

Case Study Title: Farmhouse



Project Name	Residence at Shoolagiri
Location	Sanctity Ferme, Chembaltradi Rd, Kodiga Timmanapalli, Tamil Nadu, India
Climate Zone	Tropical Savanna Climate/ ASHRAE: Zone 3A (Warm-Humid)
Latitude/Longitude	12°41'36.4"N 78°03'33.9"E
Building Type	Private residence/ farmhouse
Floor Area [sqm]	353 square metres
Building Height [m]	8.85M
Number of Storeys	Two-storey
Completion Year	In-progress (2024 - on-going), estimated completion April 2026
Project Team	Architects: Rosie Paul and Sridevi Changali, Rutuja R Project Management Consultancy: Govind

*mock-up experiments and other research-based experiments could be included as case study, aside from actual building construction projects if similar information could be provided.

1. Project Description

Project Overview

The project was conceived to offer the client an escape from urban life and to promote a more sustainable lifestyle through permaculture principles. Nestled at the base of a hillock on a 4046.86 square metres site, the project emphasises how a sustainable approach, right from the planning phase, contributes to a sustainable way of life. The site offers picturesque views of the Shoola Hills to the southwest, and the client's brief was to capture these views to allow the residence to also function as a meditative retreat overlooking the hills. The selection of materials, construction methodologies, and energy solutions was all informed by this overarching philosophy. In alignment with permaculture practices, the built-to-unbuilt ratio is set at 30:70, providing ample open space for the cultivation of fruit trees and various food plants while simultaneously enhancing the site's ecosystem with clean air. The design promotes a natural way of living through the harmonious interaction of Earth, Water, Flora, and Fauna, ultimately creating a microbiosphere.

2. Climate & Site Context

Basic Climate Conditions		
Temperature	Annual Average	23.8°C
	Annual Range	12.5°C (April) - 35.4°C (December and January)
Relative Humidity	Annual Average	71.5%- 72%
	Annual Range	11.5% (March) to 99.6% (July/August)
Annual Degree-Days (ASHRAE Standard 169-2020)		HDD18°C: <100 (minimal); CDD18°C: high (Bengaluru is cooling-dominated)
*The data collected is from the nearest local meteorological source, Hosur, Tamil Nadu, as ASHRAE data is not available for the site location. The closest location for which ASHRAE data is available is Bengaluru, Karnataka, which differs slightly from the site's climatic data. However, HDD and CDD mentioned are for Bengaluru from ASHRAE.		
Climate Analysis		
Hosur has a tropical savanna climate with distinct wet and dry seasons, and its high elevation makes it more moderate than the surrounding plains. Winters are mild and pleasant, with the coolest month being January, while summers are hot and humid, with the hottest month being May. The city receives rainfall from both the northeast and southwest monsoons, with the wettest months being October, September, and August.		
Ste Analysis		
The site is located within a gated farm community in Shoolagiri. The site spans roughly 4046.86 square metres and features a permaculture system integrated with water channels, a pond and a well. Its natural topography promotes adequate rainwater runoff for harvesting and irrigation. The green buffer on the site supports microclimate stability and biodiversity, while		

creating a calm, secluded environment through low-carbon construction methods.

Passive Cooling Strategies (please tick implemented passive cooling strategies)

- Building Orientation & Form (site orientation, building shape, etc.)
 - Envelope Design (insulation, air-tightness, shading, window system, thermal mass, etc.)
 - Natural Ventilation (cross ventilation, stack ventilation, night ventilation, etc.)
 - Evaporative Cooling (direct/indirect evaporative cooling, etc.)
 - Ground Cooling (geothermal, ground-coupled systems, basement/underground space, etc.)
 - Radiative Cooling (cool roof, night sky radiation, radiant barriers, reflective surfaces, etc.)
 - Nature-based Solutions (green roof/wall, tree shading, etc.)
- Others (human behavior, clothing, semi-passive (fans, etc.))

Description (please describe one strategy per box – you can add more boxes below if needed)

Building Orientation

The building is strategically situated in the northwest section of the plot to accommodate natural site constraints, such as boulders, and to maximise views of the Shoola hills. The entire built-up area is divided into three blocks 1. Master bedroom, 2. Living room, 3. The dining room, kitchen, and guest bedroom are connected by bridges over seasonal water bodies or courtyards. The third block also houses two bedrooms on the first floor. Each block varies in height: the master bedroom block is the shortest at 5.7m, and the semi-public block is the tallest at 8.55m. The blocks are angled and staggered so that the shadow of one falls on the other, reducing the heat gain through direct sunlight. The staggered blocks are also angled to catch the prevailing wind and channel it between the blocks, creating a tunnel effect that pushes more air into the rooms.

