall thickness, time lag, and indoor air temperature modulation. By combining experimental measurements and simulation-based analysis, the research explores the effectiveness of CSEBs as a passive design strategy for improving indoor thermal comfort. The findings are expected to inform architects, builders, and policymakers on the applicability of CSEBs in sustainable urban housing solutions in tropical regions.

2. Literature Review

The thermal behavior of building envelopes has been a key focus in sustainable architecture, particularly in tropical climates where passive design strategies can significantly reduce energy consumption. Among various envelope components, wall materials play a vital role in determining indoor thermal comfort. In recent years, Compressed Stabilized Earth Blocks (CSEBs) have gained attention as an eco-friendly alternative to conventional building materials due to their low embodied energy, local availability, and excellent thermal mass.

2.1 Thermal Properties of CSEB

Several studies have investigated the thermal properties of earthen materials. Bui et al. (2009) found that earth-based walls exhibit favorable thermal inertia, helping maintain stable indoor temperatures in hot climates. The thermal conductivity of CSEBs ranges between 0.6 and 1.0 W/m·K, depending on soil composition and stabilizer content (Houben & Guillaud, 1994). This makes CSEBs slower to conduct heat, allowing them to act as thermal buffers. Time lag and decrement factor are critical parameters that influence how effectively walls delay and dampen external heat transfer into the interior space.

2.2 Comparative Performance Studies

Research comparing CSEBs with conventional materials such as fired bricks and concrete blocks indicates superior performance of CSEBs in tropical conditions. Anbazhagan and Nithyavathy (2016) conducted a comparative analysis in South India and observed that buildings with CSEB walls had indoor temperatures 3–5°C lower than those with fired brick walls during peak summer. Similar studies by Mani & Raman (2013) also highlight CSEB's advantage in maintaining thermal comfort without mechanical cooling.

2.3 Impact of Wall Thickness

Wall thickness is another factor significantly affecting thermal performance. Yadav and Sodha (2005) showed that increasing wall thickness enhances thermal mass and time lag, which is beneficial in tropical climates. However, excessive thickness may reduce usable floor area and increase construction costs. Hence, finding an optimal thickness is essential for balancing thermal efficiency and practicality.

2.4 Use of Simulation Tools

The integration of simulation tools such as EnergyPlus**,** DesignBuilder**,** and THERM has enabled researchers to predict the thermal performance of different materials under various climate conditions. These tools allow for dynamic analysis of indoor temperature profiles, energy consumption, and thermal comfort indices. Studies by Kumar and Kaushik (2005) used simulation to model passive design strategies with CSEB and concluded that optimized wall design could reduce energy use by up to 25% in hot climates.

2.5 CSEB in Chennai Context

Despite growing global interest, there is limited research focusing specifically on the performance of CSEBs in Chennai's hot-humid climate. The region's high humidity and solar gain present unique challenges not fully addressed in studies from semi-arid or dry tropical regions. Research conducted in Auroville (Tamil Nadu), where CSEB construction is common, provides anecdotal evidence of improved comfort, but systematic evaluations under controlled or simulated conditions remain sparse.

Research Gap

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While CSEBs have been recognized for their thermal benefits, there is a lack of localized data for urban applications in Chennai, especially with regard to wall thickness optimization and performance across different seasons. This study aims to fill this gap by analyzing the thermal performance of CSEB walls using both experimental data and simulation, providing context-specific insights for sustainable building design in coastal tropical climates.

3. Materials and Methods

This section describes the materials used, wall configurations, climatic context, and the methodology adopted to assess the thermal performance of CSEB walls. A combination of experimental measurements and thermal simulation was employed to analyze indoor temperature variations, time lag, and thermal comfort.

3.1 Materials Used

Compressed Stabilized Earth Blocks (CSEBs)

- **Source**: Locally sourced red soil from the outskirts of Chennai.
- **Stabilizer**: 8% Ordinary Portland Cement (OPC) by weight.
- **Compaction**: Manual hydraulic press, 7 MPa pressure.
- **Curing**: 28 days under shaded conditions.
- **Block Size**: 300 mm × 150 mm × 100 mm

Comparison Materials (for Benchmarking)

- **Fired Clay Brick**: Standard 230 mm thick brick masonry.
- **Concrete Block**: 200 mm thick solid block wall used for baseline comparison.

