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Design Approaches for Local Materials and Climate Change Adaptation in Vernacular Architecture of Bangladesh.

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ABSTRACT

This article explores design approaches to enhance the resilience of vernacular architecture in climate-vulnerable Bangladesh. While traditional vernacular architecture historically adapted to harsh climates, intensified climate change poses new challenges. Recognizing the significance of vernacular architecture for sustainable development, the research aims to bridge the gap between traditional and modern sustainability practices. Key design strategies focus on utilizing locally available materials capable of withstanding severe weather conditions, while integrating innovative and modern techniques. Community involvement ensures cultural appropriateness and long-term sustainability. The research question centers on integrating vernacular principles with contemporary sustainable practices in rural and urban settings. Employing mixed-methods research, including case studies and expert interviews, the study seeks to revive and promote vernacular heritage as a resilient solution to climate change impacts, safeguarding the built environment in Bangladesh. Potential gaps in this research could include limited analysis of implementation challenges, insufficient evaluation of long-term structural resilience, and a lack of in-depth exploration of socio-economic impacts and community engagement dynamics in the design process. Additionally, a comparative analysis with modern architectural approaches and consideration of policy influences might enhance the research's breadth and practical relevance.

1. Introduction

Bangladesh, highly vulnerable to climate change, struggles to adapt its built environment. Vernacular architecture, historically climate-adaptive and sustainable, has lost its traditional characteristics due to foreign influences and contemporary trends. Architect Mazharul Islam aimed to revive climate-responsive architecture after Bangladesh's liberation, but many modern architects prioritize trendy designs and pseudo-sustainable materials over local resources and traditional expressions. As a result, the rich vernacular heritage remains limited to impoverished rural communities employing traditional techniques.

It is crucial to recognize the value of vernacular architecture and promote its sustainable practices to effectively address climate change and enhance resilience in Bangladesh.

To address this situation, there is a pressing need to reestablish the significance of vernacular architecture and its role in climate change adaptation. This journal aims to delve into the design approaches for climate change adaptation in both rural and urban vernacular architecture in Bangladesh. By examining the factors influencing design decisions and exploring innovative techniques, this research intends to contribute to the revival and integration of traditional architectural principles with modern sustainability practices.

This journal enquires about –characteristics of vernacular architecture of Bangladesh with climate change

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adaptation in both rural and urban areas. Furthermore, it aims to explore the limitations of using traditional techniques in terms of sustainability and investigate how these limitations can be overcome by establishing innovative and modern techniques within the context of vernacular, environment-friendly architecture in both rural and urban settings.

2. Literarure Review

Climate change presents significant challenges for the built environment, particularly in developing countries like Bangladesh, given its low-lying geography, high population density, and vulnerable infrastructure. Vernacular architecture has emerged as a crucial approach to climate change adaptation, grounded in local knowledge, materials, and building practices that respond to environmental conditions.

According to Paul Oliver, "Vernacular architecture comprises the dwellings and other buildings of the people. Related to their environmental contexts and available resources they are customarily owner- or community-built, utilizing traditional technologies. All forms of vernacular architecture are built to meet specific needs, accommodating the values, economies and ways of life of the cultures that produce them" [37]. In another definition Oliver gives a description about the context of vernacular architecture: "Within the context of vernacular architecture it embraces what is known and what is inherited about the dwelling, building, or settlement. It includes the collective wisdom &experience of a society, and the norms that have become accepted by the group as being appropriate to its built environment" [37].

Vernacular architecture is congenial to people and sympathetic to environment[38]. Several studies have investigated the thermal performance of traditional mud houses compared to brick and CI sheet houses [32]. Mud houses have been found to provide better thermal comfort levels due to their inherent insulation properties. Furthermore, the utilization of solar passive methods and techniques in modern buildings, such as those inspired by vernacular architecture, can decrease dependence on fossil energy and promote sustainability [3] [6]. The cultural and environmental value of traditional mud houses has been emphasized, highlighting the need to preserve and value indigenous practices. Adaptation to climate change did not receive much attention in the first years of the international climate change studies, where there was more focus on mitigation and impacts These vernacular houses not only demonstrate minimal environmental impact but also contribute to community bonding. Additionally, vernacular architecture, with its shared cultural heritage and identity, continues to be prevalent in the South Asian region, where a significant portion of the population lives in self-built houses [16] [25].

A good number of papers have recognized climate change as one of the emerging issues of pro-poor growth, poverty and inequality [39]. Poor people are generally the most vulnerable to the climate change as they live in remote and disaster prone areas where they have little capacity to adapt to the shocks[28].

3. What is Vernacular Architecture?

Vernacular architecture pertains to the construction of buildings using local materials and available technology, with a functional design that addresses the specific needs of ordinary people in their particular time and location. It encompasses the architectural creations of local craftsmen or master masons, who may lack formal institutional training but possess traditional knowledge and skills.[19]

The term "vernacular" originates from the Latin word "vernaculus," which means native. In the context of architecture, it refers to the distinctive style of a particular group or social class within a society.[29] It is closely tied to the language, materials, construction techniques, social customs, and systems that are unique to a specific region or country.

3.1. Key Features of vernacular architecture include:

- **Use of Local Materials:** Vernacular architecture relies on utilizing materials found locally, such as wood, stone, mud, thatch, or bamboo. These materials are readily available, cost-effective, and suitable for the specific climate and environmental conditions of the region.[14] [16]
- **Climate Adaptation:** Vernacular architecture is purposefully designed to adapt to the local climate. The arrangement, positioning, and construction techniques are customized to maximize natural ventilation, daylighting, and thermal comfort. Vernacular designs often incorporate elements like courtyards, extended roofs, and lattice screens to regulate temperature and airflow effectively.[3]
- **Cultural Context**: Vernacular architecture reflects the cultural and social values of a community [32].
- **Flexible in their use**: The design evolves over time, incorporating changes based on user requirements and technological advancements.[11]
- **Sustainability& Resource Efficiency:** Vernacular architecture promotes sustainable practices by utilizing local resources and minimizing environmental impact. It emphasizes efficient use of materials, energy, and water resources, and often employs passive design strategies to reduce reliance on mechanical systems [32].

4. Methodology

This research employed a rigorous and comprehensive methodology to investigate design approaches for local materials and climate change adaptation in vernacular architecture of Bangladesh. The study began with an extensive literature review and analysis of relevant case

studies to understand historical practices and challenges. Field surveys and documentation were conducted in various rural and urban areas, gathering primary data through interviews with stakeholders and detailed architectural documentation.

Data analysis utilized a combination of qualitative and quantitative methods to identify patterns and insights. Stakeholder experiences were carefully analyzed to incorporate valuable perspectives. A comparative analysis evaluated different design approaches used in various projects. Based on research findings, comprehensive recommendations and guidelines were formulated, emphasizing the integration of traditional techniques with contemporary sustainable practices.

The research methodology ensured a systematic and coherent flow of information, connecting data collection, analysis, and findings. The study aimed to contribute to the development of sustainable and resilient architectural solutions, addressing climate change challenges in the context of vernacular architecture in Bangladesh.

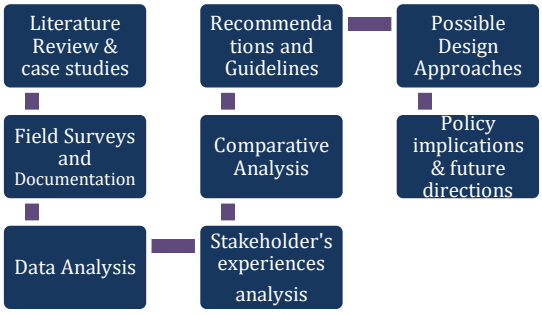

Figure 1: step by step methodology, source-author

5. Aim and Objectives:

5.1. Aim:

This research aims to explore the design approaches used in vernacular architecture of Bangladesh, specifically focusing on the integration of local materials and modern strategies for climate change adaptation.[14]

5.2. Objectives:

Investigate design approaches in vernacular architecture of Bangladesh, focusing on local materials integration.

- Comprehend the significance of utilizing local materials in sustainable architecture and their environmental implications. To identify the key challenges posed by climate change to vernacular architecture in Bangladesh.[14][3]
- Assess climate change adaptation strategies in vernacular architecture.[14]
- Explore the cultural and contextual relevance of vernacular architecture in Bangladesh [32].
- Provide insights for sustainable architectural practices, bridging traditional and contemporary approaches. The objective is to promote sustainable and resilient architectural practices in Bangladesh.

