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Passive Design in the Twin Villages of Himachal Pradesh

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Abstract
Loss Architecture in hill settlements carries a unique balance of beauty and resilience, shaped by the challenges of steep terrain, extreme weather, and ecological sensitivity. In Himachal Pradesh, the twin heritage villages of Pragpur and Garli demonstrate how communities have long responded to these conditions through climate-conscious design. Here, materiality, orientation, spatial planning, and cultural values merge to create architecture that is both sustainable and deeply tied to local identity. This study examines Pragpur and Garli as case examples of vernacular climate-responsive architecture. Using field observations, photographic documentation, and spatial analysis, the research investigates passive design strategies embedded in their built fabric. Key features identified include thick stone masonry for thermal mass, timber detailing for seismic flexibility, inward courtyards for regulating microclimates, sloped roofs to manage heavy rainfall, and natural ventilation systems to encourage airflow. Together, these strategies reveal how local wisdom creates comfort, minimizes energy reliance, and builds resilience against environmental challenges. The research concludes that the architectural practices of these twin villages are not only heritage assets but also valuable lessons for contemporary sustainable design. Reinterpreting their strategies can help architects craft context-sensitive solutions that safeguard identity while addressing modern climatic concerns.
Keywords: *Architecture, Climate, Passive, Sustainability, Vernacular.*

1. Introduction
The wisdom of earlier generations, embedded in their architectural practices, offers valuable lessons for shaping the future of eco-friendly buildings. These regional structures have stood the test of time, earning admiration for their ability to reflect the different Experiences of people across Himachal's varied climatic zones. Unlike many modern constructions of the 20th century, traditional architecture is inherently climate-responsive, having evolved in the pre-industrial era before artificial cooling, heating, or electric lighting became available. Each region developed unique building techniques and design approaches, carefully adapted to local conditions while also expressing cultural identity and lifestyle. Traditional architecture not only forms the backbone of social and cultural life but also serves as a living heritage, contributing to tourism and regional identity. Thus, preserving its integrity is essential, and contemporary architecture should seek meaningful integration with these time-tested forms rather than replacing them. Passive design strategies refer to architectural approaches that harness natural resources—such as sunlight, wind, vegetation, and thermal mass—to maintain indoor comfort without excessive dependence on mechanical systems. By emphasizing building orientation, natural ventilation, shading, insulation, and the use of local materials, passive design not only reduces energy consumption but also enhances long-term sustainability. In Himachal Pradesh, architecture has always been deeply influenced by its demanding geography and climatic conditions. The

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combination of steep slopes, heavy monsoons, cold winters, and seismic vulnerability has shaped building traditions that prioritize both comfort and resilience. Within this context, the twin heritage villages of Pragpur and Garli stand as exemplary models of passive design, where traditional houses continue to demonstrate the effectiveness of passive strategies over modern mechanical solutions. Over centuries, communities in Himachal developed construction techniques rooted in climate and culture, using available materials in innovative ways to achieve comfort. Buildings were designed with thick stone walls that provided insulation, timber frameworks that ensured seismic resilience, inward courtyards that improved ventilation, and sloped slate roofs that managed heavy rainfall. Together, these features reveal a profound understanding of the local environment and highlight how traditional knowledge can inform sustainable, climate-responsive design in contemporary practice.

1.1. Aim

To study and analyze the passive design strategies of the twin heritage villages of Pragpur and Garli in Himachal Pradesh, with a focus on their role in achieving climate-responsive architecture.

1.2. Objective

- To study spatial design strategies with local materials
- To analyze traditional architectural styles for investigate passive design techniques
- To evaluate the integration of cultural values and community practices. To derive lessons for contemporary architecture

1.3. Need of the Study

The rapid pace of urbanization and modernization in Himachal Pradesh has led to the gradual decline of vernacular building practices, threatening the architectural identity of traditional hill settlements such as Pragpur and Garli. Modern construction methods often overlook the climatic context, cultural values, and ecological sensitivity that vernacular architecture inherently respects. This shift not only risks the loss of heritage but also increases dependence on energy-intensive systems for comfort, resulting in higher economic and environmental costs.

1.4. Scope

The study examines the climate-adaptive architecture of the twin heritage villages of Pragpur and Garli in Himachal Pradesh. It focuses on how traditional design strategies, such as building orientation, courtyards, and roof forms, are used to respond to the local climate. The research also highlights the use of locally sourced materials for thermal comfort and seismic resilience, as well as the influence of traditional architectural styles and cultural values on the built environment.

1.5. Limitations

Every research study has its own set of limitations, and this work is no exception. The scope of the research is confined to a specific geographical area and case examples, which may not fully represent the wide diversity of vernacular practices found across Himachal Pradesh [1].