Envelope Design (insulation, shading, roof system):

The building envelope mainly consists of in-situ rammed earth and CSEB blocks, aligning with the design intent of minimising carbon emission during construction and substantially reducing raw material costs while providing high thermal mass for temperature moderation. In this structure, the wall thickness has been increased from the norm of 23cm, followed in India, to 30cm, enhancing thermal performance by delaying heat transfer and maintaining cooler indoor temperatures. The structure features a high-vaulted roof built with earthen blocks, topped with an external screed finish that further increases the roof's thickness and contributes to its overall thermal mass. Using earth instead of the commonly used concrete reduces heat gain from the roof and walls considerably.

The south-west facade has exaggerated verandahs to reduce heat gain from this side, which receives the highest solar exposure.

Natural Ventilation (cross and stack ventilation):

The door and windows have been specially designed to facilitate the entry of cold air and the exit of hot air. The openings have vents at the bottom to allow air to move inside the rooms. Secondly, the building's volume and form promote stack ventilation by allowing warm air to rise and exit through skylights, while drawing cooler air from lower levels. It helps maintain comfortable indoor conditions by flushing out hot air, reducing the room temperature. The design prevents stagnation and improves comfort levels without mechanical systems, emphasising passive strategies.

Nature-based solution:

The residence is designed to be fully off-grid, operating entirely on solar power, maximising the potential of local climatic conditions. Additionally, to reduce reliance on the public water supply, the site features water channels that collect runoff to replenish the pond and, in turn, the well. The sewerage system is designed for complete on-site treatment, incorporating soak pits to filter out solid waste, a baffle reactor that uses an anaerobic process to filter out grey water, and a reed bed to treat the remainder and allow it to percolate back into the ground, increasing the groundwater table over time.

3. Passive Cooling Design Details 4. Active Components**Active (Hybrid) Cooling Strategies**

(please describe one strategy per box – you can add more boxes below if needed)

While the building primarily relies on passive design strategies, a hybrid cooling approach is integrated to enhance indoor comfort during peak summer months. Ceiling fans are strategically positioned to complement the natural stack and cross-ventilation patterns, ensuring continuous air movement throughout the spaces. Additionally, the site features a permaculture layout integrated with a seasonal water body. Rainwater harvested on-site is used to maintain the flora and fauna, which, in turn, help regulate the microclimate.

5. Performance Data**Cooling Energy Use**

- The building is designed to rely on passive cooling strategies to maintain thermal comfort, thereby eliminating the need for air conditioning.
- Indoor Thermal Comfort: The building is projected to achieve required thermal comfort without active cooling systems, solely relying on passive strategies. There is a noticeable temperature difference between the exterior and the interior of the house, furthermore, the temperature is optimised when the microclimate is managed with appropriate vegetation.

6. Financial Data**Cost Benefits**

The design supports low-cost living by relying primarily on natural resources rather than paid public services such as electricity and water supply. The building’s window design and strategic orientation maximise natural daylight throughout the day, significantly reducing the need for artificial lighting and lowering electricity consumption. While on-site systems incur maintenance costs, their long-term expenses are lower than those of conventional utilities, and investing in sustainable infrastructure is economically advantageous over time.

*Please try to extract passive cooling cost and savings; however, if it is difficult, please annotate the premise. (e.g., the calculation includes the cost for both passive heating and cooling, etc.)

7. Passive Cooling Operation

Maintenance Requirement

Maintenance is minimal, limited mainly to periodic cleaning and basic upkeep of ceiling fans. The building does not require any specialised maintenance, supporting long-term sustainability and affordability. The primary long-term care involves the permaculture and rainwater systems, ensuring that the on-site ecosystem remains healthy and continues to sustain life over time.

8. Lesson Learnt / Recommendations

Technical Challenges, Solutions and Achievement

The primary challenge was minimising heat gain from the longer southwest-facing façade. This was systematically addressed through the design of overhangs, windows, the roof, and the careful selection of materials. The design was further refined through detailed computational analyses, including daylighting studies, CFD (wind flow) simulations, operative temperature assessments, and energy consumption modelling.

