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Critical Analysis & Uplifting of Rural Existing House & Its Surrounding in Accordance with Sustainability*

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Abstract

In the twenty-first century, sustainability has become a more prominent guiding concept for planners and architect s, who understand its critical role in tackling the complex problems relevant to build environment. But sustainability a lso includes energy efficiency and economic stability in addition to environmental issues.
Through the lens of sustainability, this study critically examines a rural residential house at Swat Pakistan, and its surroundings. Examining the current framework closely, the paper pays attention to its climate responsiveness, contextual relevance, and indigenous building supplies and methods. It also looks at how the residence affects society more broadly in its nearby neighborhood.

This research aims to identify these problems, explore their underlying causes, and propose long-term solutions.
By comparing the Swat house with the Solar Ark project in Tibet, China, which exemplifies advanced sustainable practices, the study highlights significant differences in design and effectiveness. The Solar Ark employs modern techniques, including passive design and eco-friendly materials, contrasting with the Swat House's challenges in climate adaptability and spatial efficiency. The research advocates for integrating modern sustainability practices, such as optimizing natural light and improving drainage, to enhance the performance and livability of rural dwellings in Pakistan. Recommendations include adopting solar energy solutions, developing a renovation framework for structural stability, and blending traditional practices with contemporary technologies. This study contributes to the discourse on sustainable architecture and offers actionable insights for uplifting rural housing in challenging climates.
Keywords: Sustainability, Climate responsiveness, Contextual relevance, Indigenous building, Passive design and Solar energy.

JEL Classification Code: O18, O21, Q01, R21, R58

1. Introduction

This study critically examines a residential building in Matta Swat and its surroundings, focusing on sustainable practices (Shahana Janjua, 2019). The house constructed using locally sourced materials resilient to the area's climate challenges and environmentally benign (Seolah Park, 2024), helps reduce carbon emissions compared to contemporary high-tech solutions. Designed organically and built with local methods, the house aims to meet the occupants' needs sustainably.

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However, despite the sustainable building methods and material selection (Haşim Altan, 2016), the house faces challenges related to its organic layout and orientation, as well as its use of natural light (Lin Chen, 2023). Issues such as incorrect drainage patterns and blocked south-facing areas jeopardize the surrounding ecosystem's balance. Additionally, the underutilization of sunlight has led to the deterioration of materials like wood and mud, increasing the risk of structural damage (Joana Correia Prata, 2022).

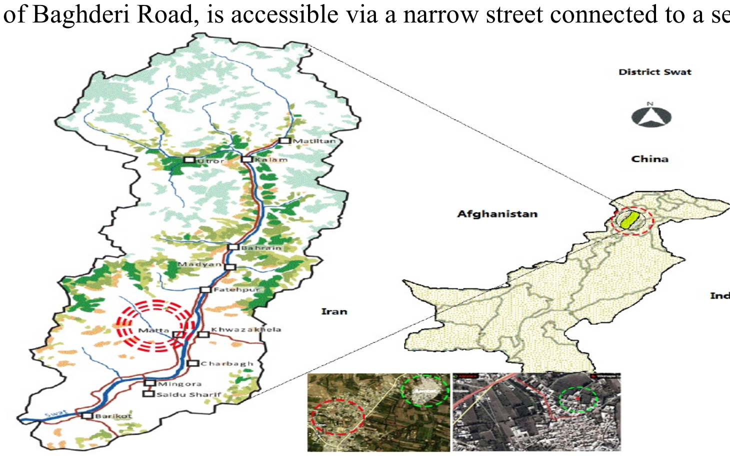
This research aims to address the identified issues by critically analyzing the current house, identifying problems, and conducting situational assessments using sustainable criteria. Understanding the underlying causes of these issues allows for the formulation of strategic goals to mitigate risks to environmental integrity, human comfort, and overall quality of life. The goal is to create architectural interventions informed by sustainability principles to prevent ecological degradation from becoming a severe issue (by Iasmin Lourenço Niza, 2023).

This study evaluates the sustainability of an existing structure by analyzing construction materials, energy efficiency, and structural durability. Through surveys, observations, and local consultations, the research explores the integration of vernacular construction techniques and indigenous materials with passive strategies. A detailed analysis aims to revitalize the structure, protecting it from environmental threats and enhancing energy efficiency. Active strategies, like recommending PV panels, are also considered to meet future energy demands. The goal is to improve building comfort and efficiency by incorporating local materials and technologies, addressing challenges in rural areas with harsh climates.

While this research concluded that there are significant differences in the design, construction, and sustainability practices of Pakistani rural dwellings when compared critically to a sustainable evaluation based on a case study from China. Pakistani rural residences frequently deal with problems like poor climate adaptability, insufficient drainage, and inefficient spatial layouts. The case study chosen in China, on the other hand, shows a great emphasis on sustainability using eco-friendly materials, passive design principles, and creative, energy-efficient building methods. This comparison highlights how Pakistani rural housing could be made better by incorporating Chinese sustainable design concepts, which would improve resource management, environmental performance, and general livability.