6. Importance of Local Materials and Climate Adaptation:

- Environmental Sustainability
- Cost-effectiveness
- Cultural Preservation
- Climate Resilience
- Community Engagement and Empowerment

Vernacular architecture embodies the principles of sustainability, cultural preservation, and community engagement [. It utilizes local materials, adapts to the local climate, and reflects the unique identity and needs of a place. By recognizing the importance of local materials and climate adaptation, vernacular architecture offers a valuable approach to sustainable and culturally meaningful construction practices.[14][3]

7. Climate Challenges in Bangladesh & Adaptation in Vernacular Architecture

Bangladesh encounters substantial climate-related difficulties as a result of its geographic location, low-lying delta terrain, densely populated areas, and heightened susceptibility to natural calamities [30]. The country experiences notable vulnerability to the consequences of climate change, which presents numerous hurdles for its socio-economic progress and the welfare of its inhabitants [31]. [6] [14] Here are some of the primary climate challenges faced by Bangladesh:

7.1.Impacts of Sea-Level Rise: Due to its low-lying nature, Bangladesh faces significant risks from rising sea levels. This escalation leads to more frequent and severe coastal flooding, erosion, and the intrusion of saltwater. These consequences have detrimental effects on agriculture, livelihoods, and the delicate coastal ecosystems.[14][3]

7.2.Escalation in Cyclone Frequency and Intensity: Bangladesh is susceptible to tropical cyclones, and climate change is projected to amplify their occurrence and strength. These cyclones bring destructive storm surges, powerful winds, and heavy precipitation, resulting in widespread infrastructure damage, loss of life, and the displacement of communities.[14]

7.3. Flooding: The country's numerous rivers and monsoon rainfall make it prone to regular flooding. Climate change exacerbates this issue, leading to more frequent and severe floods which disrupt livelihood, damage crops, infrastructure, and homes, and increase the risk of waterborne diseases.[14]

7.4. Water Scarcity and Drought: Climate change affects water availability and exacerbates water scarcity in some regions. Erratic rainfall patterns and prolonged droughts can lead to water stress, affecting agriculture,

drinking water supplies, and sanitation.[14]

7.5. Salinity Intrusion: Rising sea levels and reduced freshwater flow from rivers contribute to the intrusion of saline water into freshwater sources, making them unsuitable for drinking, irrigation, and agriculture[23]

7.6. Increased Temperature and Heatwaves: Climate change leads to higher temperatures and more frequent heatwaves. High temperatures affect human health, increase the demand for cooling, and impact agriculture by reducing crop yields and affecting livestock.[14]

7.7.Impact of Erosion and Land Degradation: Bangladesh grapples with the persistent challenge of river erosion, which is further exacerbated by climate change. This erosion process results in the loss of fertile agricultural land, displacement of communities, and heightened susceptibility to various natural hazards.[14]

8. Traditional ways of Hot Humid Climatic Adaptation:

The village people of Bangladesh took several initiatives to adapt to the diversified climatic problems they face from time immemorial.[23][17]Some of these initiatives included:

9. Wind-Resistant Build Form Design:

Buildings in areas prone to strong winds are designed with wind-resistant features. These may include aerodynamic shapes, reinforced walls, securely anchored roofing systems, and minimized wind-facing surfaces to reduce wind loads and potential damage. [22].

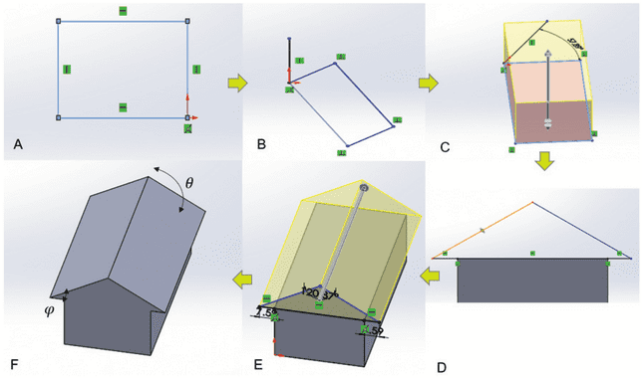

Figure 2. process flow for model construction and setting up dimensions for building orientation θ and roof angle. Source:Mata&Jerson '2022.

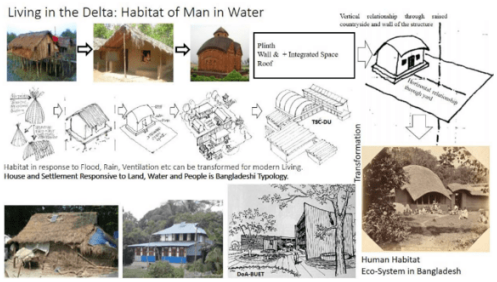

Figure 3.The influence of Delta and warm humid climate was quite evident even in the evolution of two types of huts evolving from same common principle i.e. rising above flood levels; repelling the torrential rain and encourage adequate ventilation in the buildings and subsequent buildings shaped by unique architectural features of ancient Bengal persisting to date (Source:Mowla,et.al.2019)[24][3]

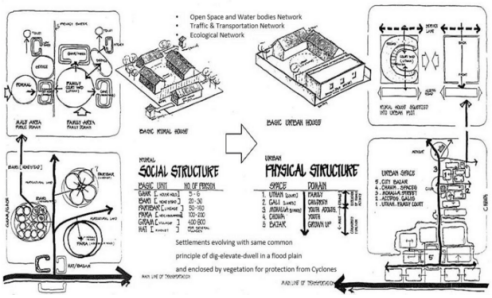

Figure 4. Settlements at various scales and levels, developing from the same common principles rooted in the context are sustainable (Source: Mowla, et.al. 1990&1997).[24]

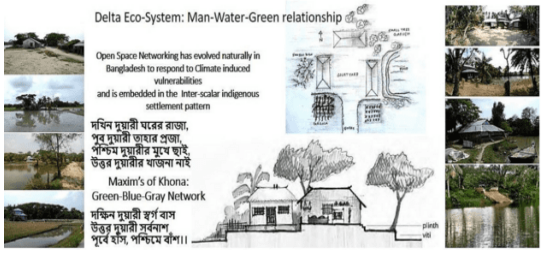

Figure 5.Built-form and settlements evolving from the geo-climatic context as described in the Khona's Maxims (Source : Mowla, et.al. 2019).[24]

9.2. Adequate Insulation and Ventilation: Effective insulation and ventilation systems are integrated to maintain comfortable indoor temperatures while reducing the need for excessive energy consumption. Insulation helps to minimize heat transfer, while proper ventilation promotes airflow and moisture control.[14]

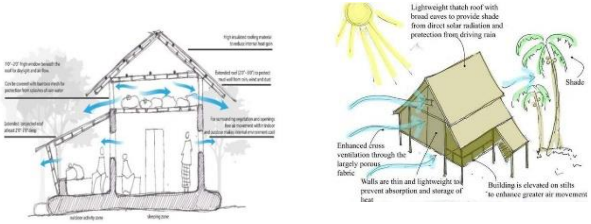

Figure 6. Conceptual Sectional View Showing Probable Ventilation (Source: Sabrina & Nuzhat et.al. 2020)[17][3]

9.3. Raised Plinth Construction: In areas prone to waterlogging and frequent monsoon flooding, villagers adopted the practice of constructing houses on raised plinths or stilts(fig-7). This helps prevent water from entering the living spaces and protects their homes and belongings [15].

