# Passive Cooling Techniques in Earth Based Construction

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***Abstract*—Passive cooling systems are critical for decreasing building energy consumption, particularly in warm areas, while increasing occupant comfort and sustainability. This study looks at the use of passive cooling systems in earth-based construction, with an emphasis on their design, thermal performance, economic efficiency, and environmental advantages. Because of the high thermal mass and breathability of materials such as adobe, rammed earth, and CSEB, earth-based building promotes passive cooling by default. The research also looks at current adaptations of ancient technologies, such as sun shading devices, and optimal orientation, and how these might be applied within the constraints of local construction codes. The investigation comprises case studies, thermal simulations, and compliance evaluations, all of which contribute to a better knowledge of India's sustainable design practices.**
*It corresponds with the India Cooling Action Plan (ICAP), which aims to reduce cooling demand by 20-25% by 2037 while prioritizing energy efficiency and environmental sustainability* **(Ministry of Environment, 2024).**

## I. INTRODUCTION

For ages, passive cooling has played a significant role in vernacular construction, especially in tropical and sub-tropical areas. The use of natural ventilation systems, shaded courtyards, and thick earthen walls in traditional Indian building has demonstrated its efficacy and durability in preserving thermal comfort without the need for energy-intensive equipment.

Conventional Methods and Development
Because of its high thermal mass, adobe, rammed earth, and wattle and daub buildings exhibit natural insulation. By absorbing heat throughout the day and releasing it gradually at night, these materials help to keep interior temperatures more consistent. According to the Auroville Earth Institute, when properly sized and oriented, compressed stabilized earth blocks (CSEB) provide effective insulation in addition to reducing embodied energy by 70% when compared to burnt bricks.

Importance of Passive Cooling
Contemporary studies indicate that passive cooling strategies, show a 30–40% reduction in cooling energy demand. These studies validate the benefits of integrating thermal mass walls with passive design features like solar shading, cross-ventilation, and vegetative buffers etc. (Sumbul Afreen1, 2018).

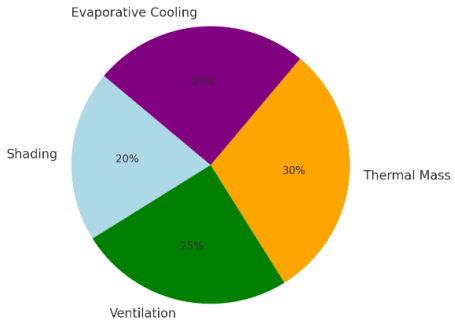



Figure 1. Energy Savings by Different Passive Cooling Techniques (BARNAŚ, 2022)

Why Earth Based construction?
With rising temperatures and growing electricity bills, many people rely heavily on-air conditioners and fans to stay cool—especially in places like India. But this creates a big strain on energy resources and adds to environmental damage. We already have traditional ways of building—like using mud, rammed earth, and CSEB—that naturally keep homes cooler (Sumbul Afreen1, 2018).

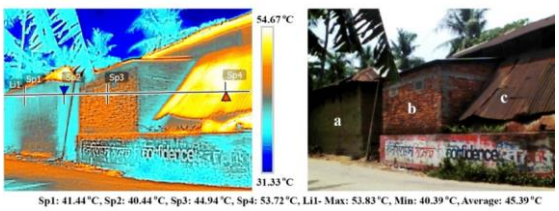



Figure 2. (Jannat, 2020)

The image showcases a thermal analysis of a building's surface. On the left side, the thermal image uses a color scale to represent temperature variations across different parts of the building, ranging from 31.33°C to 54.67°C. Specific spots (marked Sp1 as

earth-based building, Sp2, Sp3 as conventional building, Sp4 as steel structure) display their exact temperatures, showing the hottest and cooler areas. For instance, the Sp4 section is the warmest at 53.72°C (Jannat, 2020).

These earth-based construction methods, when combined with smart passive cooling techniques like earth pipes, shaded courtyards, and good building orientation, can create homes that are both comfortable and eco-friendly—without the need for expensive systems.