1.1. Geographical Location and Accessibility

The site is in Sambat Matta, the second tehsil of Swat district, at coordinates 34°45'0"N 72°21'0"E, with an altitude of 939 meters. Situated about 25 kilometers northeast of Mingora, it lies near Matta Bazaar along Baghderi Road. The village is surrounded by green hills, fields, and the Swat River and is renowned for its peach and apple orchards, as well as its Buddhist heritage. Sambat Matta also serves as an educational hub for upper Swat (Manzoor Ahmad Badar, 2017). The residence, located half a kilometer east of Baghderi Road, is accessible via a narrow street connected to a secondary road.



Source: (Nawaz, Yousafzai, Shah, Xin, & Ahmad, 2021)

Figure 1. Google map highlighting Sambat Village in Matta Tehsil, district swat.

1.2. Aims and Objectives

a. A critical evaluation of rural housing in Pakistan with a sustainability assessment based on a selected case study from China.

b. Development of strategies to mitigate environmental risks, enhance comfort, and improve the structural stability of the house.
c. Creation of practical recommendations, inspired by the Solar Ark case study, for the renovation and uplifting of the house.
d. Recommendations based on Analysis and findings.

2. Literature Review

2.1. Sustainable Buildings

According to the definition of sustainable buildings, "the results of an applied sustainable way of construction sustainability approach to create a built environment that should be focused on high-performance green buildings" (Kibert & Construction, 2012).
A green building provides specified building performance requirements while minimizing disturbance to improve the functioning of the local, regional, and global ecosystems, both during and after its construction and specified service life (Walker & Salt, 2012). The United States Environmental Protection Agency (US EPA) defined "green or sustainable buildings as creating a healthy, resource-efficient model of construction, renovation, operation, maintenance, and demolition" (Aghdam, Rad, Shakeri, & Sardroud, 2018).

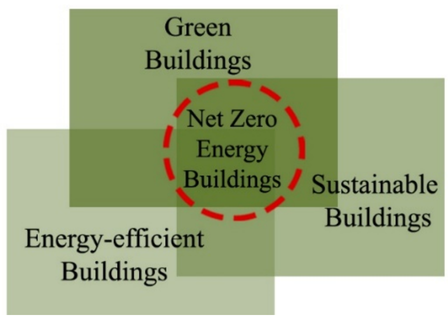


Figure 2. Net zero energy buildings

2.2. Strategies to address Climatic change in terms of Sustainability

One effective strategy for addressing climate change is to optimize the construction sector for energy efficiency (Irfan, Abas, & Saleem, 2018), (Xiao et al., 2023). Energy consumption and greenhouse gas emissions can be considerably decreased by creating energy-efficient buildings, which can be accomplished by implementing strategies like installing renewable energy sources and adopting durable materials. Retrofitting buildings can reduce energy consumption by 57% (Cai, Dong, Chen, & Gong, 2022). Energy efficiency improvements in a Turkish school resulted in a 60% reduction in energy use and CO2 emissions (Jiang, Zhang, Wen, Valipour, & Nojavan, 2022).

Energy-efficient, sustainable results can be obtained by combining conventional techniques with contemporary equipment. Subsequent research endeavors will try to refine these strategies and investigate novel materials to improve energy efficiency under varied climatic conditions (Ullah, Zhang, Ye, Ali, & Cong, 2024).

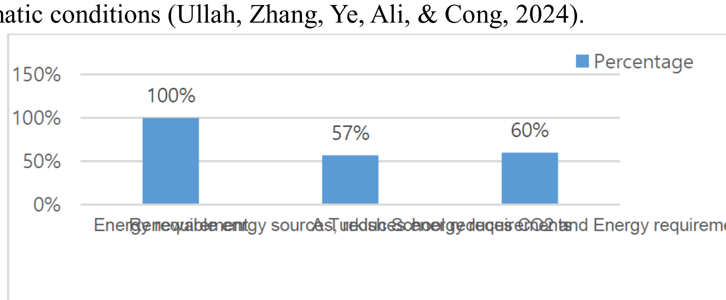


Figure 3. Energy consumption and greenhouse gas emissions can be reduced by using renewable energy sources can cut energy use by 57**%.** Energy efficiency improvements in a Turkish school reduced energy consumption and CO2 emissions by 60%.

