Computational Analysis of Model Houses of Da Kali KOR in Matta Swat

Habib Ullah[1], Syyed Mansoor Ali Shah[2], Sehar Iftikhar[2], Malik Fazal Ammar[3]
[1] School of Architecture, Southeast University, Nanjing 210096, China
[2] Department of Architecture University of Engineering and Technology Peshawar, Abbottabad campus, KP, Pakistan.
[3] Department of Architecture and Town Planning University of Kotli, Azad Jammu and Kashmir, Pakistan
***Correspondence.** Syyed Mansoor Ali Shah – smansoorshah@uetpeshawar.edu.pk
Citation | Ullah. H, Shah. S. M. A, Iftikhar. S, Ammar. M. F, "Sustainability Analysis. House 'Da Kali KOR' in Matta Swat", IJIST, Vol. 06 Issue. 03 pp 1469-1487, Sep 2024
Received | June 17, 2024 **Revised |** Sep 19, 2024 **Accepted |** Sep 20, 2024 **Published |** Sep 21, 2024.

Natural disasters such as floods and earthquakes, exacerbated by global warming and environmental degradation, pose significant challenges for modern architecture. This study critically evaluates a rural residential house in Sambat, Matta Swat, known locally as "da Kali KOR," focusing on its sustainability, climate responsiveness, contextual relevance, and use of indigenous materials and methods. It stands out for its in-depth analysis of a rural dwelling's sustainability impact, a topic often overlooked in architectural research. Through detailed site surveys, climate analysis, and assessments of materials and structures, the study identifies issues like poor drainage control, inefficient orientation, wasteful space utilization, and user discomfort, which threaten environmental integrity and human well-being. By exploring the root causes of these problems, it proposes sustainable solutions for long-term improvement. By shedding light on these issues, the research contributes valuable insights to the discourse on sustainability in architecture and urban planning, offering guidance on enhancing rural residential design for better environmental and human outcomes.

Keywords. Sustainable Housing, Sustainable Architecture, Traditional Housing, Passive Design Techniques, Thermal Comfort.

Introduction.

Sustainable architecture plays a crucial role in tackling environmental challenges and promoting resource efficiency [1]. It integrates eco-friendly practices into building design to minimize energy consumption and improve occupant well-being [2] These principles are based on passive design, using natural elements like sunlight and wind to regulate indoor comfort without relying heavily on mechanical systems [3]. This strategy is important in rural architecture where modern conveniences may be limited.

Traditional building practices offer sustainable architectural solutions by leveraging indigenous knowledge, adapting to local climates, and using locally sourced materials [4]. Using locally sourced materials like stone and timber in vernacular architecture reduces carbon emissions and ensures buildings blend well with their surroundings [5] Vernacular architecture aligns with local climate conditions to achieve natural thermal comfort [6]. This study critically examines a residential building in Matta Swat and its surroundings, focusing on sustainable practices. The "da Kali KOR" house in Sambat, Matta Swat.

Objectives of the Study.

- Critical analysis of the house, investigation of the issues, and assessment through sustainable criteria.
- Formulation of strategies to reduce risks to the environment, comfortability, and structural stability.
- Creation of architectural interventions based on sustainability principles to prevent ecological extinction.
- Data analysis through computer-based tools and Recommendations based on analysis and findings.

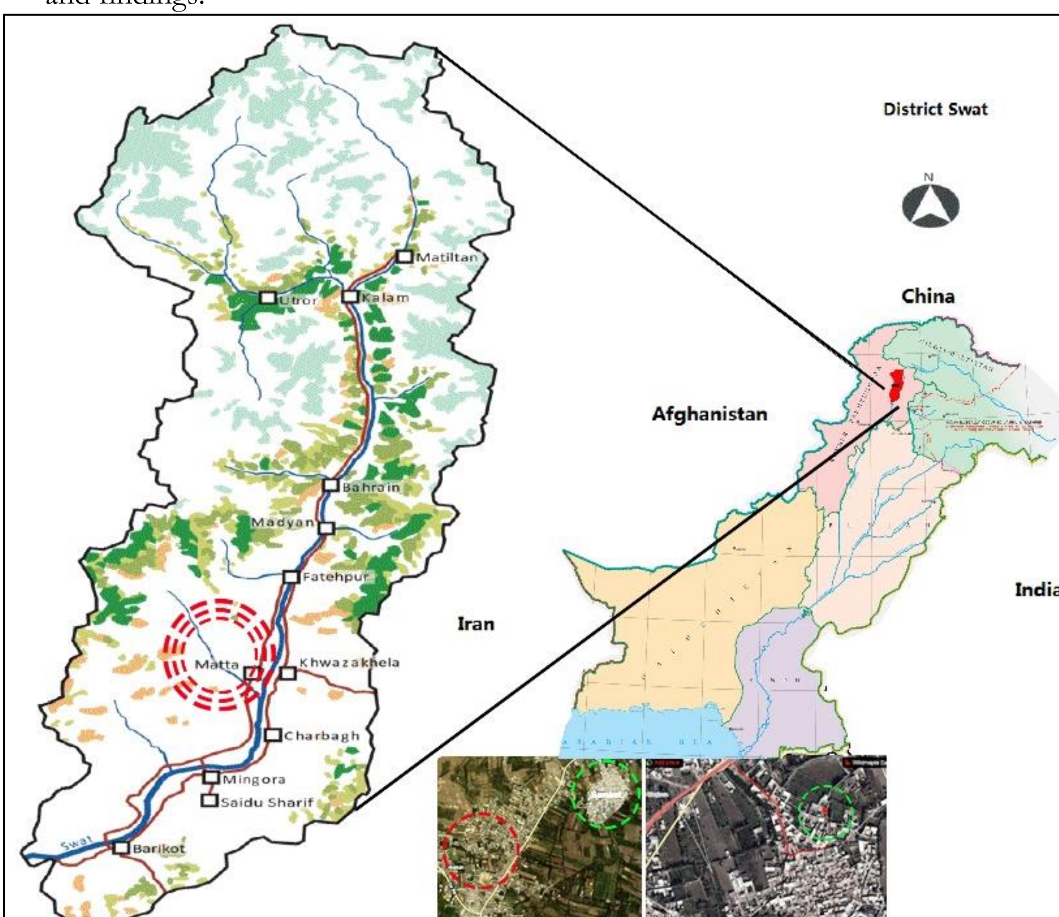

Figure 1. Map highlighting matta tehsil in district swat, Pakistan

Geographical Location.