This study is needed to explore how these simple, affordable, and sustainable techniques can be better understood and used today, blending old wisdom with modern needs. It's about finding practical ways to design cooler, greener buildings that are kind to both people and the planet (Ministry of Environment, 2024).

## III. LITERATURE REVIEW

The Ministry of Environment, Forest & Climate Change states that the five most effective tactics are: orientation, shading, natural ventilation, thermal mass, and evaporative cooling. When used correctly, these approaches can reduce indoor temperatures by 5-8°C and energy usage by up to 40-60%, particularly in composite and hot-dry areas. Traditional Indian architecture features elements such as courtyards, wind towers, jalis, and covered verandas.

These technologies take advantage of site-specific climate responses, reducing the need for active cooling equipment. For example, jalis scatter sunlight and improve airflow, but wind towers direct hot air away and bring cool air in (Ministry of Environment, 2024).

### *A. Passive Cooling strategies*

1. Heat Protection: The orientation of buildings, landscaping features, and shading elements help to decrease heat absorption.

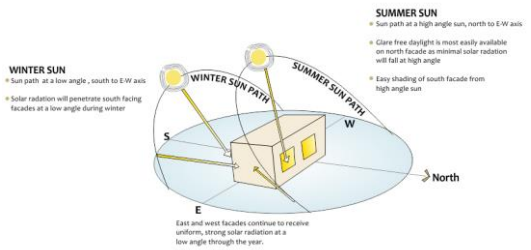



Figure 3. Building Orientation Guide *https://nzeb.in/knowledge-centre/passive-design/form-orientation/*

2. Temperature Regulation: Thermal mass combined with insulation helps maintain consistent indoor temperatures.

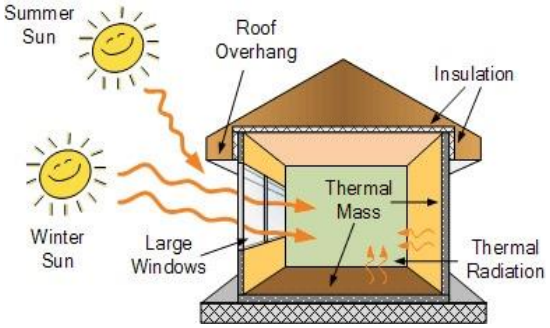



Figure 4. Thermal Regulation in house *https://www.geeksforgeeks.org/solar-energy/*

3. Heat Release: Natural airflow and evaporative cooling mechanisms help disperse excess heat.

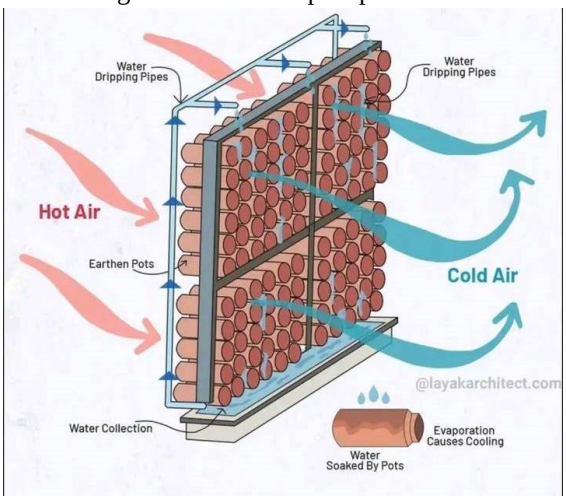



Figure 5. Beehive Coolant Evaporative System *https://www.facebook.com/photo/?fbid=582387691164736&set=pcb.2318560385169342*

### *B. Earth Based Construction Material for Passive Cooling*

1) Foundation: Stabilized Earth Base or Stone Foundation
   - i) compacted stabilized earth blocks
   - ii) Incorporate lime or fly ash to enhance waterproofing and resist termites.
   - iii) The mixture consists of 5% cement by weight, with the following proportions: 500 liters of soil, 200 liters of sand, and 1 bag of cement weighing 50 kg) (Auroville).