2.3. Sustainable aspects of Buildings

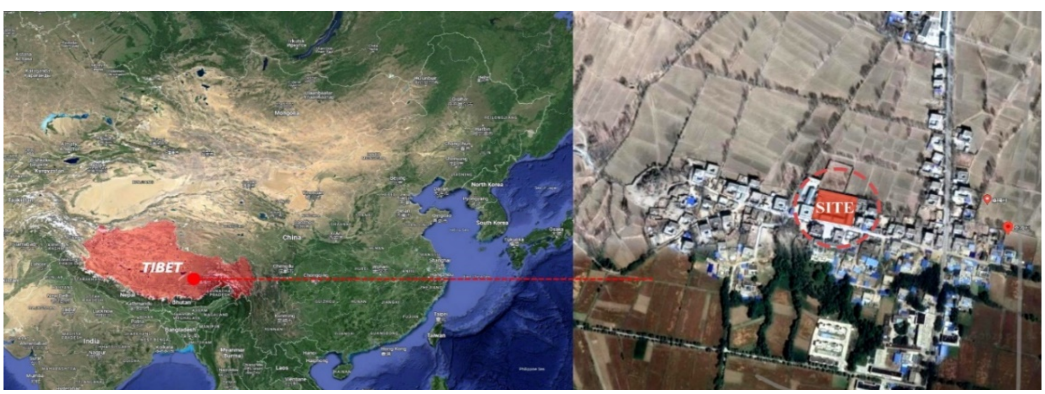
Aspects of Sustainability has been identified as having a role to play in making building activity more sustainable. It may reduce building waste, but landscaping and design will determine how it affects the environment. Transport, in comparison to traditional buildings, may have a negative impact on the environment. Sustainable aspects of prefabrication are as Follows:

a. Environmental Aspects includes: Operational energy use, transport energy, embodied energy, waste, water, and species index per hectare.
b. Economic Aspects includes: Reduction in construction costs, construction time, and defects on completion.
c. Social Aspects: Sometimes fulfilling energy demands is a challenge in extreme cases, like some of the agencies are associated with low quality housing and social exclusion; this may be the root cause of the housing sector in terms of sustainability (Kaparaju, Howlett, Littlewood, Ekanyake, & Vlacic, Eds., 2019).

2.4. Project Case Study Sunshine Ark-Sangga Village Kindergarten

Objective: Renovate a 1970 courtyard house to create a kindergarten and skill training center, promoting rural revitalization while preserving Tibetan culture and traditional village style.

This project aims to address the educational needs of 30 preschool children in Sangga Village while also meeting the community's demand for skills training and education. The transformation of the courtyard into a multifunctional educational building integrates the protection of traditional villages with the construction of new facilities. The model combines existing structures with standardized building products, making it both flexible and replicable, offering a new approach to rural revitalization in Tibet (Solar Decathlon, 2024).



Source: (Solar Decathlon, 2024)

Figure 4. Tibet Plateau AMSL 3000-5000m **Figure 5.** Sangga Village, Shannan, Tibet Autonomous Region, China

2.5. Project Overview

The project aspires to set an example as a zero-energy building within Tibet's unique local context, creating a functional and vibrant campus that will inspire both children and the community. The transformation of traditional courtyard buildings into small-scale educational facilities is expected to serve as a replicable model for similar initiatives in other traditional villages across Tibet.

Source: (Solar Decathlon, 2024)

Figure 6. Aerial view of the Sun shine Ark

2.6. Project Data and Technical Specifications

Table 1: highlighting project data and technical specifications

Project Information's	Technical specifications R-Value
Location: Sangga Village, Shannan, Tibet Autonomous Region, China.	Wall: R-21
Climate Zone: 5C	Roof: R-31
Lot Size: 0.695 acre	Floor: R-25
Building Size: 22942.2 ft2/single story	Windows: U-0.19 HVAC
Occupancy: 50 people	High-efficiency coupled heating system of gas boiler and air source heat pump.
Energy Performance: EUI w/o PV: 37.66(kBtu/ft2/yr) EUI w/ PV: -25.74(kBtu/ft2/yr)	Ventilation system with Heat Recovery On-Site PV
Construction Cost: 805,414 USD	427,038.28 kWh/yr w/o PV on existing roof
Maintenance Cost: 223,180 USD for 60 yrs	589,162.76 kWh/yr w/ PV expanded north
Embodied Carbon to grave: 391 kg CO2e/m2	

Source: (Solar Decathlon, 2024)

2.7. Design Strategy

The project faces the challenge of integrating new forms, technologies, and concepts into a traditional village environment. The design is guided by five objectives: respecting and revitalizing the site, balancing green conservation with daily habits, meeting zero-energy requirements while adapting to the local economy, benefiting both children and the broader community, and ensuring the replicability of the transformation for other traditional villages.

2.7.1. Architectural Design

The project involves modest renovations using prefabricated light steel structures for solar corridors and classrooms within the courtyard. The transparent glass solar corridor connects all parts of the building, fostering interaction among children. The classroom modules are positioned southward, connected to the inner courtyard, breaking traditional layouts to encourage outdoor activities.