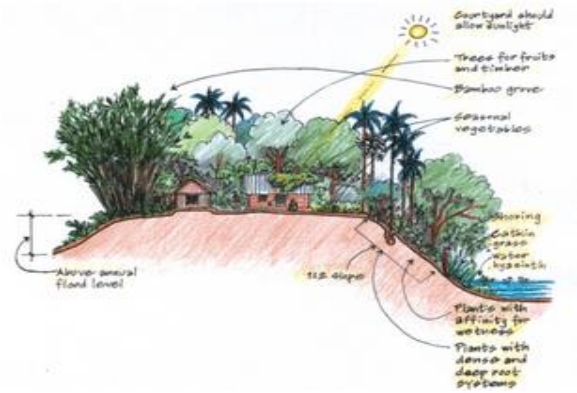

Figure 7. Raised plinth construction for flood prone area (by asian disaster preparednenter2005)[15][1] [22][6]

9.4. Sustainable Material Selection: Climate-resilient buildings prioritize the use of sustainable and locally available materials. This reduces the environmental impact of construction, promotes resource efficiency, and supports the local economy. (fig-8) They have aesthetic values too. [22][3]

Figure 8.source -Context BD:Geolocation Map of Vernacular Architecture, Bangladesh Dr. Sajid Bin Doza, Sheikh Rishad Ahmmad Aurnob, Md. Raihanul Hai, Saba Islam, Shajjad Hossain and SaimumKabir. [22]

9.5. Flexibility and Adaptability: Buildings designed for climate resilience incorporate flexibility and adaptability to accommodate changing climate conditions. This may include modular designs, expandable spaces, and flexible layouts(fig-10) to allow for future modifications and additions. Village communities in Bangladesh construct resilient dwellings to withstand floods, cyclones, earthquakes, and other climatic challenges.[19] [16]

10. Local/Traditional construction materials used in Vernacular Architecture:

In vernacular architecture of Bangladesh, several local construction materials are commonly used. Some of the prominent local materials include:[6][3]

10.1 Mud and Adobe: A blend of clay, sand, organic substances, and natural fibers are employed in the construction of walls, floors, and roofs. These mixtures are commonly reinforced with bamboo or timber, and they serve as the foundation for traditional bricks, adobe walls, and terracotta tiles. The production of adobe involves combining soil and natural fibers, adding water until it reaches a plastic consistency, molding it into bricks, and allowing them to dry under the prevailing climatic conditions (ampas et al., 2014).[23]

Figure9.source:Handmade Adobe Bricks.M Timothy O'Keefe/Getty Images&The mud houses of rural Shyamnagar battling climatic hazards,source:Dhaka Tribune[15] [1] [17][5]

10.2.Bamboo: Bamboo is a versatile and sustainable material extensively used in vernacular architecture for structural elements, such as columns, beams, and roof trusses(fig-10).[19]

Figure 10. Bamboo & wooden house exm..Marma House - Bandarban, BD & Century old Momin Jame Masjid in Mathbaria, The entire structure of the century-old Momin Jame Masjid was made of wood in 1903 Pirojpur,source:TheBuisness Post19dec'21

10.3.Thatch: Thatch refers to a densely intertwined layer consisting of both living and deceased stems, leaves, and roots, which accumulates between the actively growing grass layer and the underlying soil. For at least three centuries, people have utilized thatch as a means to shield themselves from rainwater(fig-11)

Figure 11: locality-in-sundarbans,source:Rudrapur study by Anna Heringer and [1] [15]

10.4. Jute: Jute, a natural fiber produced in Bangladesh, is utilized for various purposes, including wall coverings, insulation, and reinforcement in composite materials.[19]

10.5.Wood: Different types of locally available woods, such as Sundori, Teak, and Mahogany, are used for structural components, flooring, doors, and windows. (Fig10)[19]

10.6. Palm Leaf, Golpata: Palm leaves and Golpata find application in thatching roofs, crafting shading devices, and erecting temporary structures.[19]

10.7. Straw: Straw from rice or wheat crops is often used for wall panels and thatched roofs in rural areas.[33]

10.8. Lime and Shell Lime: Lime is derived from oyster shells and used as a binding material for plastering, flooring, and wall construction.[19]

10.9. Stone: Local stone, such as granite and limestone, is employed in foundations, walls, and decorative elements.

10.10. Cane and Rattan: Cane and rattan are woven materials used for furniture, screens, and partitions.[19]

These local materials have been traditionally used in vernacular architecture due to their abundance, affordability, and compatibility with the local climate and cultural context.[19]

11. Benefits, Sustainability, and Vulnerabilities:

Local materials play a significant role in vernacular construction practices, offering both benefits and challenges in terms of their usefulness, sustainability, and vulnerabilities. In Bangladesh, several local materials are commonly used, such as mud and adobe, bamboo, thatch, jute, wood, palm leaf, straw, lime, stone, and cane/rattan.

11.1 Benefits:

11.1.1. Abundance and Affordability: Local materials are readily available and often cost-effective, reducing the need for transportation and lowering construction costs.

11.1.2.Cultural Significance: The utilization of these materials is intricately tied to local culture and traditions, playing a vital role in safeguarding and perpetuating cultural identity and heritage.[19]

11.1.3. Environmental Sustainability: Local materials are typically natural, renewable, and biodegradable, reducing the environmental impact associated with resource extraction and disposal.[19] [3]

11.1.4. Thermal Comfort and Insulation: Materials like mud, thatch, and bamboo provide good thermal insulation, keeping interiors cool in hot weather and warm during colder months.[19] [6]

11.1.5. Sound Absorption: Some local materials, like mud and jute, have sound-absorbing properties, enhancing acoustic comfort within buildings.[19]

11.1.6. Aesthetic Appeal: The use of indigenous materials can add a unique aesthetic charm and a sense of place to architectural designs.[19]

11.2. Vulnerabilities:

11.2.1. Weather Sensitivity: Local materials, particularly mud and thatch, are susceptible to damage from heavy rain, strong winds, and flooding if not properly maintained.[24][19]

Figure 12: Flood situation worsen in BD,source-observerbd.com&traditional houses face various problems huge maintenance, damage by rain, flood& vermin infestation.[15][1][17] [5]

11.2.2. Durability: Some local materials may have lower durability compared to modern construction materials, requiring regular maintenance and repair.

11.2.3. Fire Resistance: Certain materials, such as thatch and wood, are more vulnerable to fire and require additional fireproofing measures to ensure safety.

11.2.4.Pest Infestation: Natural materials like bamboo and wood can be prone to pests and insects if not treated or protected adequately.

11.2.5.Limited Structural Strength: Some local materials may have lower structural strength, limiting their use to non-load-bearing elements or requiring additional reinforcement.[23][16]

Figure 13: planetcustodian.com/mud-house-pros-and-cons & Cross-bracing of bamboo structural frame (adapted from Chishun 1979) To maximize benefits, adopt proper techniques, integrate local materials with modern technologies, and prioritize research for durable, sustainable vernacular architecture.[23][1][17][5]

12. Architectural Design Strategies for Climate Resilience:

12.1. Pavilion Structure: In the Bengal delta, the pavilion structure is prominent and distinguished by its sweeping canopy or chhad. This design feature allows for the intense sun and heavy rain to be visually experienced. The pavilion's enclosure is typically permeable, highlighting the connection between the external natural environment& the architectural space[1].[22]

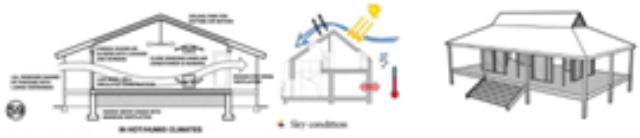

Figure 14: passive-and-low-energy cooling, basc.pnnl.gov/ resource-guides & Heat balance within a building in winter by Shen Wei 2014 , Traditional homes in warm-humid climates using light-weight construction with openable walls and shaded outdoor porches, raised above ground. (Drawing generated by climate consultant software.) (Source: www.climateconsultant. com) [4] [22] [15]

12.2.Permeable Walls: Unlike courtyard houses in hot-arid regions, pavilion houses in the Bengal delta have permeable walls that blur the boundaries between interior and exterior spaces. This design approach allows for a seamless integration of nature and architecture, creating a continuous connection between the two.[4][6]

Figure 15: A mud-house window in Koia Khulna Bangladesh , www.alamy.com,Terracotta,red Imported Clay Jally, For Building, Officer's Mess at the Bangladesh Police Academy in Sardah, Rajshahi. KarotiajamindarBari,Tangail.source[6]

12.3. Verandahs and Terraces: Terraces and verandahs are inherent features of pavilion architecture, extending the concept of being connected with the outdoor environment. They facilitate a seamless integration of nature and architecture, offering visual, spatial, and sensory interactions between the two. These spaces create a harmonious indoor-outdoor relationship, blurring the boundaries and providing in-between areas that enhance the overall experience(Fig15).[19] [22][3]

12.4.Bangla Roof: The Bangla roof, originating from the traditional Bengali hut, holds great architectural significance. It showcases a distinctively curved design that gracefully descends and is often portrayed through gently curving cornices in masonry constructions. The Bangla roof has evolved into a distinct architectural style, visible in Sultanate mosques, Hindu temples, colonial bungalows, and even modernist designs. Screened porches and patios offer passive comfort cooling through ventilation during warm weather and effectively deter insect-related issues.[1][16][27] [4][6]

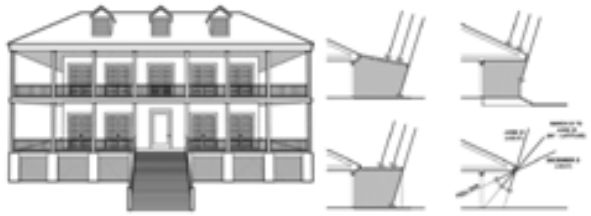

Figure 16:Passive Cooling System,Basc.Pnnl.Gov/Resource-Guides[1]

12.5.Ventilation: Utilize natural ventilation and shading through vegetation, such as trees, climbers, and high [33] [22]shrubs.