2. Methodology

2.1. Research design

This study explores architecture, sustainability, and climate-responsive design in Himachal Pradesh, this research combines qualitative and analytical approaches to study the passive design strategies of Pragpur and Garli. The following steps outline the process using qualitative data from literature reviews, case studies, field visits, and expert consultations Shown in Figure 1.

Figure 1 Rustic Alleyway with Local Shops

2.2. Tool and Technique

This study were carried out through direct field visits to document building typologies and spatial organization, this documentation was undertaken to record architectural elements, construction methods,

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and material applications, which were later used for detailed visual analysis. Secondary climate data, including temperature variations, rainfall patterns, and solar paths, were examined to contextualize the environmental setting of the study area. In addition, a comprehensive review of literature, including scholarly research and local records, provided a theoretical framework and background understanding of vernacular architecture and passive design [2].

3. Theoretical Framework

3.1. Literature Review

Literature study on Passive design strategies are widely recognized for reducing energy use and enhancing comfort by responding to local climates instead of relying on mechanical systems. Olgyay, V. (1963) in Design with Climate: Bioclimatic Approach to Architectural Regionalism. highlighted orientation, shading, and ventilation as key tools of bioclimatic design. In India, vernacular traditions—from courtyards in Rajasthan to stone and timber houses in Himachal Pradesh—show how local materials and forms achieve climatic balance. Literature highlights the need to reinterpret these traditional strategies for modern sustainable architecture Shown in Figure 2.

Figure 2 Old Rustic Stairway

Amitava Sarkar ,(2013) A study in Khyah village, Hamirpur (H.P.) found traditional hill houses to be highly climate-responsive, offering strong protection against extremes. The H.P. Government later amended bye-laws to mandate passive design features suited to local conditions. Fabrice Mwizerwa, and Mukesh Kr Gupta, in their research discussed various innovative and sophisticated-cutting-edge technologies in sustainable building design irrespective of their requirement as per the Local climate. Sandeep Sharma and Puneet Sharma, in their paper they discuss the "Study of Himachal Pradesh", highlight that traditional buildings use local materials and methods to create thermally efficient, climate-responsive, and culturally rooted designs, offering sustainability at minimal environmental cost. (Pragya, 2000). is paper documents the case studies of contemporary architect's projects with contextual response of cultural character of the place and indigenous construction techniques approaches. The collective review of various studies highlights that passive design is a fundamental pillar of sustainable architecture, ensuring energy efficiency, climate responsiveness, and cultural continuity. Key strategies such as orientation, shading, and ventilation play a vital role in aligning buildings with their local climatic conditions. Indian vernacular traditions exemplify how indigenous knowledge seamlessly balances climate, comfort, and culture. Research further reinforces that traditional hill architecture delivers thermally efficient and ecologically sensitive shelters, inspiring policy measures like Himachal Pradesh's bye-laws mandating passive features. Additionally, contemporary architects demonstrate how cultural character and indigenous techniques can be reinterpreted to meet modern needs. Altogether, the findings suggest that the future of sustainable architecture lies in integrating traditional passive wisdom with appropriate modern innovations, achieving ecological sensitivity, operational efficiency, and cultural relevance.

3.2. Case Study

3.2.1. Primary Case Study

Passive Design Strategies in the Vernacular Architecture of Pragpur–Garli, Himachal Pradesh Pragpur and Garli, twin heritage villages in Kangra Valley, showcase century-old vernacular and colonial-era houses adapted to hot summers, cold winters, and heavy monsoons. Built with adobe, stone, slate, and timber, these compact dwellings balance climate responsiveness with cultural identity.

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Located in hilly terrain with sharp seasonal variation, designs ensure winter solar gain, summer shading, cross-ventilation, and rain resilience. Settlements follow contours, forming compact clusters that stabilize slopes and conserve resources. Courtyards, veranda's, jaalis, and narrow lanes enable cross-ventilation and passive cooling, while pitched roofs with ventilating gaps release warm air.

3.2.2. Form & Materials

South-facing façades, thick adobe or stone walls, small timber-shuttered windows, and pitched slate roofs with attics provide thermal mass, insulation, and shading. Raised plinths protect against runoff. Locally sourced stone, mud plaster, timber, and bamboo ensure low embodied energy and resilience.

3.2.3. Construction Details

- **Foundations:** stone masonry in mud mortar, plinths ~50 cm high Shown in Figure 3.

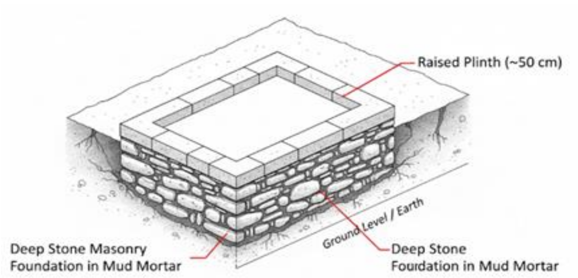

Figure 3 Stone Masonry Foundation with Raised Plinth

- **Walls:** 50–60 cm adobe; niches built into thickness for storage Shown in Figure 4.