2.7.2. Engineering and Efficiency

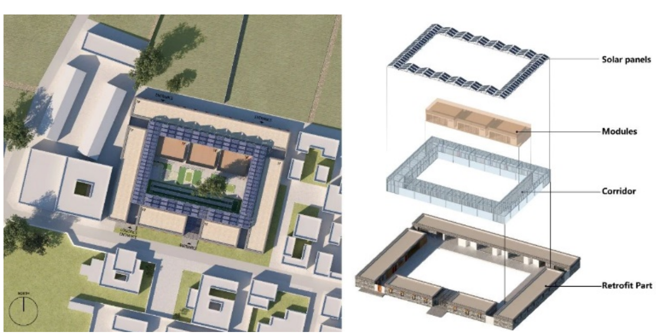
The building renovation preserves the existing structure and enhances it with standardized light steel components. New constructions use prefabricated assemblies for efficiency and cost-effectiveness. The building integrates efficient systems such as a sewage treatment system tailored to Tibet and a heating system combining air source heat pumps with underfloor heating. The envelope design utilizes local agricultural straw for insulation, reducing energy consumption and embodied carbon emissions. The building's energy efficiency is significantly improved, and it can function as a small-scale power station.

2.7.3. Environmental and Health Considerations

The design addresses the local climate challenges, such as drought and frost, with strategies like water recycling and foundation insulation. The building's lifecycle carbon emissions are minimized using local materials and prefabricated structures. Health considerations include air quality control, UV-sensitive films for optimal lighting, and sound-absorbing materials to minimize noise during children's activities.

2.8. Technical Strategy

The project aims to preserve traditional village architecture, inherit Tibetan culture, and provide multifunctional educational spaces. The strategy includes retaining the traditional courtyard layout, strengthening the existing structure with light steel components, and harmoniously integrating new and old buildings. The envelope structure uses local straw for insulation, and advanced glass technology ensures a comfortable indoor environment. The overall approach emphasizes ecological sustainability and cultural heritage preservation.



Source: (Solar Decathlon, 2024)

Figure 7. New and old building combination strategy

Figure 8. Hand model display

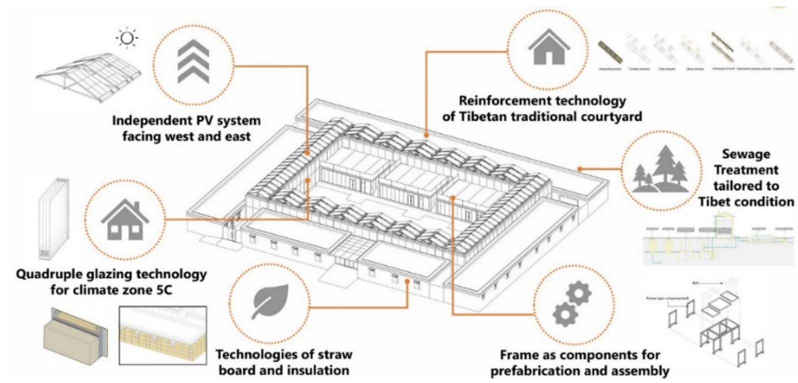
2.9. Challenges, Innovation Preservation & Renovation

Table 2: highlighting project challenges, innovations and renovations

Challenges	Innovation preservations and Renovations
How can we construct kindergartens efficiently and economically?	Maintain the layout of the existing building and its surroundings
How to preserve the nature of children?	Preserve existing building facades and materials
How can we take advantage of the existing building?	Expand the space inward without destroying the original building
How to address resource scarcity and pollution?	Fusion of new technology image and Tibetan style

Source: (Solar Decathlon, 2024)

2.10. Applied technology for the Uplifting of Structure and Energy demand



Source: (Solar Decathlon, 2024)

Figure 9. Applied technology for the uplifting of structure and energy demand

3. Research Methods and Materials

3.1 Investigation Site and Data collection

The selection of the case study, which focuses on a specific house in Swat, Pakistan, chosen for its exposure to certain climatic conditions, such as summer monsoons and winter cyclonic currents from the Mediterranean, is the first step in the research approach. A thorough examination of climate effects, including variations in temperature, yearly snowfall, and rainfall patterns, is made possible by this site. Three primary components make up data collection, which is crucial. Local meteorological departments provide climate data, which includes historical weather patterns, temperature, pressure, and humidity. To ensure accuracy, satellite imagery and site surveys are used in conjunction with GPS coordinates, topographical features, and vegetation descriptions. Furthermore, the house's building materials—mainly timber and sedimentary stones—are examined for their thermal characteristics and sustainability.

The second step in the thorough study of the gathered data is to evaluate the building material's thermal and structural efficiency. A sustainability assessment follows, which focuses on the materials' and construction method's long-term viability and environmental impact. The climatic and environmental impact analysis looks at how the local climate affects the longevity and livability of the building. A community and societal impact evaluation also consider the wider cultural, economic, and social effects of the house design and construction on the local populace.