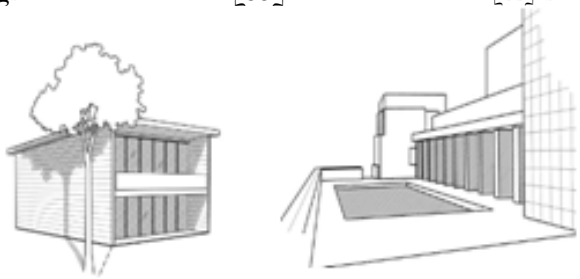

Figure 17:Passive cooling system, multiple doors and openings for proper ventilation system, source :basc.pnnl.gov/resource-guides/passive-and-low-energy-cooling[1] [22] [4] [6]

12.6 Planning: Incorporate expansive layouts and permeable internal arrangements to optimize ventilation, enabling effective shading for walls and windows, thereby minimizing heat gain.[15] [22]

12.7 Multiple doors: Incorporate multiple doors on all sides of buildings for increased airflow and ventilation (Fig17).[9][15]

12.8. North and south orientation: Align buildings along the east-west axis for optimal sun exposure and shading.[17][15]

12.9. Light and insulated roofs: Use lightweight and well-insulated roofs with reflective surfaces to minimize heat gain (Fig16).[17][15]

12.10. Protection from heavy rain: Incorporate measures to protect openings from direct sunlight and rainfall. Ensure proper drainage systems to manage rainfall effectively(Fig16).[17][15]

12.11. Low Thermal Capacity Walls and Floors: Employ building materials with low thermal mass to mitigate heat absorption. Utilize light-colored construction materials and cool roofs as a means to minimize conducted heat gain.[17][15]

12.12. Compact courtyard planning: Utilize courtyards to promote natural ventilation and create a comfortable microclimate. Courtyards serve as communal spaces for social interaction and promote a sense of community.[17]

Figure18: Common spatial form of rural settlement, Masud Ur Rashid ,researchgate.net farhatafzal.com,Historical site -Ruplal-house internal view Design courtyard &openings to allow for breeze penetration while protecting from hot and cold winds.[22] [27] [6] [3]

12.14 Permanent provision for air movement: Ensure single-banked rooms have provisions for continuous air circulation.[17][18] [22]

12.15 Size and position of openings: Opt for smaller openings (10-20%) located at body height on the windward side.[17][18] [22]

13. Case Studies:

To cover the rural, semi-urban, and urban contexts in Bangladesh, we have presented the case studies that demonstrate the design approaches for local materials and climate change adaptation in vernacular architecture in each of these settings.

13.1.a. Rural Context:

Traditional Straw and Mud Houses in North Bengal-Rajshahi, Mymensingh, Bagura,Gazipur,Nauga, Narail.

Many years ago, zamindar Banshidhar Sanyal first built this house then his son zamindar Gangadhar Sanyal later lived here but during Jeevandhar Sanyal's tenure this house was burnt in 1971&Jeevandhar Sanyal returned to the country after the war and renovated this house.Later Jeevandhar Sanyal's sons and his family are now living in this house (Fig 19).

Figure 19: Nauga, vill –Shimulia,Shahagola,Atrai,source – survey pic of Priyanka.(Curtesy – Soumi)

13.1.b Rural Context:

The Nimaidighi village in Nandigram Upazila of Bogura, Bangladesh, holds a tradition of rural Bengal, with a three-story mud house that is now on the verge of extinction. Built in 1976 by Abdur Rashid Mandal, the house features seven rooms and is located on 12 acres of land. The walls of the mud house are made by soaking soil, straw, and water into mud, with each phase of construction taking time to ensure stability (Fig20). The three-story house stands at 35-40 feet high and took around 9 months to complete with the help of 50 workers. Currently, Idris Ali Mandal and his family reside in the house, which has the potential to become a tourist attraction if properly preserved. The house represents the ancient heritage of rural Bengal and stands as the largest three-story mud house in the upazila. Although mud houses have been replaced by modern materials, Nimaidighi village remains of great interest to tourists.

Figure 20:A three-storied mud house at Nimai Dighi village, Source: Kaler Kantho & Salauddin Suman report.

13.2.a. Sub Urban context: community buildings

METIschool

Architects: AnnaHeringer,EikeRoswag
Design/Concept:AnnaHeringer
Technical Planning: Eike Roswag
Clients: Dipshikha,Bangladesh
LandscapeArchitectural,

implementation:KhondakerHasibul Kabir, Abdun Nime
Location: Rudrapur, Dinajpur district, Bangladesh
Building: Two storey school building made with earth and bamboo Ground floor: 3 classrooms, Upper floor: 2 classrooms (dividable), Footprint 275 m2, Floor area 325 m2 ,Construction period: 6 months (September to December-2005, March-April,2006)

Rudrapur is situated in the northern region of the world's most densely populated country. The lack of infrastructure and prevalent poverty drive many rural inhabitants to migrate towards urban areas. To address this, the local NGO Dipshikha has undertaken a development program that aims to provide rural communities with prospects and instill an appreciation for the value of the village, encompassing regional construction methods and local materials, while introducing innovative approaches for efficiency and structural integrity (Fig 21).

By enhancing bamboo structures and lashing techniques, it became feasible to incorporate a second story into the buildings. Brick foundationswere utilized to minimize the impact of moisture on the earthen walls, with the bricks crafted by local artisans. The construction process involved collaboration among architects, teachers, students, and locals, all respecting and honoring local heritage and craftsmanship. The entire project, including materials, construction methods, and workforce, exclusively relied on local resources, emphasizing climate-positive design and sustainability at every level—an essential criterion in the judging process.

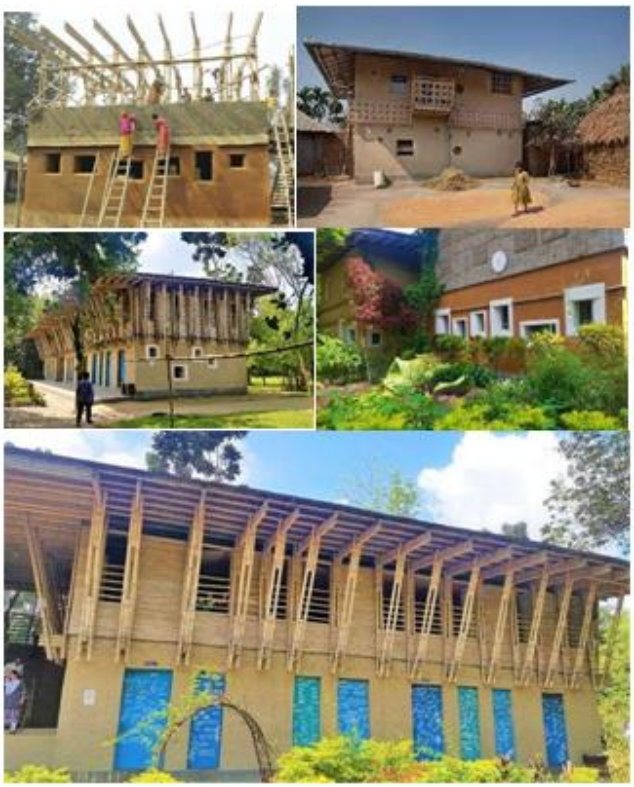

Figure 21:Dipshikha-METI-School-The-Handmade-School-in-Dinajpur-Bangladesh, source-localguidesconnect.com.

"For me, sustainability is a synonym for beauty: a building that is harmonious in its design, structure, technique and use of materials, as well as with the location, the environment, the user, the socio-cultural context. This, for me, is what defines its sustainable and aesthetic value," said Anna.