Sambat Village, located in the second tehsil of Swat district, Matta, is positioned at coordinates 34°45'0"N 72°21'0"E, with an altitude of 939 meters (3083 feet). Approximately 25 kilometers northeast of the main Mingora city, it lies adjacent to the Matta Tehsil Bazaar along Baghderi Road [7]. The village is characterized by lush green hills interspersed with fields along the banks of the Swat River. Known for its verdant valleys, fruit orchards (notably peach and apple), and crops such as rice and maize, Sambat Matta also retains remnants of its Buddhist heritage. Serving as an educational hub for the upper Swat region, the village hosts several schools and colleges [8]. Figure 1 shows a map of Matta Swat, Pakistan.

Accessibility.

The residence is in the densely populated rural village of Sambat, Matta Swat, roughly half a kilometer east of the main Baghderi primary road, which has a width of 30 feet. A secondary road provides access to the house, connecting to a narrow street that leads directly to the residence [9]. This setup may raise concerns regarding the ease of transport, especially for larger vehicles or during emergencies, and could impact the efficiency of resource delivery or waste removal services. Figures 2 and 3 highlight macro and meso-level maps.

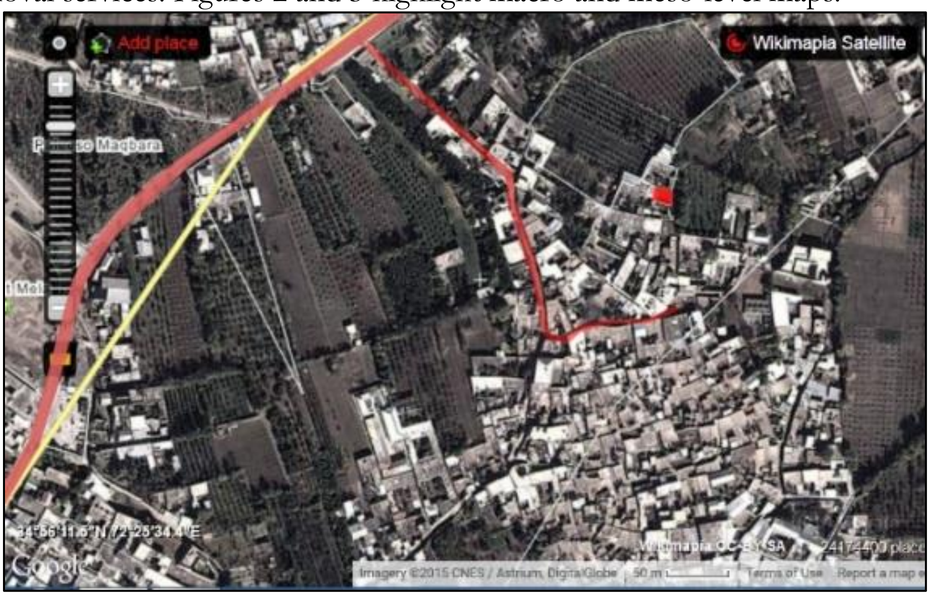

Figure 2. Google map highlighting access to the site on macro level

Figure 3. highlighting site on meso level

The house, built with local materials, showcases traditional building methods in a modern context. Its thick stone walls and mud roofs help regulate indoor temperatures [10]. This approach showcases the efficacy of vernacular practices in creating sustainable, climate-responsive structures [11]. Integrating traditional methods with modern materials and technologies can be challenging due to differences in construction standards. Thoughtful planning and adaptation are crucial when incorporating vernacular knowledge into modern environments. This house, built with locally sourced materials and environmentally friendly practices, aims to reduce carbon emissions and meet occupants' needs sustainably. This research aims to analyze the current house, identify problems, and conduct assessments using sustainable criteria to address environmental and human comfort issues. The goal is to create architectural interventions based on sustainability principles to prevent ecological degradation [12].

Sustainable architecture relies on well-designed drainage and waste management systems to be effective. Inadequate drainage can lead to water accumulation, damaging building materials and posing health risks to occupants [13]. In rural areas without centralized waste management systems, sustainable practices like composting organic waste can greatly minimize environmental impact [14]. The drainage challenges identified in the "da Kali KOR" house underscore the necessity of incorporating these systems into the initial design to avoid future issues. Passive solar design in rural architecture is crucial for sustainable building. Strategies like optimal orientation and window placement can cut down on the need for artificial heating and cooling [15]. This aligns with vernacular architecture principles, using natural resources for energy efficiency [16]. Integrating these strategies into the "da Kali KOR" house could improve its energy efficiency while preserving its cultural significance.

The social and cultural aspects of sustainability are important in sustainable architecture, especially in rural areas where traditional practices are tied to community identity [17]. The "da Kali KOR" house, with its commitment to local building traditions, stands as a cultural landmark, safeguarding the architectural heritage of the region [11]. Sustainable architecture requires a balance of environmental, social, and economic factors. The "da Kali KOR" house faces challenges with its layout, orientation, and use of natural light, impacting the surrounding ecosystem. Combining traditional and modern building methods can address these issues, as seen in this example.

Material and Methods.

Investigation Site.

The research site in Matta Swat, situated in the northern mountainous region of the Indo-Pak subcontinent, experiences a temperate climate shaped by its geographical latitude, elevation, and the influence of rain-bearing winds. The study investigates climatic impacts, including summer monsoons and winter cyclonic currents from the Mediterranean. Detailed climate data, such as temperature fluctuations, annual snowfall, rainfall patterns, and water table levels, is meticulously gathered. Spatial information, including precise latitude and longitude coordinates, topographical features, and local vegetation details, is recorded [18]. Data sources include local meteorological departments, historical weather records, agricultural reports, and satellite imagery to ensure the reliability and reproducibility of the research findings.

Data Acquisition.