Lastly, the data are summarized in the results and conclusions to shed light on the difficulties that rural housing faces due to weather conditions and the possibility of better building techniques. This thorough approach combines material, climatic, and spatial data and provides insightful recommendations for sustainable housing solutions in similar environments.

3.2. Selection of cases and comparative evaluation for sustainability assessment

This research draws inspiration from a case study in Tibet, China, featuring the Solar Ark design, which has been selected as a relevant comparison to a rural house in Swat, Pakistan. The Pakistani residence has been thoroughly evaluated for its strengths and weaknesses, while the Solar Ark case in Tibet has been reviewed for its integration of traditional and modern construction techniques. These integrated approaches serve as a benchmark for improving the Pakistani house, with a focus on maintaining social, contextual, and economic sensitivity. The research aims to incorporate both digital and sustainable construction methods to enhance the residence's functionality and sustainability.

The methodology is designed for real-time applicability, ensuring reproducibility and minimal assistance requirements. Ethical considerations involve engaging with residents to validate findings and provide sustainable recommendations.

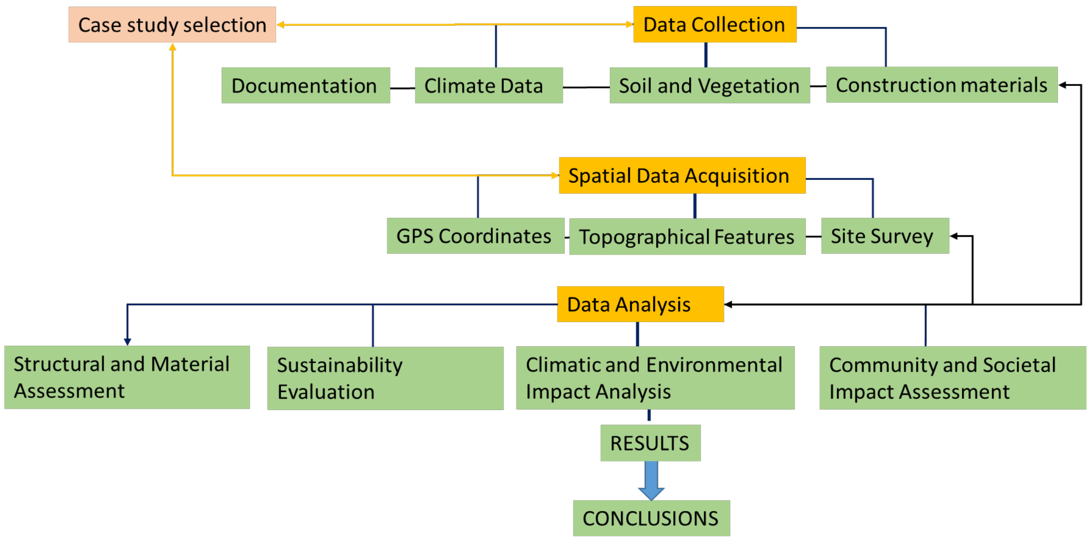


Figure 10. Research methodology and flow diagram

4. Result and Discussions

4.1 The House

4.1.1. Planning (Ground Floor Plan)

The spatial planning of the residence follows a grid pattern, with double wooden columns and timber planks fixed over them. Two major bedrooms are located on the north side, with one storage room facing south. Small bath spaces are included within these rooms. Another bedroom, complete with a bathroom, is situated at the end of the east verandah. The kitchen, later added to the residence, is positioned on the west side. The west verandah also features an open fireplace, while a summer kitchen is located on the south side. All rooms and spaces revolve around a central courtyard, a traditional architectural element.

The verandahs on the east, west, and north sides face south and are designed according to the users' needs. These verandahs are significantly wider than the rooms, measuring 14–15 feet wide and up to 35 feet in length. They serve multiple purposes: storing grain in wooden boxes during crop seasons, maximizing daylight utilization, and providing seating and dining areas. These arrangements reflect the cultural traditions and practical requirements of the users.

The design of the residence is deeply rooted in cultural practices, emphasizing privacy, verandah seating, and the central courtyard. Constructed by local masons and skilled laborers, including specialized wooden workers and stone masons, the house was not specially designed by architects. The focus was on using thermally sound and comfortable materials suitable for the harsh climate of the region.

4.1.2. Climatology

Swat, situated in the Temperate Zone within the northern mountainous ranges of the Indo-Pak subcontinent, experiences weather influenced by several climatic factors, including latitude, altitude, and rain-bearing winds such as cyclones and monsoons (Ullah, I., & Zahid, M. 2022). During the summer, the region, including Sambat Swat, is predominantly affected by monsoon winds, while in winter, it experiences the impact of cyclonic currents originating from the Mediterranean Sea. The temperature in Swat can reach a maximum of 35°C in the summer and drop to a minimum of -5°C in the winter. The region goes through distinct seasons, including winter, pre-monsoon, monsoon, and post-monsoon.