Figure 22:Dipshikha-METI-School, source-Arch Daily

Significant progress was achieved in utilizing local materials, such as introducing a damp-proof course and brick foundations, as well as incorporating straw into the earthen mixture of soil and water. Regarding bamboo, advancements were made in constructing layered ceilings using bamboo sticks, bamboo boards, and earth. The construction of first-floor walls and roofs employed a framework consisting of beams (comprising four layers of interconnected bamboo sticks) and vertical and diagonal poles.

Figure 23: DESI Trainingcenter, Rudrapur, Bangladesh,source-Anna mam

13.2.b SubUrban context: community buildings

Rohingya Refugee Response's Safe Space for Women and Girls (Camp 25).[33]
Wellbeing, Community Center,Teknaf Upazila,
Bangladesh, [33]
Architects: Rizvi Hassan,Area: 2200 ft²,Year: 2019

The interior courtyard serves as a connecting element, uniting the surrounding rooms into a unified space. While the activity space and rooms may be relatively smaller compared to other centers, the presence of openings towards the courtyard creates a perception of a more expansive area. (Fig-24) Located in Camp 11, the Rohingya Refugee Response's display center offers Rohingya women a facility where they can create, [33] showcase, and sell their handmade products to visitors.

Figure 24: - plan & top view of community-spaces-rohingya-refugee-response Source:https://divisare.com/projects/466916-rizvi-hassan-khwaja-fatmi-saad-ben-mostafa-asif-salman-community-spaces-in-rohingya-refugee-response[33]

Figure 25:- Shantikhana woman camp,Asif Salmanphoto,Arch Daily[33]

Figure :26- aga-khan-trust-culture/akaa/community-spaces-rohingya-refugee-response[33]

13.3.a Sub Urban context: Resort & spa

Panigram Eco Resort and Spa
Site: Chawgacha, Jashore, Bangladesh, Construction completed in 2018,
Land Area: 15 Acre
Architect: Marina Tabassum,

The Panigram Resort project, situated in Chawgacha, Jashore, is an exemplary model of environmentally and socially responsible tourism. Rural Bengal, with its distinct beauty and being the heart of the Ganges delta, holds profound significance. This project presented an opportunity to restore lost pride and belief in the wisdom accumulated over centuries of inhabiting the delta, by incorporating local knowledge of materials and craftsmanship [31].

The engagement of villagers from neighboring communities in the design and construction process not only stimulated the local economy but also fostered a sense of ownership. The project's foundation lies in an extensive study of the region's vernacular architecture, with a particular emphasis on reviving the unique 'Bangla roof' characteristic of the location. The planning and design of the project reflect the values of communal living around courtyards.

By taking a stance on architecture's broader responsibility, the architects behind this project transcend the traditional boundaries of their discipline. They embrace a holistic approach that encompasses social, cultural, and environmental considerations, exemplifying a commitment to creating spaces that extend beyond the realm of architecture alone.

Figure 26: Panigram Resort banquet pavilion from start to finish (Photo by Karen Chi-Chi Lin)

Figure :27- Panigram resort, Panigram Eco Resort and Spa |MTA-Marina Tabassum, Source:https:// marinatabassum architects.com/ panigram-eco-resort-and-spa/

Figure 28: The interior spaces of Panigram Resort adhere to the principles of local vernacular architecture, featuring thatched bamboo huts with mud floors arranged around traditional Bengali courtyards. The primary objective was to establish a seamless integration between the resort and its neighboring villages. The walls were constructed using a mixture of unburnt mud blocks, mortar, and cow dung.

Figure :29- Panigram resort, Panigram Eco Resort and Spa | MTAMarinaTabassum,https://marinatabassumarchitects.com/panigram-eco-resort-and-spa/

13.3.b Urban context: commercial building

This rooftop restaurant in Dhaka, Bangladesh, offers a peaceful and green escape from the busy city below.

Green Lounge: An Enchanted Sky Garden

Name:	Al Mamun Ur Rashid | AMUR Architecture
Year:	2018
Location:	Kazi Nazrul Islam Avenue, Dhaka
Spatial Description :	Perched atop a high-rise building, this restaurant offers a tranquil oasis above the bustling urban landscape. Its design embraces a lush, verdant garden that fosters a serene ambiance. Boasting a seating capacity of approximately 500 guests spread across two levels.

Figure :30- Green Lounge: An Enchanted Sky Garden,source-https://contextbd.com/green-lounge-enchanted-sky-garden/

It proudly claims the title of being the largest rooftop restaurant in Bangladesh.Inspired by rural village architecture,the spaces within the establishment draw upon various metaphors, including courtyards, river edges, village house forms, and vegetable cultivation structures. These elements seamlessly come together to create a unified and meaningful experience for visitors. The design pays particular attention to the harmonious relationship between the soil and trees, incorporating the presence of a pond and providing seating areas beneath the shade of trees to deepen the connection with nature.

Figure 31- Green Lounge: An Enchanted Sky Garden,source-contextBD

13.4: Case study through stakeholder's involvement and experiences about vernacular architecture practice in Bangladesh:

Figure :32- working procedure of case study analysis process

13.4.1:Interviews: Conduct interviews with stakeholders to get their firsthand accounts of their involvement in vernacular architecture practice. This could include architects, engineers, builders, community members, and government officials.

13.4.2:Focus groups: Gather stakeholders in focus groups to discuss their experiences with vernacular architecture practice to get a variety of perspectives and to identify common themes.

13.4.3:Surveys: surveys to collect quantitative data about stakeholder involvement in vernacular architecture practice to learn their perceived benefits of vernacular architecture, and their suggestions for improvement.

13.4.4:Visual representations: to represent data after analysis.

Abdun Nime, an individual deeply connected to nature, finds solace in the elements of plants, soil, and water. Despite lacking formal architectural training, he passionately crafts architectural wonders in rural and urban settings, using natural ingredients and locally sourced vernacular materials. Collaborating with visionaries like Hasibul Kabir and renowned architect Ana Heringer, they embarked on a remarkable journey, embracing mud, bamboo, and tin shade roofing systems. This audacious project garnered global attention and earned them the prestigious Aga Khan Award, celebrating their architectural prowess and inspiring cultural introspection. Abdun Nime's unwavering commitment to sustainability and his profound affinity for the natural world result in creations that harmoniously coexist with nature itself.

Figure33:working glimpse of Abdun Nime (curtesy: Mr.Nime)

Abdun Nime's remarkable success led to a scholarship in Austria, where he immersed himself in earth structures. Returning to Bangladesh, he collaborated with esteemed architects like Hasibul Kabir, Saif ul Haque, Jalal Ahmed, and Nahas Khalil. Together, they honored the architectural legacy of Majharul Islam and Bashirul Haque, merging indigenous styles with contemporary aesthetics. Inspired by these pioneers, they create architectural marvels using mud, bamboo, and stabilized composite materials. Their harmonious fusion of tradition and modernity stands as a beacon of sustainability and environmental consciousness, captivating the eye while preserving Bangladesh's vernacular heritage.

Figure 34:Mud wall & Rammed wall;working glimpse of Abdun Nime in Rudrapur,Joypurhat and Ar. Jalal ahmed's project Gazipur Baker resort (curtesy :Mr. Nime)

Nime eloquently expresses his profound admiration for the fertile soil of Bangladesh, which bears immense potential for constructing various forms of architectural

splendor. Through his explorations in the enchanting hilly regions, he has unearthed a palette of sixteen captivating soil colors, each imbued with its unique allure. Embracing this vibrant diversity, Nime fearlessly incorporates these vivid soils into his projects, introducing a tapestry of hues that celebrates the rich heritage of the land.

Figure 35: Mud wall, Shubarnadighi ,Client:Brigadier Baker, Gazipur, now being used as a resort.

Rainwater filter system installed, gained Berger awards, tinned steel structures on the roof. He says," The mud house needed a hat on head& a boot on feet to ensure safety from rain or storm water. As binding material he uses lime,shurki,thatch,Gum of trees, powder of leaves,cowdung, cheese etc from nature.