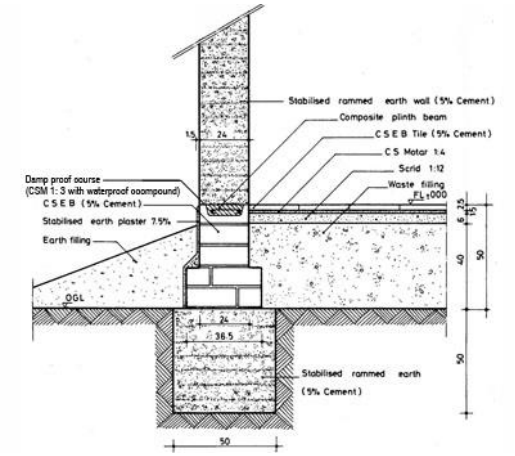



Figure 6. Stabilized Rimmed Earth Foundation (Auroville)

| One-floor building: | Two-floor building: | Three-floor building: | Four-floor building: |
|---|---|---|---|
| 50 x 50 cm | 60 x 60 cm | 75 x 75 cm | 90 x 90 cm |

Figure 7. Standards of Foundation in Auroville Buildings (Auroville)

Role in Passive Cooling- Serves as a thermal barrier against ground heat. Facilitates moisture movement, thereby preventing indoor humidity accumulation.

2) Flooring: Earth or Lime-Crete Flooring
   i) Options include terracotta tiles, rammed earth floors, or a lime-Crete blend (lime, brick dust, and sand).
   ii) Finished with linseed oil for added waterproofing.

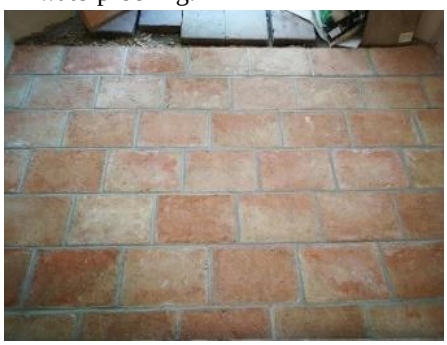


Figure 8. Terracotta Tiles
*https://www.themudhome.com/mudbuilding/5-ways-tocreate-a-natural-floor*

Role in Passive Cooling- Features a high thermal mass, which allows it to store heat during the day and release it after sunset. Ensures floors remain cool to the touch, even during the hottest summer days. (Sharma, 2015)

3) Walls: Rammed Earth / Adobe / CSEB Blocks
   i) Thick load-bearing walls (30–45 cm).
   ii) Mix: Clayey soil + sand + small percentage of lime/cement.

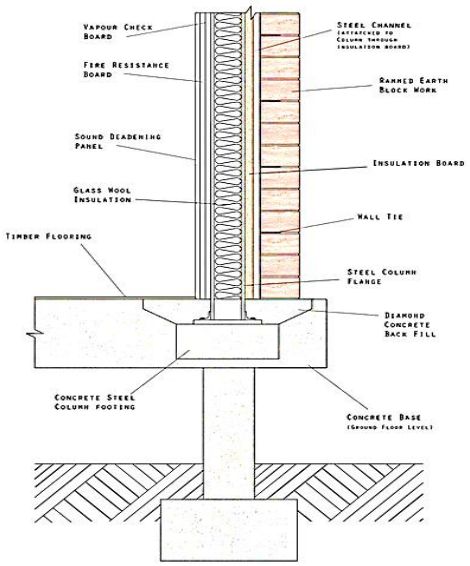



Figure 9. Rammed Earth wall Section
*https://architechandenvironment.weebly.com/the-project/rammed-earth-blockwork*

Role in Passive Cooling-Excellent thermal insulation and mass. Walls store heat and release it slowly, regulating indoor temperature (Narendran, 2022).

4) Wall Finishing: Lime or Mud Plaster
   i) To reflect heat and mitigate moisture, the exterior is finished with lime plaster. Interior: Mud plaster or clay-based natural finishes.