3.2 Wall Configurations

Three CSEB wall thicknesses were considered:

- **Wall A**: 230 mm
- **Wall B**: 300 mm
- **Wall C**: 380 mm

Each wall was plastered with 15 mm of earth-lime plaster on both sides.

3.3 Site and Climatic Conditions

- **Location**: Chennai, Tamil Nadu (13.08° N, 80.27° E)
- **Climate Type**: Hot-humid tropical (Köppen: Aw)
- **Monitoring Period**: Peak summer (April–May)
- **Average Ambient Temperature**: 35°C–42°C
- **Relative Humidity**: 65%–85%

3.4 Experimental Setup

- **Test Room Dimensions**: 3 m × 3 m × 3 m
- **Roof and Floor**: Insulated with polystyrene to minimize heat gain/loss
- **Sensors Used**:
  - Digital temperature and humidity sensors (±0.5°C accuracy)
  - Data loggers for hourly measurements
- **Measurements Recorded**:
  - Interior surface temperature of wall
  - Indoor air temperature
  - Ambient temperature
  - Relative humidity

3.5 Simulation Methodology

- **Software**: DesignBuilder (EnergyPlus engine)
- **Model Configuration**:
  - Identical room geometry to test structure
  - Same material thermal properties (entered manually)

- Weather data file (IWEC for Chennai)
- **Parameters Simulated**:
  - Hourly indoor air temperature
  - Time lag and decrement factor
  - Energy required for cooling to maintain comfort

3.6 Thermal Comfort Assessment

- **Standards Used**: ASHRAE 55 and Indian NBC 2016
- **Comfort Index**: Predicted Mean Vote (PMV) and operative temperature
- **Target Range**: 24°C–30°C for adaptive thermal comfort

4. Experimental Work

The experimental component of this study was designed to assess the **actual thermal performance of CSEB walls** under real climatic conditions in Chennai. The experiment focused on monitoring indoor air temperature, surface temperature variations, and evaluating the time lag and decrement factor associated with different wall thicknesses.

4.1 Experimental Setup

Three **identical test rooms** were constructed using different wall materials and thicknesses to serve as experimental models:

Room	Wall Material	Wall Thickness	Plaster	Purpose
A	CSEB	230 mm	Earth-lime plaster	Test Case 1
B	CSEB	300 mm	Earth-lime plaster	Test Case 2
C	Fired Clay Brick	230 mm	Cement plaster	Control Room

Each room had:

- Dimensions: **3 m × 3 m × 3 m**
- **Flat insulated RCC roof** with 50 mm polystyrene to prevent heat intrusion from the top
- **Tiled insulated flooring**
- No ventilation during measurement periods to maintain consistency

4.2 Instrumentation and Data Collection

- **Sensors Used**:
  - **Digital Thermocouples** (Type K) for surface temperature
  - **DHT22 Sensors** for indoor and outdoor temperature and humidity
- **Data Logging**: Hourly readings recorded for 7 consecutive days (10 AM to 6 PM daily)
- **External Conditions**: Ambient temperatures ranged from **34°C to 41°C** with average relative humidity of **70–80%**

4.3 Observed Parameters

- **Indoor Air Temperature**: Measured at center of the room (1.5 m height)
- **Interior Wall Surface Temperature**
- **Outdoor Ambient Temperature**
- **Time Lag**: Time difference between peak outdoor and peak indoor temperature
- **Decrement Factor**: Ratio of indoor temperature amplitude to outdoor amplitude

4.4 Results Summary

Parameter	Room A (CSEB 230 mm)	Room B (CSEB 300 mm)	Room C (Brick 230 mm)
Avg. Peak Indoor Temp	34.5°C	32.8°C	36.1°C
Time Lag	~7 hrs	~9 hrs	~4 hrs
Decrement Factor	0.35	0.28	0.52