Figure 36:Mud made stair,discovery with different mud color ,use of raw wooden door. (curtesy: Mr. Nime)

Nime values mud as a versatile construction resource, using it for foundations, walls, floors, and courtyards, often combined with terracotta blocks. He advocates rainwater harvesting, bio-gas plants, and solar energy for sustainability. Nime's vision transcends current trends, aiming for buildings in harmony with nature and supporting local farmers by transforming into paddy fields. He envisions a world where architectural splendor and ecological responsibility coexist, leaving a lasting legacy. Admiring Bangladesh's fertile soil with sixteen captivating colors, he incorporates them into projects using stabilization techniques and modern technology. Nime urges architects and policymakers to prioritize local materials for sustainable and cost-effective structures, envisioning a future embracing nature's grandeur over skyscrapers.

13.5.Co.Creation.Architects: Architect Khondaker Hasibul Kabir is renowned for his community engagement and meaningful architecture, centered around simplicity, self-reliance, and celebrating everyday life. His notable projects include the "Platform of Hope" in Dhaka's Korail slum, the nature-integrated Jol O Jongoler Kabbo retreat, cyclone-affected homes rebuilding in Satkhira, and the inclusive "Houses for Everyone, Made by Everyone" initiative in Jhenaidah. Kabir's work prioritizes co-creation, trust-building, and participatory processes, empowering communities and enhancing living conditions. His approach diverges from mainstream architecture, serving as inspiration for young architects aiming to create a positive impact.

Collaborating with Suhailey Farzana as "Co.Creation.Architects," Kabir opened up the Nabaganga River's banks in Jhenaidah, Bangladesh, to benefit the local community. The community-driven project aims to provide public spaces for the riverine city's 250,000 residents, offering walkways, gardens, and cultural facilities while promoting environmental initiatives to enhance biodiversity along the river. Utilizing local materials and involving local builders, masons, and craftsmen, the project preserves existing trees and vegetation, maintaining a contextual approach. Future phases will focus on enhancing public utilization with promenades, gardens, cultural facilities, and further biodiversity initiatives. Nime also contributed to this project alongside the team.

Figure 37:The project comprises two 'ghats' - stairways leading down to platforms in the river, with adjacent walkways - and the opening of previously obstructed footpaths that now lead to them.Simplecontextual designs.Housing Project in Jhenaidah, Photo: Bengal Institute**,** https://bengal.institute/news/kabir-an-architect-of-the-life-world/

Chetona, a renowned architectural firm in Bangladesh founded by Ar. Majharul Islam in 1964, is highly esteemed for blending traditional Bangladeshi architectural styles with contemporary designs. The firm's notable projects, including the Bangladesh National Museum, National Parliament House, and Bangabandhu International Conference Centre, showcase their innovative approach while preserving Bangladeshi culture and heritage. Chetona prioritizes sustainable practices, emphasizing environmental considerations in their designs.

Nahas Ahmed Khalil, an esteemed Bangladeshi architect, urban planner, and educator, advocates for sustainable building design in both urban and remote areas. He highlights the importance of shading elements to reduce sunlight penetration, employing wavy concrete louvers to block the western sun while maintaining openness. Nahas believes in using local materials and context-specific

solutions to create serene and beautiful environments. He sees biophilic and high-tech mechanical designs as complementary approaches and urges collaboration among stakeholders to tackle global warming. Nahas emphasizes architects' vital role in reducing carbon emissions and finding sustainable solutions derived from nature, echoing the quote, "Touch the earth lightly."

A Sub Urban residential buildings:Paternal home of Nahas Khalil,Kishorganj,Nandina:

Figure 38- Beautiful vacation house with brick landing stage, Split Bamboo pith, frame remains hidden inside. Pavilion like in between space. Indoor outdoor relationship.
Source –survey pic of Priyanka,(curtesy: Mr. Lutfur)

Figure 39- backyard garden, internal spaces Source –survey pic of Priyanka, (curtesy: Mr. Lutfur)

An urban vacation Duplex Mud house in Savar designed by Ar.Nahas Khalil :

Figure 40-Structural formation &interior spaces of Nahas sir's sister's home in Savar. Source –survey pic of Priyanka 15 years running of thai building -to ensure low maintenance tali/terracotta was added on the plinth level of the building.

Floor was made of Drymix concrete(sand, cement, brick chips) then rammed compactly to save the top soil from producing dust, rain protection purpose, wall half/1/3 regular maintenance drip course of cement on wall. , (curtesy: Ar. Waseef Hossain)

14. Sustainable design principles

Sustainability is based on a simple principle. Everything that we need for our survival and well-being depends, either directly or indirectly, on our natural environment.[21][18][10]

Maximize the potential of the site.

1. Minimize the use of non-renewable energy.
2. Utilize environmentally friendly products.
3. Improve the quality of indoor environments.
4. Optimize practices for operations and maintenance.[21][18][10]

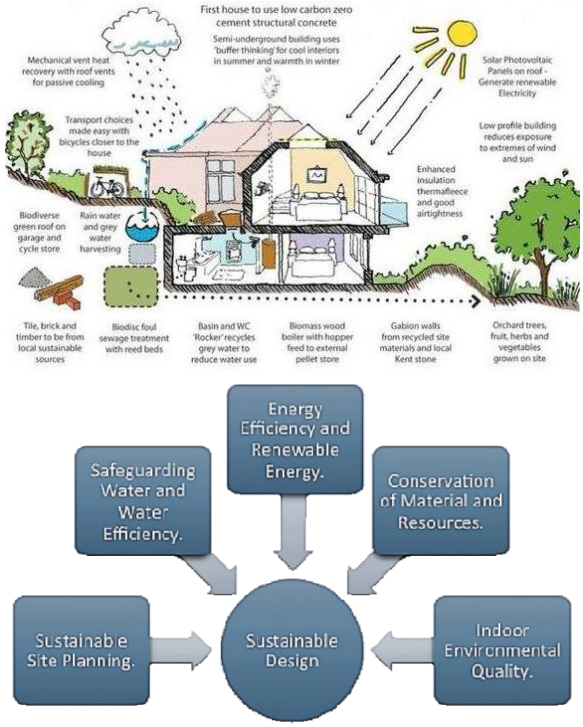

Figure 41- Source –Place54architects.Com. First House To Use Low Carbon Zero Cement Structural Concrete& Sustainable Design Principles. [21][18] [10]

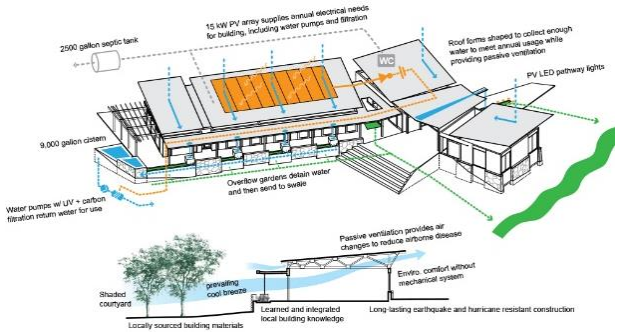

Figure 42-Energy efficient sustainable building design. Source:/www.rdcollab.com/how-we-work/sustainable-designRothschild Doyno Collaborative, Pittsburgh's vibrant Strip District

"When considering sustainability in construction, traditional architecture can be more sustainable if enhanced with modern technology[21] [10] Sustainable architecture:

- Relies significantly on locally available materials and transportation methods.
- Utilizes resources that are abundant enough to meet general demand without harming the environment.
- Does not rely on equipment that is difficult to obtain.
- Leverages skills that can realistically be developed within the community.
- Remains affordable within the local socio-economic context.
- Yields long-lasting results, Adapts and withstands the local climate.