- **Climate Data.** Collected from local meteorological departments, including temperature, pressure, humidity measurements, and historical weather records.
- **Soil Characteristics.** Sourced from agricultural reports.
- **Spatial Data.** Documented using GPS coordinates, topographical features, and local vegetation details obtained from satellite imagery.
- **Construction Materials.** Analyzed for thermal properties and sustainability, focusing on sedimentary stones and timber.

Data Analysis.

Figure 4 demonstrates the various computer-based tools, used during the Data Analysis stage. The process started with a plan created in AutoCAD 2018. The 2D plan was then imported into Google SketchUp 2021 and extruded into a 3D model. Lumion 10 was used to render the images, which were then extracted. Photoshop 7 was used to label and refine the drawings and rendered images [19]. This shows how various computer-based tools were integrated into the research process. 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 [20].

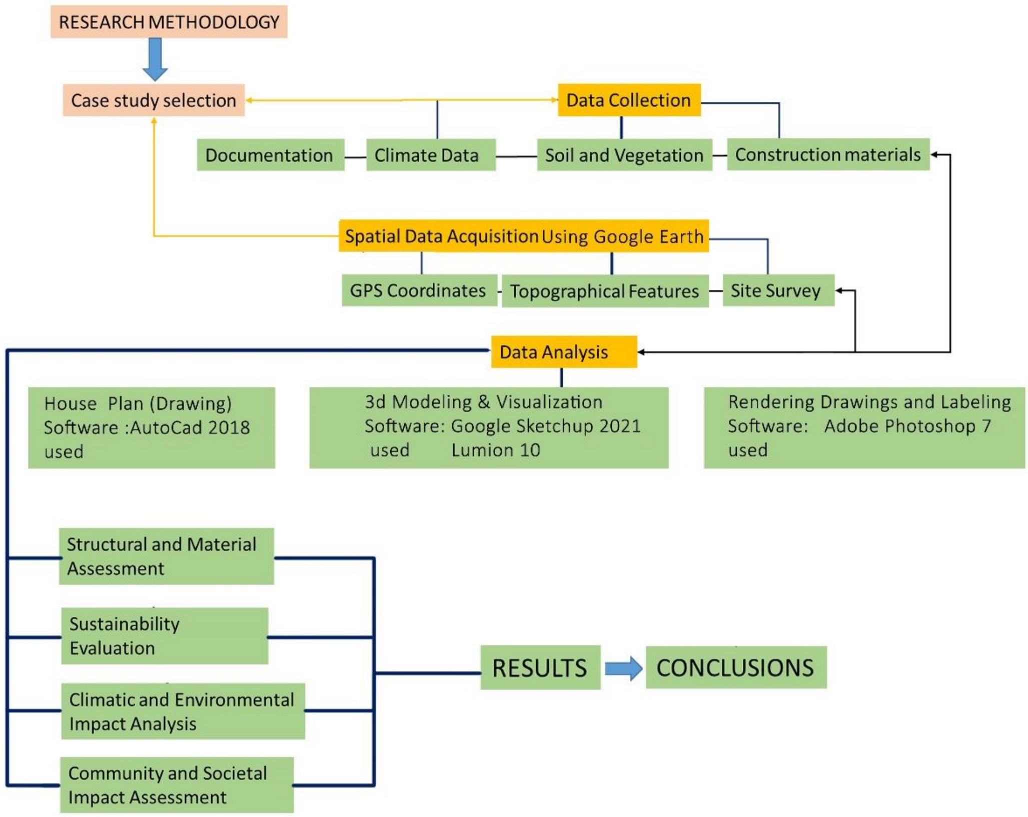

Figure 4. Showing methodology flow diagram

Google Earth.

We generated Figures 1,2,3 and 23 by Google Earth computer application to understand the geographical context of a site, including its topography, surrounding buildings, and overall layout. Analyzing the Site Constraints. Identifying natural and man-made constraints in terms of building existing within the location, its neighborhood, approach, and accessibility of the building, topography and location have been illustrated and obtained through Google Earth. Assessing the potential visual impact of the building (case study) on the surrounding area, including view sheds and sightlines and its demarcation boundaries.

AutoCAD 2022.

Figures 4,18,22 and 25 are generated in the AutoCAD application which is a powerful tool in architectural research, offering precise drafting, modeling, and visualization capabilities. Here's how AutoCAD generates images and drawings. We used this application for detailed and accurate two-dimensional floor plans, elevations, sections, and other architectural drawings essential for documentation [21].

The application is used to generate and study the site plans that include topographic contours, elevation changes, and existing conditions. This helps in understanding how a design will interact with the landscape [22]. The tool for spatial configuration analysis, circulation patterns, and functional relationships within a building to optimize design efficiency and usability. to analyze aspects like structural performance, energy efficiency, and environmental impact. Which we mentioned in our study.

Google Sketch up 2021.

We used this application for the generation of Figures 11,12,17,19,20,24 and 25 in our research for its intuitive 3D modeling Here's How Sketch Up-generated images and models are leveraged for the results of our discussions. Three-dimensional models help visualize architectural designs more clearly than two-dimensional drawings. This aids in understanding spatial relationships and design features.

Three-dimensional models are used for the study of neighboring buildings and infrastructure to understand the impact of the design on the surrounding environment. Also, Perform sun and shadow studies to analyze how the design will be affected by natural light throughout different times of the day and year. We use this application for the use of the three-dimensional model to assess the volume and spatial organization of the design, helping to optimize space usage and functionality.

Lumion 10.

Figures no 11,12,17,19,20 and 24. we used this software in our research because it is a powerful rendering software widely used in architectural research to create high-quality, photorealistic images and animations [23]. Here's how Lumion-generated images can be used. We used this application to represent architectural designs with realistic lighting, materials, and environmental conditions.

This is particularly useful for showcasing how a building will look and feel in its actual setting. For sunlight and artificial lighting analysis, it is used that how natural and artificial light affects the building's appearance throughout the day and year. We use this tool to visualize environmental factors such as weather conditions, vegetation, and surrounding infrastructure to understand the design's impact on and interaction with the site. Also used for helping to understand how people will perceive and interact with the space.

Adobe Photoshop 7.0.