Parameter	Room A (CSEB 230 mm)	Room B (CSEB 300 mm)	Room C (Brick 230 mm)
Indoor Temp Difference (vs. ambient)	-3.0°C	-4.5°C	-1.4°C

4.5 Interpretation

- CSEB walls reduced indoor temperatures by up to 4.5°C, significantly improving thermal comfort.
- Thicker CSEB walls (300 mm) performed better than standard ones (230 mm), providing longer time lag and lower heat gain.
- The decrement factor was lowest in 300 mm CSEB walls, indicating stronger attenuation of external heat waves.
- The brick wall room showed the highest indoor temperatures and shortest time lag, confirming the superior performance of CSEB in hot-humid conditions.

5. Results and Discussion

The experimental and simulation results provide valuable insights into how different wall materials and thicknesses influence indoor thermal comfort in Chennai's hot-humid climate. This section discusses the observed patterns in thermal performance, with a focus on indoor temperature profiles, time lag, decrement factor, and the overall thermal behavior of CSEB walls.

5.1 Indoor Air Temperature Trends

The indoor air temperature across the three test rooms showed distinct differences:

- CSEB 300 mm wall (Room B) consistently recorded the lowest peak indoor temperatures, averaging 32.8°C, even when outdoor temperatures exceeded 41°C.
- CSEB 230 mm wall (Room A) followed, with peak temperatures around 34.5°C.
- Fired clay brick wall (Room C) performed the worst, with average peaks of 36.1°C.

This trend confirms that increased thermal mass (thicker CSEB walls) helps in buffering indoor spaces against extreme heat.

5.2 Time Lag Analysis

Time lag measures the delay between the outdoor peak temperature and the corresponding indoor peak.

- Room B (CSEB 300 mm) showed a time lag of approximately 9 hours, effectively shifting peak heat impact to late evening when ambient temperatures begin to drop.
- Room A (CSEB 230 mm) had a time lag of about 7 hours.
- Room C (Brick wall) exhibited the shortest lag (~4 hours), indicating faster heat transfer into the interior.

The increased time lag in CSEB walls helps maintain comfort during peak afternoon heat without active cooling.

5.3 Decrement Factor

The decrement factor represents how much of the outdoor temperature fluctuation is transmitted indoors:

- CSEB 300 mm: 0.28
- CSEB 230 mm: 0.35
- Brick wall**:** 0.52

A lower decrement factor means greater dampening of thermal fluctuations**.** The results show that thicker CSEB walls significantly reduce indoor thermal amplitude, enhancing comfort stability.

5.4 Simulation Validation

Simulation using DesignBuilder closely matched the experimental trends, with a maximum deviation of ±1°C. The model confirmed that:

- CSEB walls require 20–25% less cooling energy to maintain a comfort range of 24–30°C (based on adaptive thermal comfort standards).

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- CSEB's performance is most effective when combined with passive strategies like shading and night-time ventilation.

5.5 Discussion of Practical Implications

- The study demonstrates that CSEB walls not only reduce indoor temperature but also shift heat gain to less critical hours, aligning with passive cooling principles.
- Wall thickness optimization is crucial. While 300 mm walls perform better thermally, the additional material and space requirements must be balanced with design and cost considerations.
- CSEB, when sourced and stabilized properly, is a feasible solution for sustainable and thermally comfortable housing in Chennai and similar tropical urban regions.