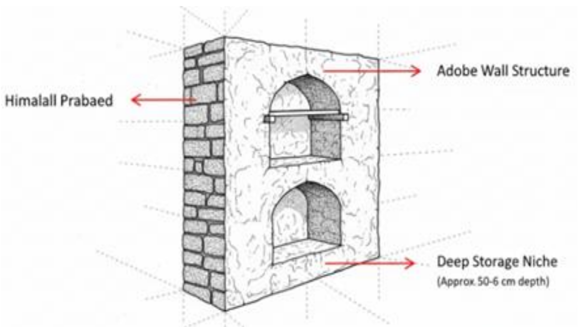

Figure 4 Adobe Wall with Storage Niches

- **Roofs:** pitched slate with timber/bamboo grids and attic insulation Shown in Figure 5.

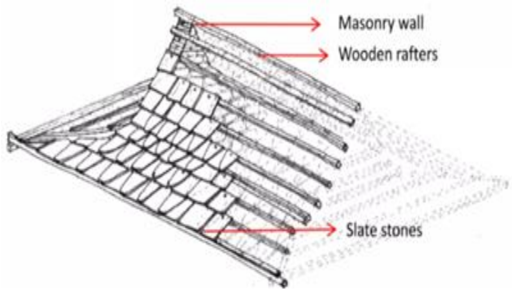

Figure 5 Traditional Slate Stone Roof

- **Openings:** <15% of floor area, deep-set to reduce heat loss/gain Shown in Figure 6.

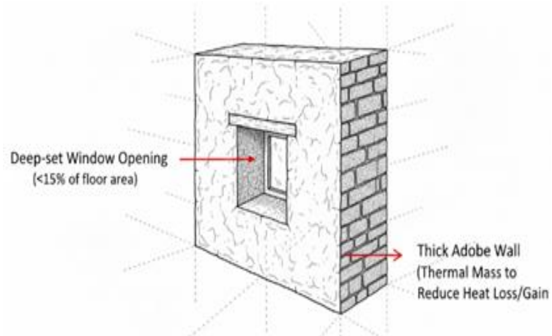

Figure 6 Thick Adobe Wall with Deep-set Window

3.2.4. Challenges

Modern RCC buildings with large, glazed facades erode passive advantages. Craft skills and material maintenance are declining. Climate change and seismic risks demand adaptive updates.

3.2.5. Conclusion

Pragpur–Garli exemplify passive design through orientation, compact massing, thermal mass, and local materials. These strategies deliver year-round comfort and ecological sustainability. Preserving and reinterpreting them can inform resilient, low-energy architecture for Himachal Pradesh and other hill regions.

3.2.6. Secondary Case Study

- **Title:** Adaptation of Vernacular Architecture in Contemporary Practices of Hilly Terrain
- **Author/Institution:** Stuti Sharma, Bachelor of Architecture student, Delhi Technical Campus (affiliated with GGSIPU).

3.3. Aim, Scope & Objectives

- To explore the importance and relevance of vernacular architecture in hilly areas.

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- To identify key features of vernacular practices: materials, techniques, climatic responsiveness, cultural factors, cost, and sustainability.
- To propose strategies by which vernacular architecture can be adapted in modern/contemporary construction for better sustainability, passive design, and local appropriateness.
- Scope is geographically focused on the hilly regions of Northern India, with special attention to Himachal Pradesh, Jammu & Kashmir, Ladakh, Uttarakhand. Limits include availability of data, and feasibility of applying all vernacular techniques in modern settings.

3.3.1. Main Findings

- **Thermal stability:** vernacular buildings provide substantially greater indoor thermal stability through thermal mass and roof time-lag. The simulation shows vernacular interiors stay within a narrower temperature band across the day compared to modern houses — providing thermal comfort without mechanical heating/cooling. This supports the literature on Himalayan vernacular performance.
- **Time-lag effect:** slate roofs + attic or thick composite roofs produce a time-lag (often > 6–8 hours) that moves external peak heat away from occupancy hours — beneficial in both hot and cold seasons.
- **Opening strategy:** smaller, shuttered windows and verandas are a deliberate trade-off — controlled solar gain in winter and shading in summer, plus lower night-time heat loss in winter.
- **Settlement morphology matters:** cluster arrangement, narrow lanes and south-facing open yards/verandas at house fronts are not incidental — they are systemic elements that improve micro-climate (capture sun, shelter from cold winds), which is visible in Pragpur/Garli morphology.
- **Modern replacements** (RCC slab roofs, thin walls, larger glazed openings) often reduce thermal mass, reduce time-lag, and thereby increase reliance on mechanical systems — consistent with broader Indian hill-regions studies.