Figure10.Lime Plaster
*https://www.facebook.com/ThannalHandSculptedHomes/photos/herbal-lime-plaster-at-sri-ramana-ashram-tiruvannamalailime-and-surkhi-plaster-w/1024113577742318/*

Role in Passive Cooling- Reflects solar radiation. Maintains breathable surface for natural humidity control. Reduces wall heat absorption (Govaerts, 2018).

5) Overhangs and Shading device
   i) Overhanging roofs, verandahs, ornamental screens jaalis, screens, or green trellises.

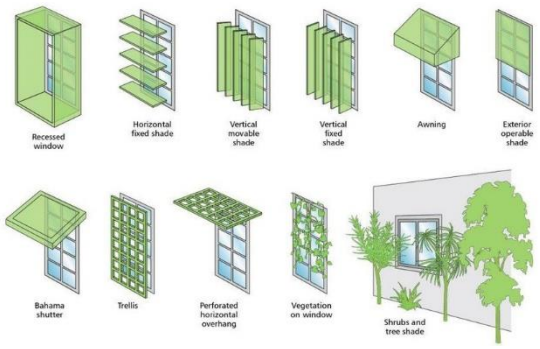



Figure10.Different Types of Shading Devices (Al-Yasiri, 2021)

Role in Passive Cooling-Blocks direct sun from heating walls. Allows diffused light and ventilation. Promotes shaded exterior surfaces = less internal heat gain (Fernández-González., 2025).

6) Slabs and Intermediate Floors:
   i) Use jack arch flooring or compressed earth blocks in floor/roof slab construction.
   ii) Combine with false ceiling air gaps.
   iii) Terracotta Slabs or Hollow Terracotta Blocks
   iv) Mud Flooring with Lime Stabilization

Figure 11. Terracotta pot – filler slab © www.urbannext.net

Role in Passive Cooling- High thermal mass in slabs resists heat transfer. Air cavity acts as insulation barrier, reducing indoor heat. Terracotta is naturally porous and allows slow thermal conductivity, making it excellent for regulating internal temperatures. Hollow terracotta blocks further reduce heat transfer due to their air gaps (Gaikwad, 2024).

7) Roofing Options: Merging Earthen Roofing Systems with Green Roof or Tile Overlay
   i) Mud + lime roof finished with clay tiles or coconut coir + lime screed.
   ii) Option for terracotta filler slab or brick dome roofing.

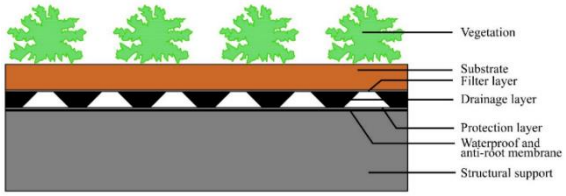



Figure 12. Green roof layers (Cascone, 2019)

Role in Passive Cooling- Multiple reflective and insulating layers. Green roofing adds evaporative cooling and thermal insulation. (Gaikwad, 2024).

8) Openings: Earth-Framed Windows with Natural
   i) Cross-ventilated windows placed as per wind direction.
   ii) Timber or CSEB window frames, shaded by jaalis or vegetation.

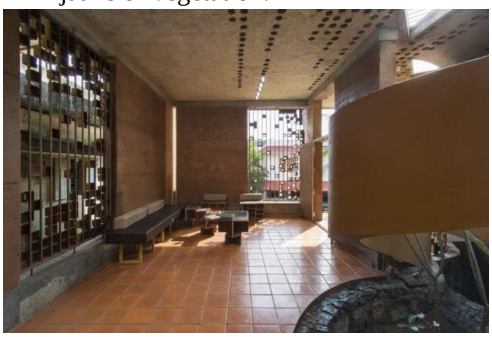


Figure 13. Window & Jali openings with Courtyard *https://www.archdaily.com/903691/debris-house-wallmakers*

Role in Passive Cooling- Facilitates the release of warm air while permitting the entry of cool air.Stack effect when used with high vents or wind catchers (Ministry of Environment, 2024).