Source: (Ullah, H., Shah, S. M. A., Iftikhar, S., & Ammar, M. F. 2024)

Figure 11. Floor Plan Highlighting spatial planning and its Relationship.

4.1.3. Construction Techniques

The construction techniques observed in this project reveal that the house's design and construction were carried out with a smart and sustainable approach. The use of purely indigenous materials and simple construction methods, managed by local masons, highlights the resourcefulness of the builders. Materials were transported from local quarries using donkeys, ensuring sustainability. Despite these sustainable practices, the house has a life span exceeding 70 years.

However, some construction issues present non-sustainable aspects. For instance, materials were used without proper management or measurement, resulting in inconsistencies, such as large stone blocks being placed at the top of walls instead of the bottom. Additionally, while the structure is stable, the heavy mud on the roof poses a significant threat, particularly during the rainy season, as it adds a considerable dead load that could compromise the structural timbers.

The local masons aimed to construct a house that met the residents' needs, but they were not trained to follow standard construction practices, leading to these structural challenges.

Figure 12. Showing primary material highlighting the sedimentary stones

4.1.4. Foundation Detail

A foundation was excavated to a width of 3 feet and a depth of 3 feet 6 inches, with the soil compacted. Stone masonry was employed for the foundation, without mortar or steel reinforcement. This technique was extended up to the natural surface level and finished with the same method until the floor level. After completing the floor level, mud mortar was added with stone, extending up to the roof.

4.1.5. Structure and Methodology

The structure features thick, heavy stone masonry walls, 18 inches in width, which support the entire building. Wooden beams are also used in the construction. The columns consist of straight members connected at their ends by hinged joints to create a stable framework.

The current condition of the structure is compromised due to climatic factors. Rainwater collected on the roof and the mud layer covering it absorb this water, causing significant damage to structural elements such as the wooden planks. To mitigate these issues, local methods involve spreading salt over the roof’s mud layer to prevent vegetation growth and reduce water absorption. This approach is a form of sustainable practice adapted to the local conditions.

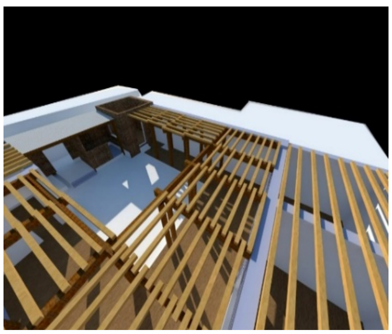


Figure 13. 3D-view highlighting the placement of wood as a structural element
Figure 14 and 15. Perspective Highlighting the column and beams as A structural element

4.1.6. Masonry Detail

The exterior and interior walls of the building are constructed from sedimentary stone sourced locally, with walls measuring 18 inches in thickness. These walls are built using mud mortar mixed with bhoosa (dry grass). Subsequently, a kitchen was added to meet the residence's needs, which is constructed from bricks. The interior walls and the inner surface of the exterior walls are plastered with mud, and the final finishing is completed with lime.



Figure 16. Highlighting Masonry/stone at exterior. **Figure 17 and 18.** Highlighting mud/cladding at interior

4.1.7. Opening Door and Windows

All the windows in the residence are designed as primary sources of light and ventilation, with their size and placement carefully considered to meet daylight, privacy, and ventilation needs. Window dimensions vary, with widths starting at 7 feet and heights up to 8 feet, some featuring ventilators that extend up to 9 feet. Given the region's harsh climatic conditions, the window panels are covered with wood rather than glass.

The windows are rectangular, reflecting local architectural style, and are oriented to face and open into the verandah and courtyard to maintain privacy. The use of glass on the inner side of the windows is essential for diffusing light, reducing glare, and minimizing direct light and radiation.

4.1.8. Roof

The roof is specially designed to address both summer heat and winter cold through passive techniques. It is covered with a 12-inch thick layer of compacted mud, without mortar, and a plastic sheet membrane is placed between the mud layers to prevent seepage, particularly during the rainy season. This construction method has proven to provide excellent thermal comfort in both extreme summer and winter conditions.

However, there is a risk of water absorption on the roof, which can impact the stability of the structure. To mitigate this issue, inhabitants in the region have adopted the use of galvanized corrugated sheets placed over the roof to offer additional protection and prevent damage.