Offers flexibility to accommodate local customs and needs&Can be replicated by the local community.(NORTON, 1999)

15. Why should architects prefer indigenous method over conventional system?

Here is a comparative chart on the total analysis between Traditional approach and Modern approach in designing build form in Bangladesh in terms of Cost effectiveness, climatic comfort, outlook, sustainable and environment friendly issue [14] [20] Fig 43

Factor	Traditional Approach	Modern Approach
Cost effectiveness	Less expensive - Can be built using locally available materials - Requires less skilled labor	- More expensive - Requires imported materials - Requires more skilled labor
Climatic comfort	- Better suited to the hot, humid climate of Bangladesh - Can provide natural ventilation and shading - Can help to reduce energy costs	- May not be as well-suited to the hot, humid climate of Bangladesh - May require air conditioning and other energy-intensive systems
Outlook	- Can provide a sense of community and history - Can be more aesthetically pleasing to some people	- Can be more modern and stylish - Can be more functional and efficient
Sustainability	- Can use more sustainable materials - Can be designed to be more energy-efficient - Can be designed to capture rainwater and use it for irrigation	- May use less sustainable materials - May not be as energy-efficient - May not be designed to capture rainwater and use it for irrigation
Environment friendly	- Can be built using natural materials - Can be designed to reduce pollution - Can be designed to conserve water and energy	- May use more synthetic materials - May not be designed to reduce pollution - May not be designed to conserve water and energy

The kutcha style unifies both realms, claiming 74.4% of the architectural tapestry. Drawing on local materials and heritage, we can weave an exquisite architectural grandeur that honors our beloved Bangladesh in the most captivating manner. Additionally, traditional building systems often have environmental benefits, such as lower carbon emissions and reduced energy consumption, which can contribute to long-term cost savings and sustainability. [33] [20] [34]

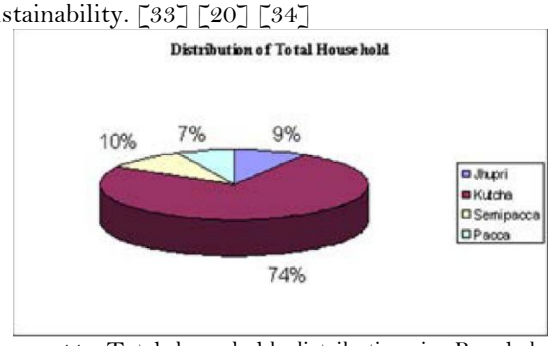

Figure 44- Total household distribution in Bangladesh[20] [34] labor costs percentages in reinforced ICSEB masonry and hybrid roofing.

Cost-benefit analysis[20] [36] of conventional and modern building materials for sustainable development of social housing:

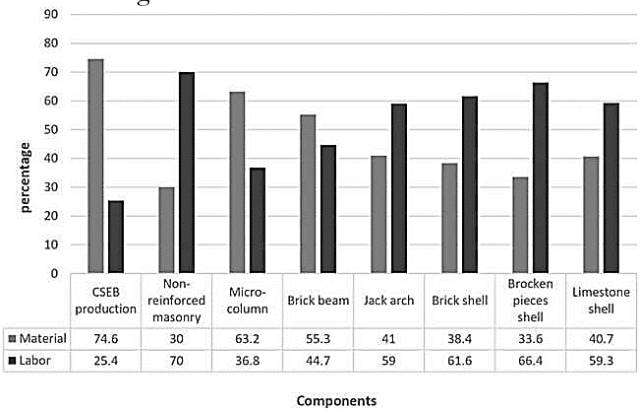

Figure 45- material& labor basis cost comparative analysis [18] [36]

The cost of different types of traditional and conventional style buildings in Bangladesh in (BDT) source –BNBC ,[20] [23]:

Construction Style	Building Type and material	Dwelling structure	Cost per Square Foot with material &labor
Traditional	Bamboo structured straw shade&mud wall and plinth	Jhupri style	750 BDT
	Tin shade stabilized Mud wall with Bamboo reinforcement	Kutcha style	1000 BDT
	Tin shade, Bamboo structure, Mud wall	Semi Pucca	850 BDT
	Rat Trap Foundation,18"Rammed Earth Wall, Concrete	Pucca	1150-1200 BDT
Conventional	Slab 2 Floors		
	Wooden frame, Tin shade,Tin wall, Plinth Brick soiling cc plastered	Kutcha style	850-1000 BDT
	Wooden frame, Tin shade, Brick cement wall, Plinth Brick cc plastered	Semi Pucca	1200 BDT
	Beam Column Structure	Pucca	2000-2200BDT
	Steel Structure	Pucca	3000-3500BDT

Figure 46: As we can see, the cost of traditional style buildings in Bangladesh is generally lower than the cost of conventional style buildings. However, it is important to note that the cost of a building will also depend on the size and complexity of the structure. For example, a large, complex traditional style building may be more expensive than a small, simple conventional style building. [23]

16. Integration of Traditional and Modern Techniques: Sustainable modern modifications: Recommendation for architects [20]

- Strengthening local low-cost traditional materials in modern technology and style[19]

16.1.Earth Strengthening& Stabilization Techniques: [25] [1]

a) Cob
b) Adobe bricks.
c) Wattle-and-daub.
d) Rat trap foundation system
e) Rammed Earth (usually stabilized with cement)
f) Poured Earth (stabilized with cement)
g) Pressed Earth bricks (stabilized with cement)
h) In-situ Adobe (stabilized with cement)

16.2. The key differences between earth strengthening and stabilization[25][1]:

Feature	Earth Strengthening	Earth Stabilization
Materials	Natural materials, such as fly ash,cement,Geosynthetics,lime, Cementitious Grouts, Fixing mesh and anchoring	Chemicals, such as bitumen, Gravel or Aggregate,Bentonite, asphalt, Gabions or Geopolymers
Techniques	Involves techniques such as compaction, soil reinforcement, and soil compaction grouting.	Involves techniques such as soil stabilization additives, soil nailing, and slope stabilization methods.
Purpose	Focuses on improving the strength and load-bearing capacity of the soil.	Focuses on preventing soil erosion, controlling slope stability, and reducing the risk of landslides.
Applications	Walls, floors, roofs, etc.	Roads, embankments, etc.

Figure 47: differences between earth strengthening and stabilization,Source: Shelf Study of Priyanka[14] [20]

a.Cob: Cob, an age-old construction technique, combines sandy subsoil, clay, and fibrous organic materials like straw. These ingredients are thoroughly mixed, creating a cohesive mixture used to build solid walls by stacking and gently compacting earth balls. Cob structures are renowned for their long-lasting nature and excellent thermal properties (Houben and Guillaud, 1994).[12]

Fig48. Cob,Soil Stabilization materials & Methods[12]

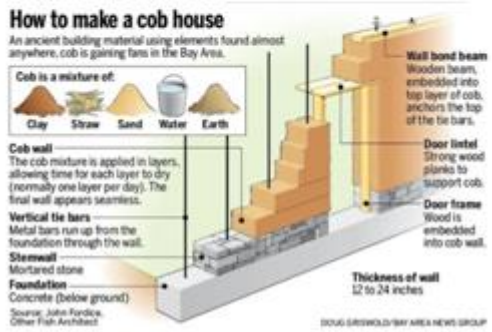

FIg49: A wall being constructed of cob,source -[27] [12] [9]www.mercurynews.com ,published March 28' 2014

b.Adobe Bricks : Adobe is a blend of soil, natural fibers, and water that is shaped into bricks and subsequently dried under specific climate conditions. The use of adobe in construction has been prevalent and is appreciated for its cost-effectiveness and ability to provide thermal comfort (Illampas et al., 2014). The adobe wall reinforced with modified mud masonry and steel-wire-mesh ties in wooden structures had the highest overall performance improvement in seismic and collapse resistance. Adobe brick, an ancient construction material, endures due to its durability, versatility, and use of renewable resources. [17]

Figure 50: Abode brick picture &watte construction process, Source:www.clovisstone.net&www.lowimpact.org[17]

c.Wattle and Daub: Wattle and daub is a technique where wooden strips (wattle) are woven together and covered with a mixture of clay earth, straw, or other vegetable fibers (daub). This method provides structural strength and minimizes shrinkage cracks upon drying (Houben and Guillaud, 1994). It is sustainable, durable, and encourages creativity in building design.[9][1]

d.Rat trap foundation system: The rat trap bond, also referred to as the Chinese brick bond, is a specific kind of masonry bond. In this modular arrangement, bricks are positioned vertically, resulting in a cavity within the wall. Despite this variation, the overall thickness of the wall remains unchanged compared to traditional brick masonrywalls. [36][9]

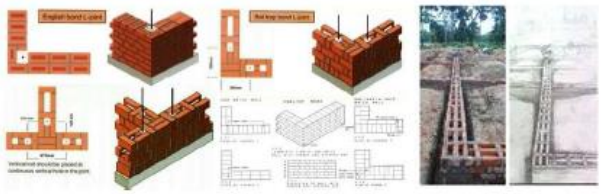

Fig51:Rat Trap Foundation construction process [36] [18],curtesy-engineeringdiscoveries.com and Abdun Nime[1]

e.Rammed Earth: Rammed earth involves pouring moist soil into formwork in layers and compacting it manually or with pneumatic rammers. The technique creates a monolithic wall by dynamically compacting the soil. Reinforcement with rebars is sometimes used to increase structural integrity[18]