## IV. CASE STUDY

Name: - Mareddi Residence
Location: - Hayath Nagar, Hyderabad
Site Area: - 2.15 Acres
Built Up: - 1245 Sq.M
About: - This villa project is the result of a thorough comprehension of the users, taking into account their family dynamics and preferences, which were gathered through interviews that explored their daily routines and lifestyle.

The client's interest in regional (Telugu) vernacular lifestyle/architecture resulted in incorporation of key elements of traditional courtyard house (Manduva) in its contemporary form. The client's pursuit of self-reliance was integrated into the site planning, which included solar power generation, organic vegetable

farming, a goshala for milk production, and systems for harvesting rainwater.

*A. Key Features*

Designed for Hyderabad's hot semi-arid climate. Maximizes indirect light and minimizes heat gain from the west. Shaded sit-outs and porches reduce the cooling load on the interior.

*B. Design and Planning*

1)Site

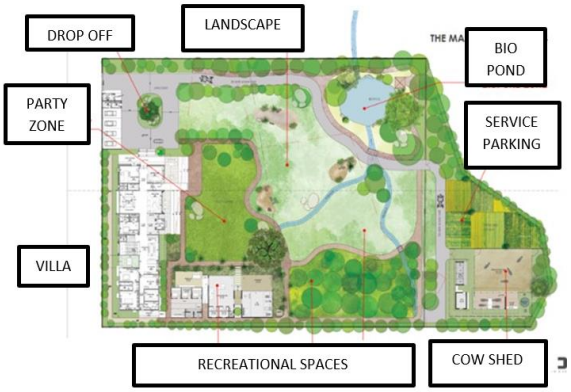



Figure 13. Site

Source – Author

2) Site Study- Wind Analysis

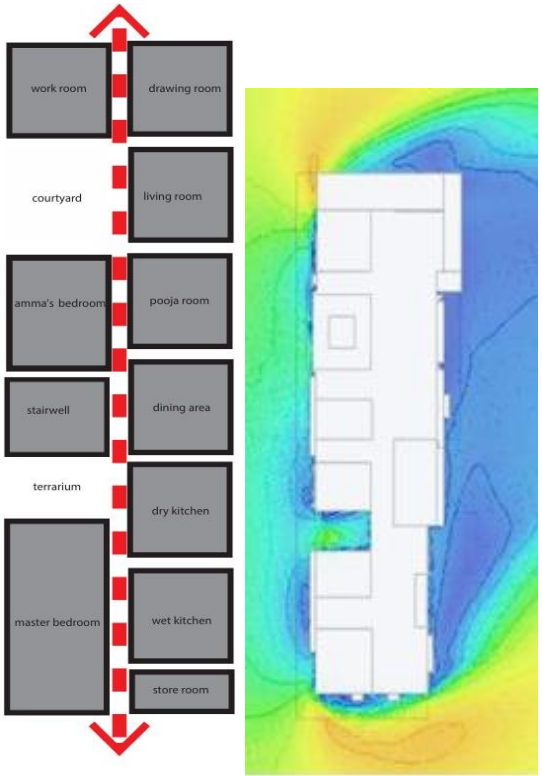



Figure 14. Zoning and Wind Analysis up to 5m Height

Source – Author

Blue zones are characterized by their calm environments, shielded from strong winds, while red zones are marked by significant wind currents. This provides the means to position openings, walls, and other components best to control the flow. The building's orientation and the positioning of its openings are designed to align with the prevailing winds, as indicated by the red arrows. This clause guarantees that the structure will capitalize on existing winds in terms of natural cooling and ventilation Source- Author.

This design took advantage of the ground floor courtyard for good air circulation. This open space serves as a natural ventilation, letting the wind blow in and out which reduces the heat inside the space and maintains a comfortable temperature inside. that way, this data is used to change designs—like repositioning windows or adding windbreaks—to improve circulation without sacrificing structural integrity Source- Author.