By this application, we generate Figures 3,4,13,21,22 and 25. This is a versatile tool in architectural research, primarily used for image editing, enhancement, and composition. For a better understanding of the case study, this app adds or enhances details in renderings, such as textures, materials, and lighting effects, to make them more realistic for the easiness of analysis. We used the application to add annotations, labels, and graphical elements to figures to highlight specific features, materials, or design aspects [24].

Results and Discussion.

The House.

The house exemplifies vernacular architecture, reflecting the cultural traditions and practical needs of its residents. Its design features a central courtyard, spacious verandahs, and an emphasis on privacy and thermal comfort.

Spatial planning (Ground Floor Plan).

The site is a rectangular or parallelogram. The spatial planning of the residence as shown in Figure 5 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 [25].

The verandahs on the east, west, and north sides face south and are designed according to the user's 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 [26].

Figure 5. Floor plan highlighting spatial planning and its relationship.

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 [27]. The focus was on using thermally sound and comfortable materials suitable for the harsh climate of the region.

Climatology.

Situated in a temperate zone, the site experiences fluctuating seasonal weather patterns. The house design incorporates vernacular strategies, such as thick mud roofs, to address these conditions and regulate temperature extremes. Figures 6, 7, and 8 present climatic data, including snowfall and rainfall trends, highlighting the environmental challenges faced in the area. Table 1 shows the technical Data sheet for the uplifting of Existing residential buildings according to Sustainability in the context.

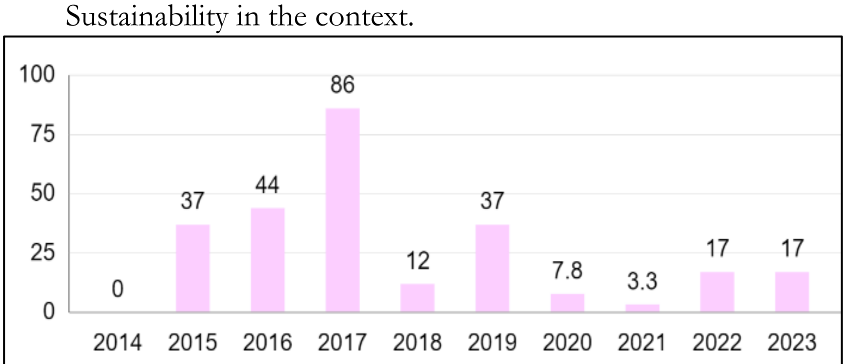

Figure 6. Graph Highlighting Annual Snowfall

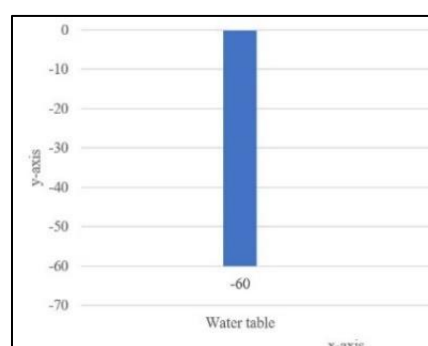

Figure 7. Graph Highlighting Water table

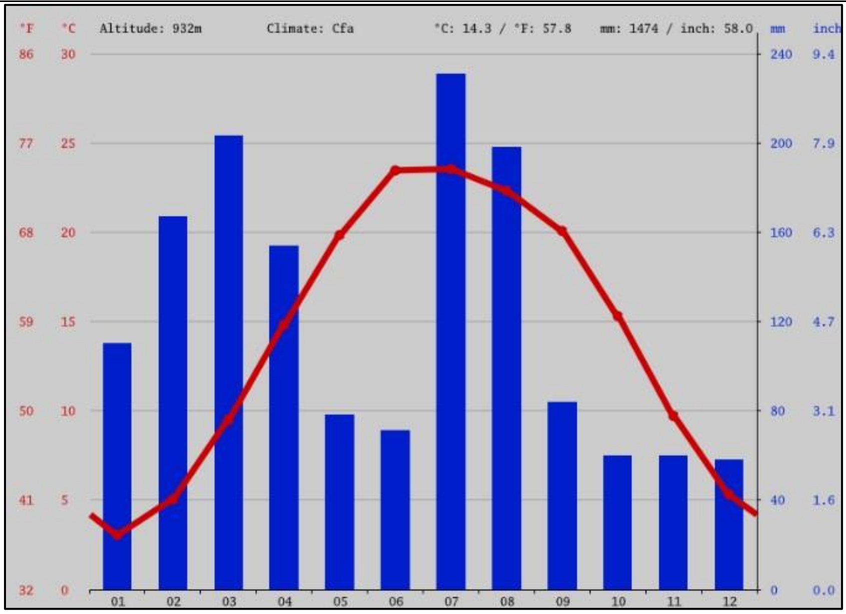

Figure 8. Graph Highlighting Annual Rainfall and temperature

Table 1. Technical datasheet for the uplifting of Existing residential buildings according to Sustainability in the context.

Orientation.

The house is strategically positioned to capture ample daylight and promote ventilation. The north is at a 30-degree angle to the site. The sun's path is east toward the west through the south. In summer, wind direction is from south to north, while in the winter, they shift direction from north to south, creating a cold-composite climatic condition. The mass of the residence is oriented towards the south. Three verandahs enhance user comfort by providing multiple orientations. The main front verandah faces south, the left-side verandah faces west, and the third verandah faces east. These verandahs ensure ample daylight throughout the day and revolve around a central courtyard. However, the exterior on the east side of the residence is obstructed by a dense line of trees, limiting exposure to daylight from that direction.

S. No.	Type	Resources				Skills
1	**Activity**	**Equipment's**	**Fieldwork**	**Data Set / Statistics**	**Individual**	**Skills/Training**
2	**Tools / Source Require**	Identification of Existing Materials on site and in the context.	Site visits for Sustainable materials & Analysis	Site visit permission and interviews amongst inhabitants and users.	Surveys and Discussions with professionals on-site.	a.Temperature/environmental Measurements Training & use of tools required. b. Technical data Sheet require for the evaluation of materials. c. Energy simulation and analysis Software's.
		Existing Materials on site and Proposed Materials for the miniatures.	Site visits for Sustainable materials selection & Analysis,		Interviews & Discussions with professionals on-site & industry.	