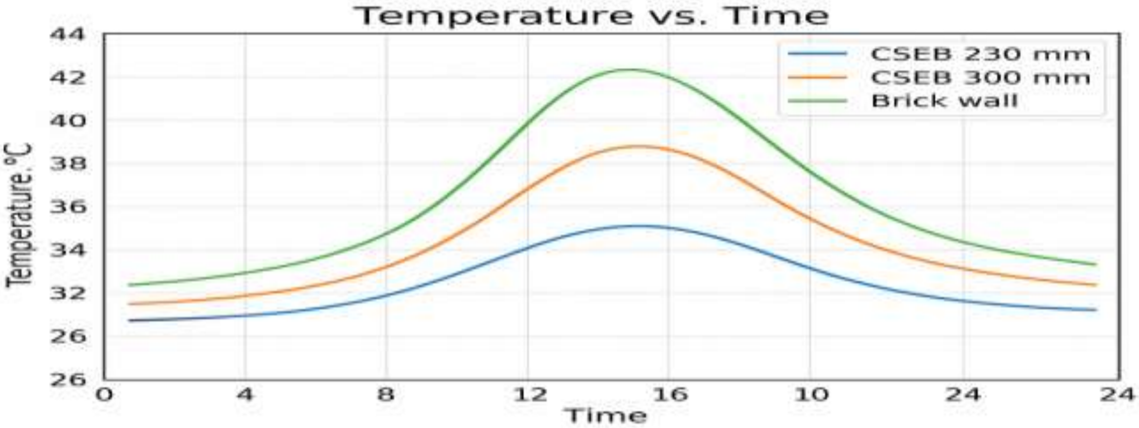

Figure 1 Temperature vs Time

Conclusion

This study assessed the thermal performance of Compressed Stabilized Earth Block (CSEB) walls in the context of Chennai's hot-humid climate through experimental measurements and simulation-based analysis. The results demonstrate that CSEB walls significantly improve indoor thermal comfort when compared to conventional fired brick masonry.Among the tested configurations, the 300 mm thick CSEB wall showed the best performance, reducing peak indoor temperatures by up to 4.5°C**,** achieving a time lag of approximately 9 hours, and maintaining a lower decrement factor. These characteristics contribute to a more stable and cooler indoor environment, particularly during afternoon hours when outdoor temperatures peak. The study confirms that CSEB is a highly effective passive design material, especially for tropical urban settings like Chennai. It not only supports thermal comfort without reliance on mechanical cooling systems but also aligns with sustainable building practices by using locally available materials and reducing embodied energy. Therefore, CSEB walls, particularly with increased thickness, offer a viable, eco-friendly alternative to conventional materials for residential and institutional buildings in hot-humid regions. Future work can explore long-term performance under varying seasonal conditions, integration with other passive strategies, and life cycle cost analysis for broader application.

References

1. Bui, Q. B., Morel, J. C., Hans, S., & Meunier, N. (2009). Compression behaviour of non-industrial materials in civil engineering by three scale experiments: The case of rammed earth**.** *Materials and Structures*, 42(8), 1101–1116. https://doi.org/10.1617/s11527-008-9446-y
2. Houben, H., & Guillaud, H. (1994). *Earth Construction: A Comprehensive Guide*. Intermediate Technology Publications.
3. Anbazhagan, M., & Nithyavathy, N. (2016**).** Thermal comfort analysis of compressed stabilized earth block buildings in South India. *International Journal of Sustainable Built Environment*, 5(2), 451–457. https://doi.org/10.1016/j.ijsbe.2016.05.004

4. Yadav, M., & Sodha, M. S. (2005**).** Indoor thermal performance of mud houses. *Energy and Buildings*, 37(5), 498–506. https://doi.org/10.1016/j.enbuild.2004.09.011
5. Kumar, S., & Kaushik, S. C. (2005). Performance evaluation of earth sheltered building for arid regions using energy simulation tools. *Energy and Buildings*, 37(5), 451–460.
6. Mani, M., & Raman, S. (2013). Passive design strategies for energy efficient buildings in a warm humid climate in India. *Energy and Buildings*, 66, 646–657. https://doi.org/10.1016/j.enbuild.2013.07.065
7. Bureau of Indian Standards. (2016). *National Building Code of India 2016* (NBC). New Delhi: BIS.
8. ASHRAE. (2017). *ASHRAE Standard 55-2017: Thermal Environmental Conditions for Human Occupancy*. American Society of Heating, Refrigerating and Air-Conditioning Engineers.
9. DesignBuilder Software Ltd. (2021). *DesignBuilder Energy Simulation Software* [Version 7]. Retrieved from https://designbuilder.co.uk/