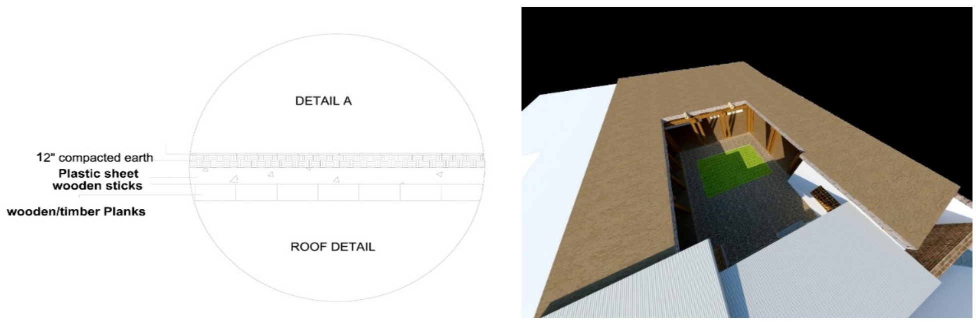


Figure 19. Roof top and Typical Section of a roof and highlighting the details in slab

4.1.9. Thermal Comfort ability

In this research, it was observed that while there is a lack of natural light and ventilation in the house, it remains psychologically and thermally comfortable due to the materials used, particularly the mud-covered roof. The roof plays a crucial role in thermal regulation, as it accounts for up to 50% of heat gain and loss. The combination of stone walls with mud mortar and the insulating mud roof helps maintain a comfortable interior environment, directly influencing the occupants' psychological comfort.

Ventilation is a key aspect of the house's design, with openings such as ventilators, windows, and doors oriented towards the central courtyard. There are no openings facing the exterior of the house, limiting direct fresh air intake from the prevailing wind directions (north-south or south-north). This design prioritizes privacy, with streets surrounding the building on three sides. While this configuration may offer some protection against the harsh winter climate, it can lead to suffocation in summer. Furthermore, the construction of a south block in the neighborhood before 2007 has obstructed the direct southerly winds, which previously contributed to the stack effect in the central courtyard.

Natural daylight is another crucial element, and although the house has three primary sources of direct light—east, south, and west—the south-facing light is obstructed, leading to insufficient natural illumination. Consequently, artificial lighting is used to compensate for the lack of natural light, which is necessary to meet the lighting needs of the space.

The architectural design includes a central courtyard, which serves as a landscaped area with trees and flowers. This courtyard is integral to the traditional architectural style, providing a space for fresh and cool breezes. The verandahs, which surround the courtyard on all sides, connect the central courtyard to the various rooms, enhancing both the aesthetic appeal and functionality of the space.

4.1.10. Waste Management/ Recycling

Waste management in the house involves directing all waste to a nearby space known locally as "deeran." This area collects both household waste and solid waste from the animal farm, which includes two buffaloes. The combined waste is then used as urea for fields and gardens, representing a natural and sustainable practice compared to artificial urea, which is less ecological and potentially harmful to health. While this recycling method for agricultural use is effective, the management of toilet waste is inadequate. Unlike the animal waste, which is well-recycled, the solid waste from toilets lacks proper facilities such as septic tanks. Instead, it flows directly into adjacent drains connected to canals, representing a non-sustainable and inefficient waste management solution. Overall, there is a lack of a structured sewerage system or waste management infrastructure, leading to inadequate handling of toilet waste.

4.2. Immediate Surrounding

4.2.1. House its four Sides

All three sides are blocked: south, north, and west. There are residential blocks only on the on the east face, which is open, but there is a street, so for privacy, there are no openings towards the east.

4.2.2. Levels and Vegetation

The south face of the building, which is intended to receive direct daylight, is obstructed by a newly constructed structure. This building, which has a ground floor and a first floor, blocks the sunlight that would otherwise reach the south corner of the courtyard. The new building is elevated about 3 feet above the natural surface level, whereas the existing building is elevated only 1 foot. Consequently, the new building, with its total height of approximately 26 feet, significantly surpasses the height of the existing building.

Additionally, the existing building is situated 2 feet below the main south-facing front street, which provides the primary access to the house. This elevation difference creates a psychological discomfort for the occupants. Overall, the height of the existing structure reaches up to 12 feet, contrasting sharply with the height of the new building.

The east face of the building block presents a blank wall with no openings, as it is entirely bordered by lush green fruit gardens. When exiting the central courtyard and heading toward the south street, a turn eastward leads to an opening in the garden, which is densely vegetated.

4.2.3. Rainwater Drainage Pattern

Rainwater from the roof collects in the central courtyard and, during heavy rainfall, flows from the north side to the south. It is then channeled through a narrow drain to the South Front Street, eventually reaching a main drain, which is a small canal on East Street. Additionally, water from dishwashing, kitchen waste, and washrooms is also directed to this main drain. A significant issue with the drainage system is that when the roof collects water, it accumulates in the central courtyard and struggles to drain properly due to the lower elevation of the house on all four sides. This causes inefficiencies in the drainage process and can lead to water stagnation.