		Sustainable Measurements Tools,		literature review & visits to relevant buildings in the context	Questioners	d. Professional documentation i-e. Videography or photography skills need to be adapted. e. Data Analysis needs improvement. f. Experimental Base Model for the Analysis of Data etc. g. Any other by the instructions of the Project Supervisor.
		Documentation tools.				

Primary Materials.

The use of local, sustainable materials, primarily sedimentary stone, and wood is evident throughout the structure (see Figures. 9, and 10). These materials offer thermal comfort, but challenges arise from their inconsistent application and maintenance.

Figure 9 & 10. Showing primary material highlighting the sedimentary stones, and the wood as a structural element.

Construction Techniques.

The building's durability, spanning over 70 years, can be credited to resourceful construction techniques. However, certain unsustainable practices like improper stone placement and heavy mud roofs have resulted in structural challenges. Figure 11 illustrates the use of wood as a structural element, showcasing both the strengths and weaknesses of the construction approach. 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.

Foundation Detail.

A stone masonry foundation was constructed without mortar or reinforcement, relying on traditional methods for stability. While sustainable, this approach lacks the precision of modern techniques. 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.

Masonry Detail.

The stone masonry walls reflect local building traditions. Figures 11, 12,13, 14, and 15 illustrate the details of the wall construction, highlighting the use of locally sourced materials and straightforward construction methods. 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.

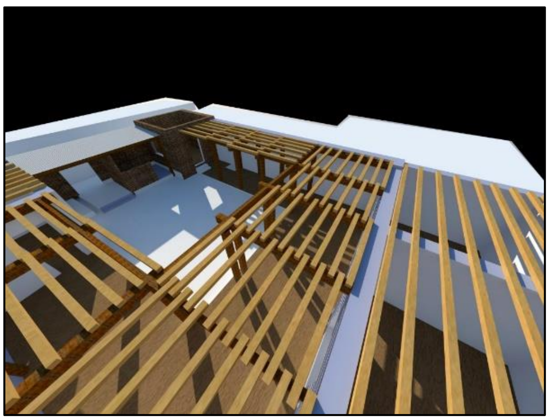

Figure 11. 3D-view highlighting the placement of wood as a structural element.

Figure 12. Perspective Highlighting the column and beams as A structural element

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.

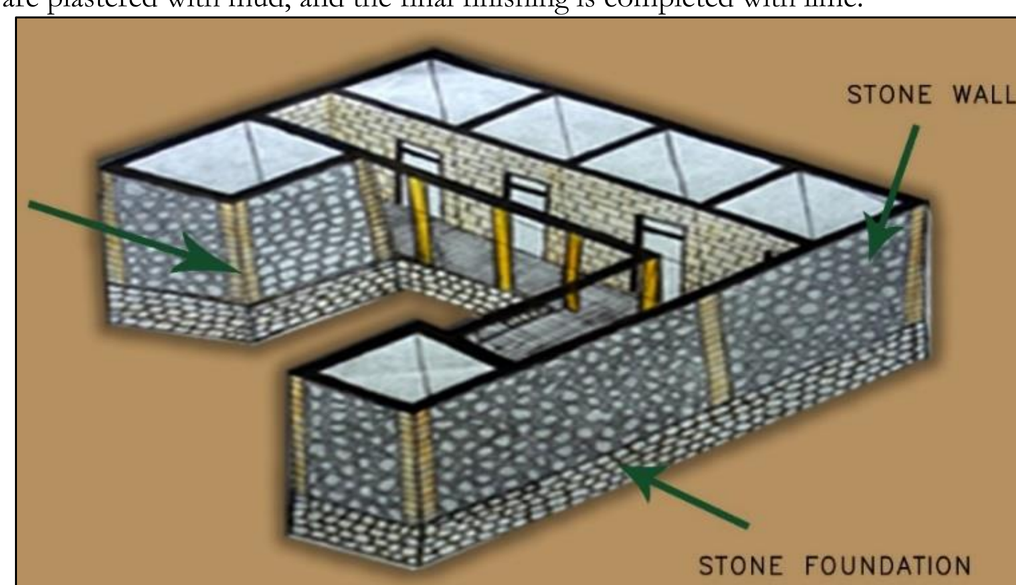

Figure 13. Typical Section of a Wall, Highlighting the Masonry work and details.

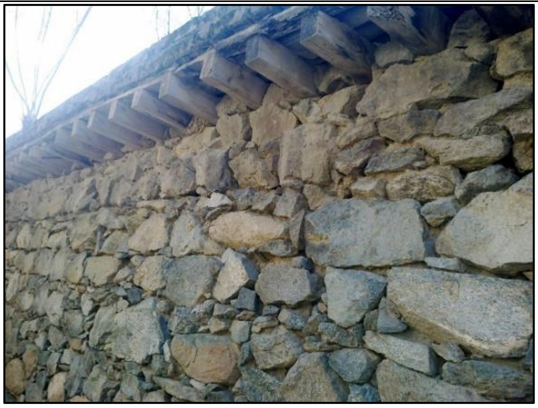

Figure 14. Highlighting Masonry/stone at the exterior

Figure 15. Highlighting mud/cladding on the interior

Opening Doors and Windows.

Windows and doors serve the purposes of ventilation, privacy, and light. Traditional wooden coverings are utilized to address extreme weather conditions. Figures 16 and 17 illustrate the door and window schedules, emphasizing the importance of balancing functionality and aesthetics to ensure privacy while maximizing natural light and airflow. 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 the 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.

Figure 16. Pic highlighting opening schedules/windows

Figure 17. Pic highlighting opening schedules/Doors

Roof Design and Thermal Comfort.

The thick mud roof is central to the thermal comfort of the house (Figures. 18, 19, and 20). While effective, the roof's susceptibility to water absorption during rainfall poses a significant challenge. The overall thermal performance of the house, while providing comfort in extreme temperatures, is compromised by limited natural ventilation. 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. To mitigate roof water absorption issues, inhabitants in the region have adopted the use of galvanized corrugated sheets placed over the roof to offer additional protection and prevent damage.