Financial Challenges, Solutions and Achievement

Using earth as a building material typically requires skilled labour and additional materials, such as lime, which can increase costs. However, training the local labour team in handling and constructing with these materials not only reduced expenses but also enhanced their skill set. Sourcing earth in situ or from nearby locations (within a 10 km radius) further minimised transportation costs. For vault construction, a support template was required; the on-site team designed a reusable, movable template that was consistently used throughout the process, improving efficiency and reducing waste.

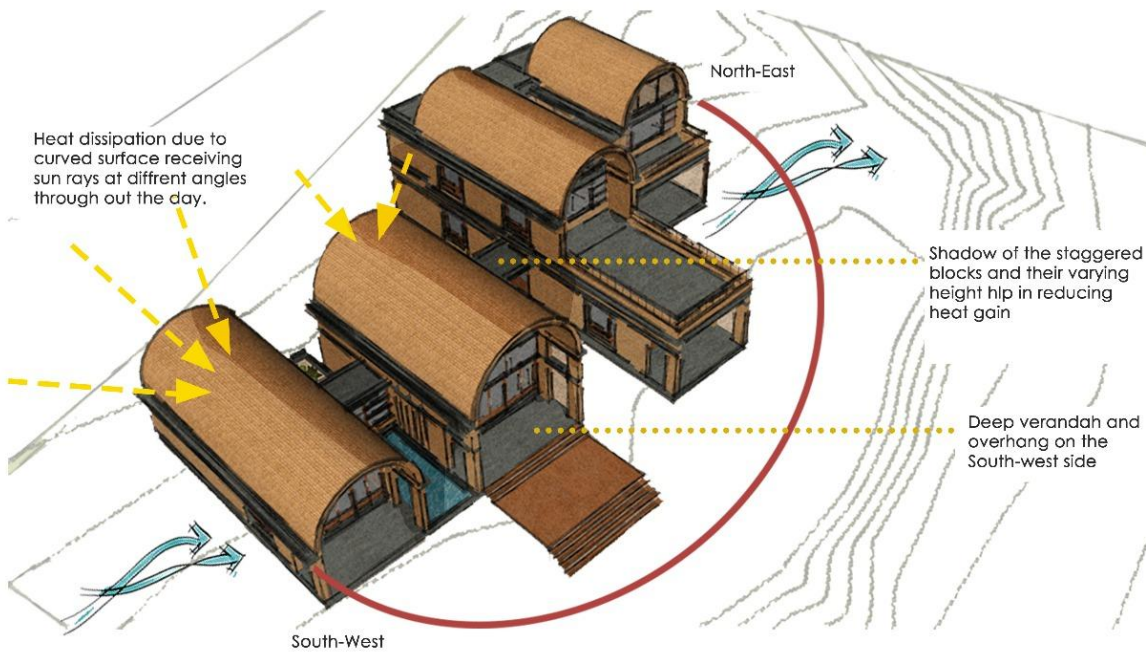
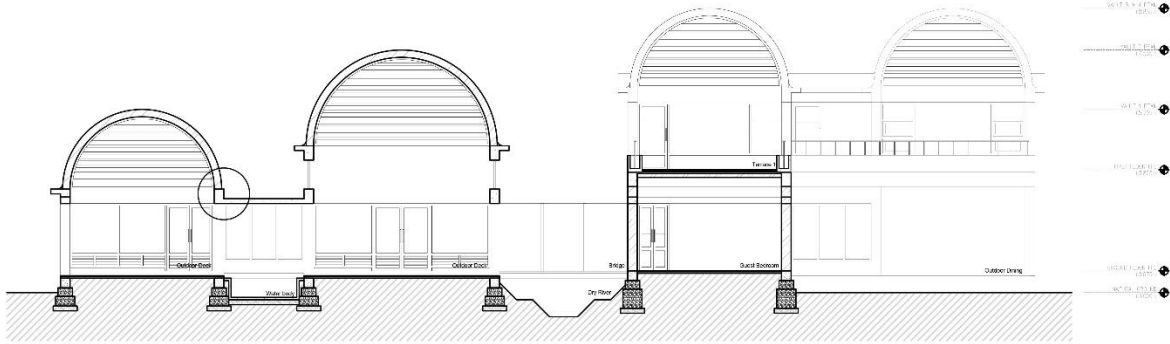
Other Challenges, Solutions and Achievement

The site’s remote location posed challenges for material procurement, prompting a focus on locally available resources. For example, CSEB blocks are typically made with sand, but due to its unavailability, locally sourced quarry dust was used as a substitute.