3.3.2. Linking to Objectives & Literature

- If your objective is to quantify passive strategies transferable to twin-village retrofit guidelines, the simulated results argue for prioritizing:
- preserving/integrating thick wall systems (or retrofit with internal thermal mass),
- (ii) roof design that includes an insulated cavity/attic or insulation over the slab,
- (iii) controlled opening sizes with shutters/operable shading,
- (iv) orientation and plot planning that favour south-facing activity spaces.
- This match documented passive measures in hill-architecture studies (e.g., case studies of Khyah and other HP villages) where vernacular measures gave measurable indoor comfort without mechanical systems. (User-provided case studies you gave earlier support these principles.)

3.3.3. Unexpected or Innovative Insights (from Synthesis)

- **Settlement-level passive design — not just house-level:** Pragpur/Garli morphology (streets, courtyards, water bodies) acts as a village-scale passive strategy; this is useful if your research aims to recommend planning-level interventions.
- **Behavior + design synergy — occupants' adaptive behaviour** (verandah use, clothing, timing of activities) plays a major role; combining behavioural recommendations with small geo-technical interventions (e.g., adding thermal mass benches, passive solar dryers) yields high impact at low cost.
- **The importance of orientation** (sun path, slope orientation) for maximizing solar gain in winter and minimizing unwanted heat in summer.
- Use of thick walls, small openings, roof overhangs/verandahs for insulation and protection from precipitation.

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- **Material selection:** locally available, low embodied energy; e.g. stone, mud, wood, slate.
- **Design typologies** (e.g. Kath-kuni, Dhajji) that naturally resist earthquakes and are suited to hilly terrain.
- **Building regulations / guidelines** can support vernacular adaptation: the case study shows how regulations around ground coverage, material usage, slope stability, facade design etc. can help [3].

4. Results and Discussion

4.1. Results

The study of Pragpur–Garli alongside broader vernacular practices in Himachal clearly reveals that traditional hill architecture is not just heritage, but a sustainable design system shaped by climate, terrain, and culture. The results show that features like compact layouts, south-facing orientation, thick adobe or stone walls, courtyards, verandahs, pitched slate roofs, and limited yet strategic openings ensured passive heating, cooling, and rain protection with minimal energy use. Locally sourced materials such as mud, timber, and slate provided both thermal efficiency and ecological balance, while cultural craft traditions enriched architectural identity. However, both studies highlight growing threats from modernization, concrete construction, large, glazed facades, and loss of craftsmanship. The major outcome is that adapting rather than merely replicating vernacular strategies is the key—integrating orientation, thermal mass, ventilation, and indigenous materials with modern safety standards can create resilient, low-energy, context-sensitive buildings. This demonstrates that vernacular wisdom offers not only lessons for conservation but also a framework for sustainable and climate-responsive architecture in the hills today.

4.2. Discussion

- The study highlights that vernacular houses in Pragpur and Garli provide greater thermal stability than modern RCC structures through thick adobe walls, high thermal mass, and slate roofs with attics that create a time-lag of 6–8 hours, shifting peak heat away from occupied hours. Smaller shuttered windows, verandahs, and clustered settlement forms regulate solar gain, enhance shading, and protect from cold winds, ensuring comfort without mechanical systems. In contrast, modern thin-walled, glazed designs reduce thermal performance and increase energy dependence, echoing findings from other Himalayan villages.

For retrofit guidelines, key strategies include retaining wall mass, integrating insulated roof systems, maintaining controlled openings with shading devices, and orienting plots toward south-facing activity areas. An important insight is that passive design functions not only at the building scale but also at the settlement level, where narrow lanes, courtyards, and water bodies improve the microclimate. Additionally, the synergy of design with occupant behaviors such as verandah use, clothing, and activity timing—further enhances resilience and comfort at low cost [4].

Conclusion/Considerations

Vernacular architecture in Pragpur and Garli—thick walls, slate roofs with attics, small openings, and careful orientation—minimizes indoor temperature fluctuations, often eliminating the need for HVAC. In contrast, modern construction reduces passive performance, but retrofits that restore thermal mass, time-lag, and controlled glazing can recover efficiency. Settlement patterns also play a role: clustered layouts, narrow lanes, and south-facing yards enhance microclimate comfort. Practical recommendations include retaining/adding thermal mass (walls, benches, earthen floors), incorporating ventilated or insulated attics, insulating RCC slabs, and using controlled glazing with shutters and overhangs. Raised plinths and deep eaves protect mud walls, while interiors can benefit from masonry seating, heavy curtains, and daylighting strategies. At the settlement scale, preserving south-facing yards, windbreaks, and compact clusters supports resilience. Future research should include year-round field monitoring, wall/roof U-value and time-lag assessments, occupant comfort surveys, and energy cost-benefit modelling of retrofit strategies.

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