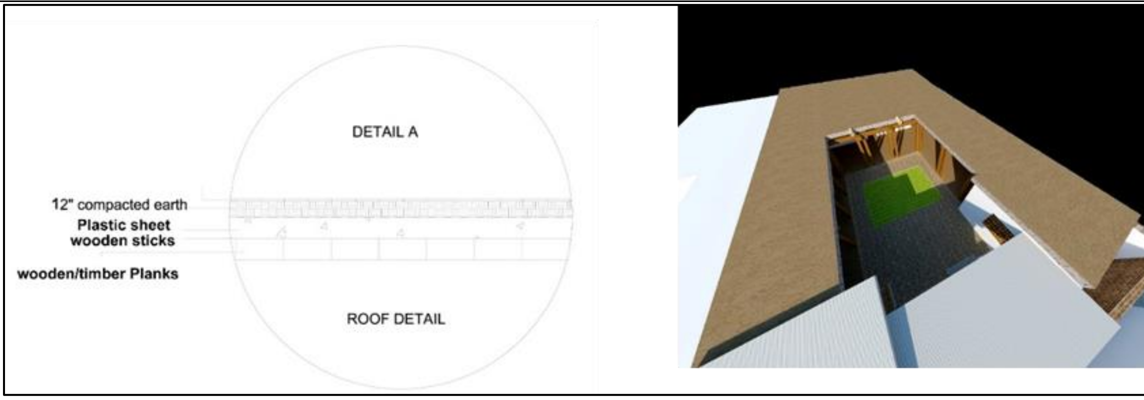

Figure 18. Rooftop and Typical Section of a roof. Highlighting the details in the slab

Thermal comfort is essential for well-being and is influenced by the built environment. This study highlights the importance of materials like mud-covered roofs in maintaining comfort. The house's design prioritizes ventilation through openings facing a central courtyard, though privacy concerns limit direct fresh air intake. Natural daylight is insufficient due to obstructed south-facing light, necessitating artificial lighting. The central courtyard, a traditional architectural feature, enhances aesthetics and functionality by providing a space for fresh air and connecting rooms through verandahs.

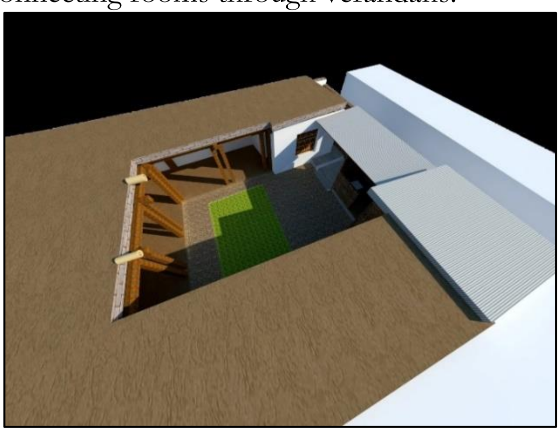

Figure 19. 3D-view showing courtyard/Landscape & open space

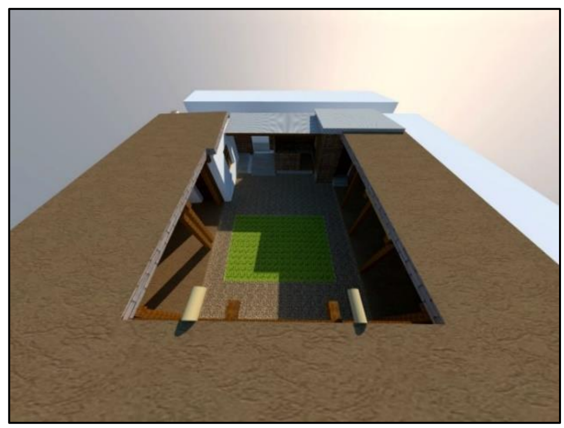

Figure 20. 3D-view showing courtyard & open space

Open/Covered Area.

- Total site area. 3727 sq ft (Marla's)
- Total covered area. 2841 sq ft (Marla's)
- Total open area. 886 sq ft (Marla's)

From the above calculation, it is identified that the house is not constructed on a proper solid void ratio, which means the covered area and open space ratio are not properly utilized. That is why the house is not thermally comfortable, even though the material used in the house is sustainable.

Form of the Building.

The building has a simple rectangular form with a central courtyard that enhances both its visual appeal and functionality. However, the ratio of open-to-covered spaces is not ideal, which affects the building's thermal performance.

Services Availability.

Basic utilities like electricity are available, but the lack of natural gas and insufficient waste management solutions, especially for toilet waste, impact the sustainability of the house.

Waste Management/ Recycling.

Waste management practices vary, with organic waste being efficiently recycled for agricultural purposes. In the house involves directing all waste to a nearby space known locally as "deer." This area collects both household 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 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. Nevertheless, the inadequate sewage infrastructure leads to unsustainable management of human waste.

Furniture.

The furniture in the house is crafted from sustainable materials, mainly wood and animal leather, showcasing traditional craftsmanship. Mostly the beds used in the house are made of wood, which is called charpai, a traditional piece of furniture, and even the chairs used in the kitchen, locally called Katkai, are made of wood and animal leather by local skilled persons. The furniture used in the house is sustainable.

Immediate Surrounding.

House on Four Sides.

Three sides of the house are surrounded by neighboring buildings as shown in figure 21, with the east side being the only open side, but it lacks windows for privacy. The layout of the surrounding buildings limits airflow and sunlight.