3) Passive Cooling Strategies

- Vegetation is placed outside the structure t o act as a natural shading element, cutting o ff hard sunlight and cooling the air.
- wisely designed overhangs or chajjas on the windows, signifying solar geometry used to provide optimal shading in summers and sunlight in winters. And likely optimized as per latitude (Hyderabad's ~17.4°N) and solar path.
- Overhangs are measured (600 mm and 450 mm)
- The wall and insulation thicknesses appear compatible with earth- or thermally-massive walls (e.g., CSEB), dampening internal temperature oscillation.
- Sun breakers are created with angled projections or depth of windows such that there is no direct entry of the sun.
- Stacked windows and voids between closets may promote cross and stack ventilation

Figure 14. Solar Shading Analysis

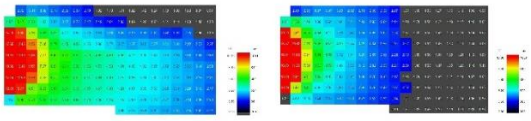
- The angles (highlighted as 45 degrees) appear to be guides for adding shading devices like overhangs or louvers. These details work to reduce direct light entering the building, therefore reducing heat gain during the day.

- Moreover, sunlight passes through the jalis and enters the building but in a diffused manner, so the direct glare and heat is broken off from burning human beings and generating inward comfortable climate.
- The pool is situated near the location, which serves to improve the microclimate, and as such creates a more enjoyable outdoor and indoor experience.
- the courtyard in fact encourages cross-ventilation and stack ventilation naturally and thus provides the much-needed comfort for occupants, with lower indoor temperatures.
- The terrarium is a natural insulator and it absorbs heat from the sun throughout the day radiating heat back through the night. This smaller space for your plants creates humidity and oxygenates the surrounding space, improving air quality.

4) Outcomes

- Direct sunlight comes in through the windows and walls, bringing up the inside temperatures. Higher inside temperatures make people rely more on artificial means of coolness like air conditioners or fans.

- Shading devices like overhangs louvers mud jalis block direct sunlight and reduce heat gain by a large percent. Better thermal insulation makes cooler indoor spaces. The addition of courtyards and open spaces with shading increases cross-ventilation and stack effects.



(i) (ii)

Figure 15. (i) Before Shading Devices (ii) daylight analysis taken after in corporating 4 horizontal slats of 0.5m louvres

- Red Zones-High Daylight Intensity These areas get direct sunlight and are most illuminated during the day. Black Zones-Low Daylight Intensity These areas are shaded or where there is minimal natural light; often, this is due to obstruction by walls, trees, or other structures.
- Bright areas suit living rooms, atriums, or workspaces, while dimmer spaces are better for bedrooms or storage.
- Hence the planning is achieved with passive cooling techniques.

## V. CONCLUSION

This study reveals the incredible potential of earth-based construction as a sustainable and climate-responsive solution for modern buildings.

From the foundation to the roof, using locally available materials like mud, CSEB blocks, terracotta tiles, filler slabs, and kulhad roofs—combined with thoughtful design strategies such as proper building orientation, shaded openings, jaalis, and overhangs—creates comfortable spaces that naturally stay cooler in hot climates.

These passive cooling techniques don’t rely on artificial systems but instead work with nature.

Earth materials naturally regulate heat, keeping interiors up to 3–5°C cooler, even during peak summer. What’s more, these methods are rooted in traditional knowledge passed down for generations, yet they still stand strong when compared with modern, energy-intensive systems.

Case studies like the Mareddi Residence in Hyderabad show us how passive cooling isn’t just theory, it’s practical, beautiful, and effective.

With the right design choices, even a simple home can offer comfort, save energy, and reduce environmental impact.

Ultimately, earth-based architecture is more than a building method—it's a mindset that respects the environment, values cultural heritage, and promotes healthier living.

As we face rising temperatures and growing climate concerns, returning to these natural, passive solutions isn’t just smart-it’s essential.

## VI. ACKNOWLEDGMENT

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