Fig52.Rammed earth formation source: Abdun Nime ,Earth constructor

Concerns about sustainability in construction focus on reducing the energy and carbon footprint of materials. Cement and fired clay products contribute significantly to CO_2 emissions, leading to a growing interest in unfired earthen materials. Rammed earth, an in-situ construction method, is experiencing a global revival supported by limited guides and standards. This is the latest technique

for seismic rammed earth construction:

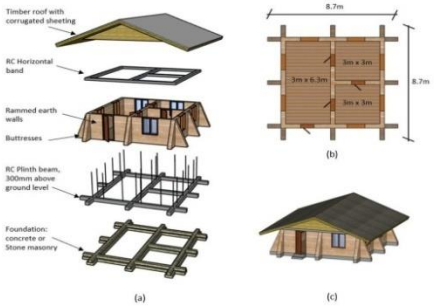

Figure 53: Exploded-view-a-plan-view-b-and-finished-view-c-of-proposed-rammed-earth-house ,source -[18] [35]

g.Compressed Earth Block (CEB): CEB [26]construction involves mechanically pressing soil particles into small-sized blocks, which are then installed on walls with thin layers of mortar for bonding. The compacting process improves the engineering properties of the soil, making it stronger and more durable (Rigassi, 1985). The compressive strength of the CEB basically depends on the block density, amount of stabilizer such as lime or cement, and composition of the soil. 3–4 MPa in compressive strength is an average result of 7% cement in sandy soil composition [26]

Fig 54:CEB Blocks, source https://www.structuralguide.com/compressed-earth-block/[26]

h.Autoclave Aerated Concrete (AAC) Block, Eco Friendly Green Bricks Ltd.[19] [26]

Figure 55: ACC Blocks- https://nextblock.build/about

Next block is an eco-friendly construction material that replaces concrete blocks, wood, and bricks. AAC blocks offer sustainability benefits such as reduced waste, land preservation, lower pollution, water efficiency, thermal efficiency, fire resistance, and durability.[19] [18]

16.2. Soil Stabilization Methods:

Soil stabilization aims to enhance the strength and properties of natural soil for construction purposes. The [26] following methods are commonly used:[25]

- **Stabilization by Reinforcement:** This method involves reinforcing the soil with materials such as geo-synthetics or metallic elements toimprove its mechanical capability and increase compressive and tensile strength.[25]
- **Stabilization by Waterproofing:** Water-proofing agents or techniques are employed to reduce the volume of voids in the soil, minimizing shrinkage cracks caused by moistureproofing agents or techniques are employed to reduce the volume of voids in the soil, minimizing shrinkage cracks caused by moisturefluctuations.[25]

For waterproofing adobe bricks, the method of stabilization through cementing is employed. This involves mixing mortar with the bricks and allowing themto reach a semi-stabilized or fully stabilized state. The recommended cement for this purpose is Portland cement. By adding 3-6% of Portland cement by weight,the result is a semi-stabilized block, while adding 7-12% of Portland cement by weight produces a fully stabilized block. To achieve waterproofing, a mixture of the brickswith 5% Portland cement should be combined using a mixer.

- **Stabilization by Chemical Treatment**: Chemicals, such as stabilizers or modifiers, are introduced to the soil to alter its properties andenhance its performance against environmental factors.

16.3. Modern Techniques: Adaptable & Sustainable modifications: materials and systems [7][15][9]

Adaptable Vernacular Building system	wall materials:	Roof materials:	Floor materials:
Mud brick vaults and domes	Rammed earth walls	Stabilized earth floors	Earth reel roofs
Earthquake resistant mud/bamboo structures	Compressed soil block walls	Burnt clay and concrete components	soil brick roof
Adobe brick house	Bamboo reinforced earth walls	Precast concrete ceiling components	Clay tile roofs
Modular framed earth block construction	Burnt clay brick walls	Timber floors	Precast concrete channel roof
Lok Bild system	Concrete hollow block walls	Common floor finishes	Ferro cement roofs
Concrete panel house	Bamboo walls		Corrugated fiber concrete roofing sheets
Ferro cement housing units	Timber panel walls		Durable thatch with stiff-stem grasses
Fibracreto building system	Walls from agro waste		Bamboo roof structure
Bamboo Crete construction			Pole timber roof structures
Bamboo and mud houses			Bamboo and wood shingles
Prefabricated timber hut			Fiber and micro concrete tiles
Prefabricated wooden house			
Timber houses for flood areas			
Rha-lime prototype house			

Figure 54. Building techniques options, source - Appropriate Building Materials for sustainable development guide. [7] [15] [9]

17. Initiatives to promote Sustainable [9] passive design system in architecture in Bangladesh:

17.1.Architects and Design Professionals:

To solve the challenges and promote the traditional approach with enhanced strength through modern techniques, architects can [2]:

- Conduct thorough research to understand limitations and explore modern enhancements.
- Test and develop indigenous materials through collaboration with material scientists.
- Collaborate closely with local craftsmen to combine traditional knowledge with modern practices. [2]
- Advocate for building codes that support the use of indigenous materials in industrial projects.
- Educate clients, developers, and the public about the benefits and advancements in indigenous materials. [2]
- Undertake pilot projects and document case studies to showcase successful integration.
- Continuously learn from traditional practices and adapt to emerging technologies. [2]

By implementing these strategies, architects can overcome limitations, promote sustainability, preserve cultural heritage, and meet the demands of industrial construction.

17.2. Government Agencies and Policy Makers [2]:

- Ban conventional brick manufacturing and promote environmentally friendly practices.
- Provide affordable housing for slum dwellers and publish guidelines for disaster-resilient rural housing.[2]
- Formulate laws to prevent construction on agricultural land.Integration into building codes and regulations.[2]
- Promote alternative construction materials like sand and silt blocks. Arrange proper energy audit and training on traditional material use.
- Increase the use of sustainable blocks in government construction projects.[2]
- Launch awareness campaigns to educate the public and professionals about the benefits and value of traditional construction methods.
- Provide financial incentives and subsidies to encourage the use of traditional construction techniques and materials. This can include tax breaks, grants, or low-interest loans for builders and homeowners who opt for traditional methods.[2][1]

17.3.Future Directions: Probable alternatives of burnt brick-

To protect agricultural land, the government is formulating a draft law on urban and regional planning to prevent construction on agricultural areas. As an alternative to traditional bricks, the HBRI is manufacturing blocks made from sand and silt. The government aims to gradually increase the use of these blocks in its construction projects, starting at 20% in 2020-2021 and reaching 100% by 2025-2026. This transition is driven by the demand for green buildings and the need to reduce air pollution.[2][34]

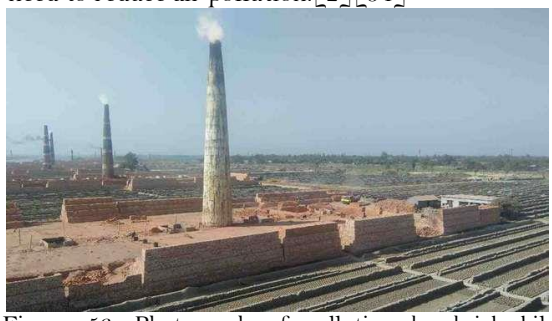

Figure 56: Photograph of pollution by brick kilns in Bangladesh (Published in Dhaka Tribune on 9 th November, 2017)[2][34]

So we must find some solution of this problem.[18] [26] Here are some alternatives to traditional bricks:

- Terracotta hollow blocks
- Interlocking mud blocks
- Soil stabilized blocks
- Big size lightweight Aerocon blocks
- Concrete blocks
- Fly ash bricks
- Calcium silicate bricks
- Cast-in-situ Ferro-cement

18. Conclusion:

This research paper has examined the design approaches for local materials and climate change adaptation in the vernacular architecture of Bangladesh. The study highlights the importance of traditional design practices using locally available materials and their sustainability within rural and urban communities. The changing global context has influenced architectural evolution, with new developments often compromising sustainability criteria. The research emphasizes the need for a sustainable approach to architectural changes and calls for integrated studies of different settlement levels. Despite limitations in documentation and analysis, as well as the lack of a universally applicable method, this research lays the groundwork for future investigations. It provides valuable insights for architects, planners, and policymakers seeking to effectively integrate local materials and climate change adaptation strategies into Bangladesh's vernacular architecture.

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