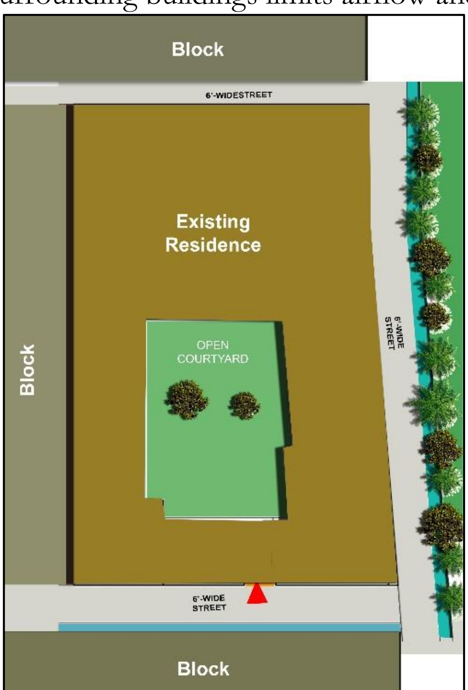

Figure 21. Map highlighting building blocks, solid/voids, and their immediate surrounding

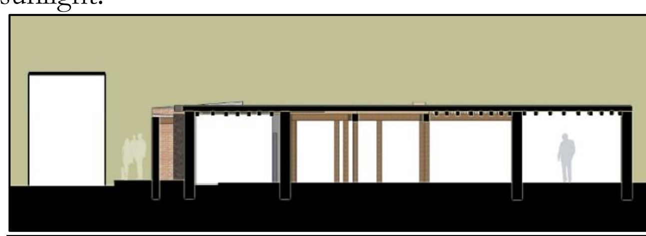

Figure 22. Section at a-A'. Highlighting the levels i-e. plinth level and heights of the house.

Figure 23. Google map highlighting vegetation in the immediate surroundings of the site.

Levels and Topography.

The house is lower than the surrounding streets, a notable issue is the plinth level of the building is set lower than the surrounding streets. This discrepancy occasionally causes drainage problems during heavy rainfall, as the site does not facilitate proper runoff contributing to drainage problems during rainfall. The surrounding area features a mix of contours and flat terrain. The south face of the building, which is intended to receive direct daylight, is obstructed by a newly constructed structure. This building has a ground floor and a first floor, which blocks the sunlight that otherwise would have reached the south corner of the courtyard. The new building is elevated 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. Fig. 22 illustrates the plinth levels and height disparities between the existing house and newly constructed buildings. 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 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.

Vegetation.

The east face of the building block presents a blank wall with no openings, as it is entirely bordered by lush green fruit gardens. Figure 23 illustrates the garden's proximity, highlighting the close relationship between the house and its natural surroundings. 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.

Rainwater Drainage Pattern.

Rainwater from the roof accumulates in the central courtyard and flows from the north side to the south during heavy rainfall, as depicted in Figure 24. It is then directed through a narrow drain to South Front Street, eventually reaching a main drain, a small canal on East Street. Additionally, water from dishwashing, kitchen waste, and washrooms also flow into this main drain. A significant issue with the drainage system is that water collects in the central courtyard due to the lower elevation of the house on all four sides, hindering proper drainage and causing water stagnation, leading to inefficiencies in the drainage process.

Figure 24. Pic showing the parnalas/rainwater drains from the roof

Planning and Neighborhood Context.

Communal Spaces.

The house is part of a broader neighborhood, with limited communal spaces nearby. It is situated near fields and is somewhat distant from the village's main bazaar, which is approximately a 15-minute walk to the north. There is one open communal space located to the north, about a 5-minute walk away. This space is primarily used by villagers for parking their vehicles and is adjacent to the Mohallah Mosque. The organic layout of the village, including the location of the mosque and bazaar, reflects traditional planning practices.

Basic Services.

Basic services are available such as electricity in the area, the reliance on wood for cooking and the lack of pure drinking water systems highlight sustainability challenges in the village. Inhabitants rely on a water canal that originates from the river, though this canal is also used for waste drainage from nearby residences. The village lacks access to natural gas, so residents use wood which is sourced from nearby forests and mountains. This reliance on wood contributes to deforestation in the region. Figure 25 shows the details, elements, and spaces of the selected house.

Conclusion.

Through this research, modernity alone is not enough to address everyday problems and environmental dangers in architecture. Modern architecture provides high-tech solutions to improve user comfort, but it frequently ignores sustainability, which goes against the fundamental intent of the design. The way forward necessitates striking a careful balance between respecting environmental stewardship and the necessity for progress. It is critical to recognize these issues and find solutions, particularly when it comes to human-caused problems like the release of chlorofluorocarbons (CFCs) from the use of materials. Because of these emissions, the environment is becoming worse, which makes preventative actions necessary to protect the environment and human health. This study examined a rural house in Matta Swat, carefully examining how materials were utilized, how they were built, and other features of the structure from a sustainable perspective. I now approach architectural design with a fresh sense of duty after gaining these ideas. Incorporating sustainable ideas into my next projects is my goal to reduce environmental risks and improve user comfort. Every structure needs to minimize the amount of energy and resources used while providing basic amenities like lighting, ventilation, heating, and cooling. Architects can design environments that blend in with their surroundings and enhance the built environment by putting occupant comfort and environmental protection first.

This research work concluded the four major sustainable and indigenous techniques to enhance energy efficiency and sustainability.

- Solar energy. Utilizing photovoltaic (PV) panels to harness solar energy.
- Rainwater harvesting. Implementing channels throughout the roof to collect rainwater.
- Biogas production. Using cattle waste to produce and assemble a biogas plant.

Integration of indigenous practices and digital strategies. Combining traditional methods with modern digital tools enables the house to produce its energy and reduce its carbon footprint.

Sectional 3D Views and Details.

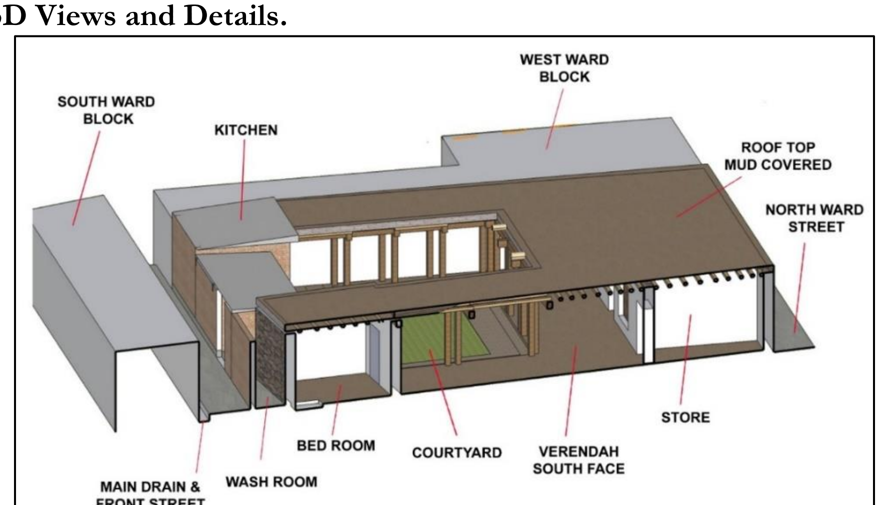

Figure 25. A sectional 3D-View Highlighting details, elements and spaces of the selected house.