4.2.4. Link with Immediate Surrounding/Context

In the context of the existing residence, the three sides North, West, and South are surrounded by other buildings, while the East side opens into an apple garden. The house primarily connects with a narrow front street on the South, which is accessible via the East Street that intersects with the South Street. The immediate surroundings consist of a residential neighborhood and a relatively large community. To the East, a row of lush green trees casts shadows on the East-facing wall, contributing to the deterioration of both wall materials and roofing wood. According to local, these shadows, caused by the rising sun, are a significant factor in material degradation and block direct access from the East.

4.2.5. Planning/Organic or Planned

The selected house for this research exhibits an organic planning approach. The construction does not strictly adhere to functional requirements but instead appears to have been designed around the existing site constraints. The builders, likely local masons or the owners themselves, seemingly extended the house within the boundaries of the site, rather than following a structured plan. The open-to-covered ratio is not optimally followed, and functional spaces were added as needed within the existing site lines. This organic approach resulted in a structure that evolved over time, with later additions and extensions, particularly on the south-facing side.

4.2.6. Sectional 3D Views and Details

4.2.6. Sectional 3D Views and Details

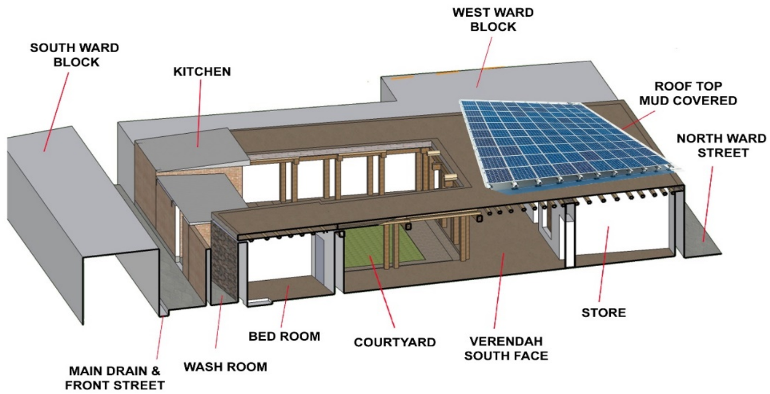


Figure 20. A sectional 3D-View Highlighting details, elements and spaces of the selected house.

4.3. Future work and Directions

a. Life Cycle Analysis (LCA)of Low Carbon Emission structure.
b. Mathematical Analysis & Carbon Emission based on the Life Cycle assessment of existing structure.

Standard: *Standard for Building Carbon Emission Calculation (GB/T 51366-2019)*
Total carbon emission of the whole building life cycle:

$$C = C_{MP} + C_{CM} + C_T + C_{Con} + C_{OP} + C_{Decon}$$

Where C= Total Carbon Emission, C mp is material + Ct is transportation + C con is construction or crafting + C op is use or operation + C Decon is Dis assembling & Reassembling Phase.

c. Detail carbon evaluation using BIM simulation and advanced digital strategies to further integrate these indigenous techniques.

5. Conclusion

The research critically evaluates a rural house in Swat, Pakistan, with a focus on sustainability, climate responsiveness, and contextual relevance. The study reveals that while the house employs indigenous materials and construction techniques conducive to sustainability, several significant issues threaten its long-term viability and comfort. These issues include poor drainage control, inefficient spatial layouts, inadequate natural light, and improper orientation, all of which compromise the environmental and structural integrity of the house.

The comparison with the Solar Ark project in Tibet highlights that while both case studies aim to incorporate sustainable principles, the Solar Ark employs more advanced techniques, such as passive design, eco-friendly materials, and energy-efficient systems. In contrast, the Swat house, despite its traditional construction methods, suffers from challenges like poor climate adaptability and insufficient drainage systems. This comparison underscores the need for improvements in rural Pakistani housing, particularly by adopting design principles from more sustainable models.

This research concludes that integrating modern sustainable practices, such as using prefabricated materials, optimizing natural light, and addressing drainage and energy efficiency, can significantly enhance the sustainability and livability of rural dwellings in Pakistan. Furthermore, the adoption of solar energy solutions, as demonstrated in the Solar Ark project, could mitigate energy challenges and reduce carbon emissions. By addressing the identified structural and environmental issues, the research provides a framework for renovating and uplifting traditional homes, preserving their cultural value while ensuring they meet modern sustainability standards. This study contributes to broader discussions on sustainability in architecture and offers practical solutions for improving rural housing in challenging climates.

This research work concluded the three major sustainable and indigenous techniques to enhance energy efficiency and sustainability while investigating the relevant work done in the sector for the uplifting and revitalization of existing buildings are:

i. Solar energy solutions to mitigate energy consumption and lower carbon emissions.
ii. Develops a framework for the renovation and uplifting of existing residential homes.
iii. Blending indigenous construction practices with modern digital strategies.

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