10. Annex

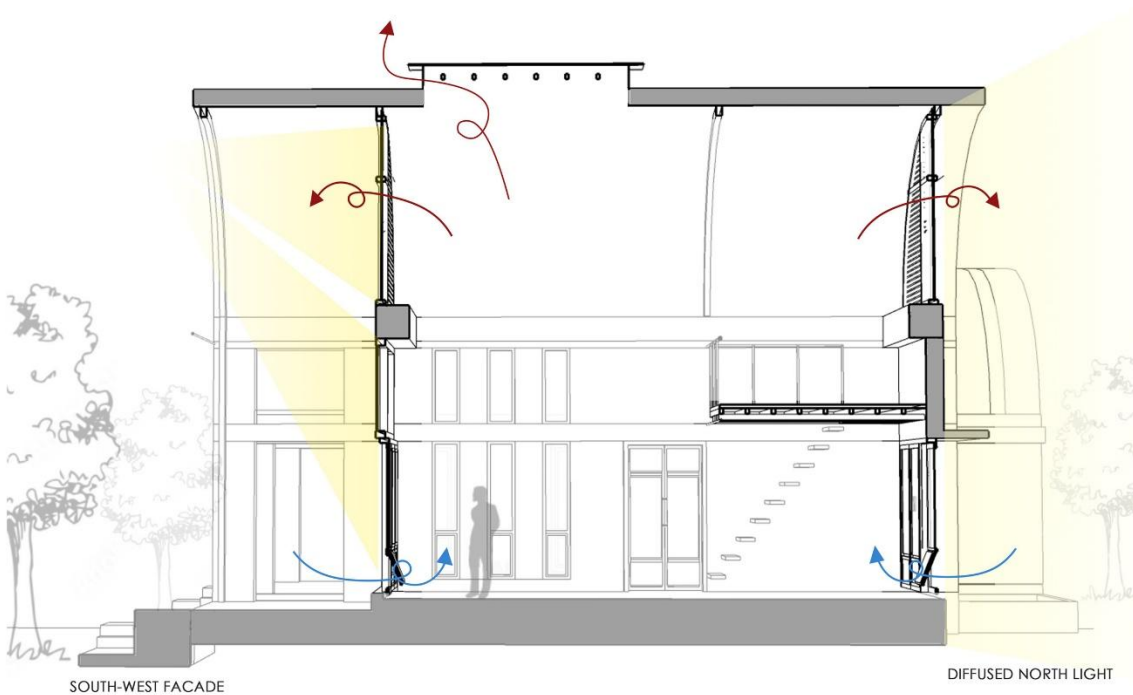
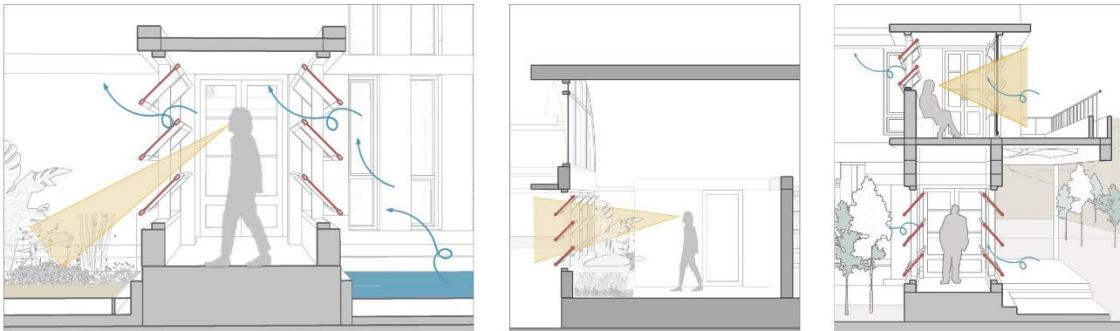
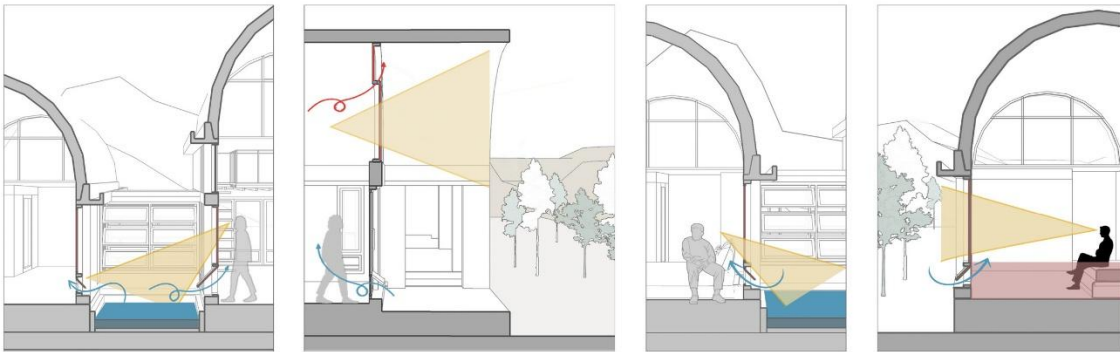
Supporting documentations