Python-based script for identifying the structure of Houses.

```
import numpy as np
import matplotlib.pyplot as plt
# Define a function to create a basic truss structure
def create_truss_structure():
    # Node coordinates (x, y) in meters
    nodes = np.array([[0, 0],  # Node 0
                      [2, 0],  # Node 1
                      [1, 1],  # Node 2 (Roof)
                      [0, 2],  # Node 3
                      [2, 2]]) # Node 4
             # Elements connecting the nodes, each row is (node_1, node_2)
    elements = np.array([[0, 2],
                         [1, 2],
                         [0, 3],
                         [1, 4],
                         [3, 4],
                         [3, 2],
                         [4, 2]])
    # Material and geometric properties
    E = 210e9  # Young's modulus in Pascals (steel)
    A = 0.005  # Cross-sectional area in square meters
    return nodes, elements, E, A
# Function to plot the truss
def plot_truss(nodes, elements, title="Truss Structure"):
    plt.figure(figsize=(6, 6))
    for element in elements:
        node1, node2 = element
        x_values = [nodes[node1, 0], nodes[node2, 0]]
        y_values = [nodes[node1, 1], nodes[node2, 1]]
        plt.plot(x_values, y_values, 'bo-', markersize=8, linewidth=2)
    plt.title(title)
    plt.xlabel('X (m)')
    plt.ylabel('Y (m)')
    plt.grid(True)
    plt.axis('equal')
    plt.show()
# Finite element stiffness matrix computation
def compute_stiffness_matrix(nodes, elements, E, A):
    # Placeholder for global stiffness matrix
    K_global = np.zeros((2 * len(nodes), 2 * len(nodes)))
    # Compute stiffness for each element (simplified)
    for element in elements:
        node1, node2 = element
        x1, y1 = nodes[node1]
        x2, y2 = nodes[node2]
        length = np.sqrt((x2 - x1)**2 + (y2 - y1)**2)
        # Simplified stiffness matrix calculation (bar element)
```

```
        cos_theta = (x2 - x1) / length
        sin_theta = (y2 - y1) / length
        k = E * A / length
        # Element stiffness matrix in local coordinates
        k_local = k * np.array([[cos_theta**2, cos_theta*sin_theta, -cos_theta**2, -cos_theta*sin_theta],
                                [cos_theta*sin_theta, sin_theta**2, -cos_theta*sin_theta, -sin_theta**2],
                                [-cos_theta**2, -cos_theta*sin_theta, cos_theta**2, cos_theta*sin_theta],
                                [-cos_theta*sin_theta, -sin_theta**2, cos_theta*sin_theta, sin_theta**2]])
        # Mapping to the global stiffness matrix
        indices = [2*node1, 2*node1+1, 2*node2, 2*node2+1]
        for i in range(4):
            for j in range(4):
                K_global[indices[i], indices[j]] += k_local[i, j]
    return K_global
# Main function to analyze the truss structure
def analyze_truss():
    nodes, elements, E, A = create_truss_structure()
    plot_truss(nodes, elements)
    # Compute the global stiffness matrix
    K_global = compute_stiffness_matrix(nodes, elements, E, A)
    print("Global Stiffness Matrix:\n", K_global)
    # Apply boundary conditions and external forces (example)
    # For simplicity, assume fixed supports at node 0 and 1, and a load at node 2
    forces = np.zeros(2 * len(nodes))
    forces[4] = -10000  # 10 kN downward force at node 2 (roof)
    # Apply boundary conditions (fixed nodes at node 0 and 1)
    fixed_dofs = [0, 1, 2, 3]  # Fix both X and Y directions at node 0 and 1
    free_dofs = np.setdiff1d(np.arange(2 * len(nodes)), fixed_dofs)
    # Solve for displacements
    K_free = K_global[np.ix_(free_dofs, free_dofs)]
    forces_free = forces[free_dofs]
    displacements = np.zeros(2 * len(nodes))
    displacements[free_dofs] = np.linalg.solve(K_free, forces_free)
    # Display displacements
    print("Nodal Displacements:\n", displacements)
    return displacements
# Run the analysis
displacements = analyze_truss()
```

Discussion.

The **Computational Analysis of Model Houses "Da Kali KOR" in Matta Swat** involves the application of computer science techniques to evaluate and optimize architectural designs, structural integrity, and energy efficiency. Computational models, such as Building Information Modeling (BIM) and finite element analysis (FEA), are crucial in assessing the structural performance of houses. These models help simulate various environmental factors like wind, seismic activity, and temperature changes, ensuring that the houses are built to withstand natural forces. In Matta Swat, where seismic activity may pose challenges, computational simulations allow engineers to test the resilience of "Da Kali KOR" model houses, making sure they meet safety standards.

In terms of **energy efficiency**, computer science plays a significant role through the use of algorithms and simulations that optimize the use of natural light, ventilation, and insulation in homes. Techniques such as computational fluid dynamics (CFD) allow for the analysis of airflows within these model houses, ensuring adequate ventilation. By analyzing solar exposure patterns, designers can also optimize window placement and insulation materials. This can lead to reduced energy consumption and a more sustainable living environment for residents in Matta Swat.

Lastly, **data analytics and machine learning** can be utilized to monitor the performance of these model houses over time. By installing sensors, engineers can gather real-time data on temperature, humidity, and structural strain, which can be processed using machine learning algorithms to predict maintenance needs and detect potential issues early. This computational approach ensures that the "Da Kali KOR" model houses not only remain safe and efficient but can also adapt to changing environmental conditions over time, ultimately enhancing the quality of life for their occupants.

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