Passive Cooling Case Studies

FEESTRATION AND VENT DESIGN





Passive Cooling Case Studies

Produced by the Passive Cooling Working Group hosted by the UNEP-led Cool Coalition and GlobalABC



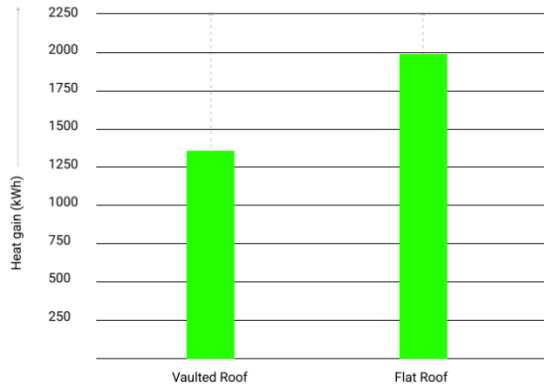
Passive Cooling Case Studies

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Analysis — Heat Gains

Gains into the interior spaces through different roofs

A generic block model comparison between flat roof and vaulted roof (same site and location has been taken)



- A generic model to the size of the West bedroom was made and iterated for different roofs- Vaulted and Flat, to understand the heat gain into the spaces through them.
- The heat gain through the **vaulted roofs is lesser** reaching up to 1320kWh and the flat roof reaching up to 2000kWh.
- This is primarily due to the **curvature of the vaulted roof**, which distributes the radiation across the entire roof surface. The larger surface area and the uneven exposure resulting from the curvature **lead to reduced heat gain**.
- Materials also play a role but, only comparing the geometry here- **vaulted roof system performs better** in terms of heat gain.

(The radiation pattern on vaulted and flat surfaces can be referenced in the "Radiation, Temperature, Orientation, and Form Analysis - V01" report, page 4)

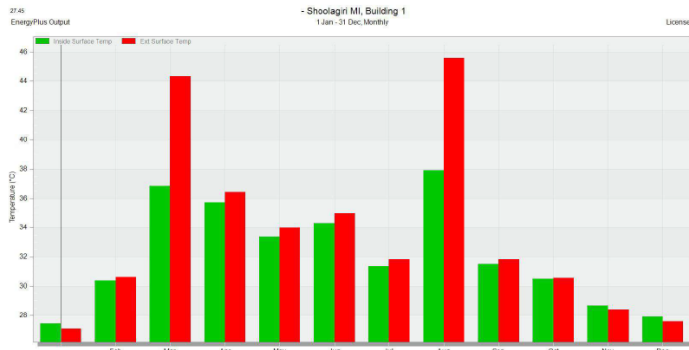
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Analysis — External and Internal Surface Temperature

Overall Building - Monthly

External and internal surface temperature for all the months throughout the year



The greens represent the internal surface temperature
The reds represent the external surface temperature

- The primary materials used are **Earth-CSEB and Rammed Earth**. One unique property of these earthen materials and homes is their ability to **stay cooler** on hot days and warmer on colder days, as clearly observed in the graph. During periods of **higher external surface temperatures**, these materials effectively manage heat flow due to their low thermal lag properties.
- The reverse is seen as well during the months of Nov, Dec and Jan where even with the **diurnal temperature difference** the internal temperature is slightly high compared to the external wall.



Note: The above analysis is a created using an advanced virtual simulation tool on DesignBuilder and EnergyPlus software. The effectiveness of the same will be studied post construction.

11. Citation

Citation
1. https://youtu.be/2HZpW-m4U6k?si=NGe1gb8FILTk9VfS

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