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VERNACULAR STYLE OF ARCHITECTURE AND ARCHITECTURAL ELEMENTS IN BENGAL, INDIA

[1] Sanchari Chatterjee, [2] Ar. Rizwan Kazmi.

[1] Architect, [2] Assistant Professor.

[1] Department of Architecture and Planning,

[1] Birla Institute of Technology, Mesra, Ranchi, Jharkhand, India.

***Abstract**: The architecture of a place is the interplay of several factors ranging from climatic, geographic, physical, socio-cultural, environmental, economic, and resource availability. The vernacular architecture based on traditional wisdom helps bring a comfortable built environment for the people and the community. Vernacular architecture style includes sustainable construction techniques and building materials that can be adopted in contemporary architecture style. This paper aims at studying sustainable and local practices of architecture and its application in the case of Bengal. The study's methodology is the descriptive analysis through comprehensive literature of the published works relevant to the vernacular architecture of Bengal and secondary case studies demonstrating the vernacular architectural elements and style and their advantages in bringing a comfortable built environment for the community. In the process, the study helps analyze the climate responsive architectural features adopted in the buildings. This study ultimately helps in understanding the factors and the design solutions to achieve a sustainable building with the vernacular architectural style and locally available cost-effective materials in the case of Bengal.*

Index Terms **- vernacular architecture, climate responsive architecture.**

1. INTRODUCTION

Buildings and the environment always have significant impacts on one another. Sustainable techniques in architecture have an excellent effect on the environment and the users. However, the choice of materials and design strategies plays an essential role in attaining sustainability and achieving desired thermal comfort. The prime factors in achieving thermal comfort are solar radiation, humidity, overall temperature, precipitation, and wind flow.

Also, in the present scenario, modern techniques and solutions are being adapted for various architectural problems as this field has experienced a lot of advancement in construction techniques and practices. With time the existing methods are losing their identity. However, the main root of these advanced technologies is those ancient techniques and procedures. With the help of modern techniques, traditional building styles can still be used. E.g., As traditional mud is not considered a high-end material, CSEB blocks (compressed stabilized earth blocks) could be used instead.

This study will discuss various vernacular techniques and materials that will help attain sustainability concerning the warm and humid climate of Bengal.

This paper aims: "To study sustainable and vernacular architecture techniques and its application, along with various Bengal architectural elements in a modern context." In the process the study analyzes traditional and vernacular building science and its significance in the current time and climate-responsive architectural concepts adopted and implemented in conventional buildings in Bengal.

2. METHODOLOGY

The methodology adopted for the study is divided into three stages.

1. A comprehensive literature review (derived from various books, articles, research papers, and secondary case studies) relevant to vernacular architectural elements and a technique adopted in Bengal is conducted in the first stage.
2. In the second stage, a few selected secondary case studies are conducted that highlight architectural elements and techniques relevant to Bengal architecture.
3. Finally, in the third stage, inferences are drawn through the comprehensive literature review, and secondary case studies and the findings are highlighted.

3. LITERATURE REVIEWS

A clear understanding of the concept of Building Science was done by Peter H., 2018. Peter H. highlighted that building science includes physics, chemistry, biology, climatology, and ecology related to the built environment. The difference between Building Physics and Building Science is that Building Physics focuses on the movement of heat, air, and humidity inside and around the building envelope, while Building Science involves inhabitants who have an impact on the building's efficiency.

Various architectural surveys of traditional buildings of India were carried out by Cooper. I –et al., "Traditional Buildings of India," Thames and Hudson,1998) to study India's existing vernacular building methods. In the book, locally available building material and local building techniques are discussed along with the traditional mud houses of Bengal made up of mud and cow dung and different Bengal roofs **(dochala, charchala, aatchala**) and how different building techniques are a result of locally available materials (mud and bamboo in case of Bengal). In addition to this, climate's role in the building design, which includes orientation, design, the material selection, was discussed. And lastly, it was stated that it is impossible to return purely to traditional building materials because they lacked structural stability and durability (Cooper. I -etal., "Traditional Buildings of India, "Thames and Hudson,1998).

In the south of Bengal (warm, humid climate), one of the unique features of vernacular architecture is the roof style. Bangla roof and various "Chalas" are integral parts of Bengal architecture. Vernacular architecture of a region depends on its climate and culture. Also, with the help of building material, the shape of the building, orientation, things could be designed in a way that it becomes thermally comfortable for the climatic region. For Bengal, the "Bangla roof" helps as the canopy-like structure helps against both sun and rain. (Gupta Janmejoy et al., 2018).

The First Bangla roof was seen on the terracotta temples of Bengal during the 15^{th}-16^{th} century. Eventually, during the 1760s, the English settled in lower Bengal. Due to the tremendous heat, they made canvas tents and tried living inside them, but that too was not easy as the inside temperature rose very quickly. Later during the 1820s, they started constructing huts and used to cover the roof and doors and windows with Jhamp (a mat-like structure), which also helps in ventilation. Figure 1.1 illustrates the evolution of the Bangla Roof from tent to Dochala roof. During the late 1800s, these huts evolved structurally, such as the roofs forming eaves. Then during the 1900s, the curved roofs transformed into square pyramidal roofs and were termed "Charchala." Then during the 1960s,these 'charchala roofs 'transformed into 'aatchala, a double roofing system. Figure 2.2 illustrates the evolution of the Bangla roof from 'charchala' to 'aatchala.'

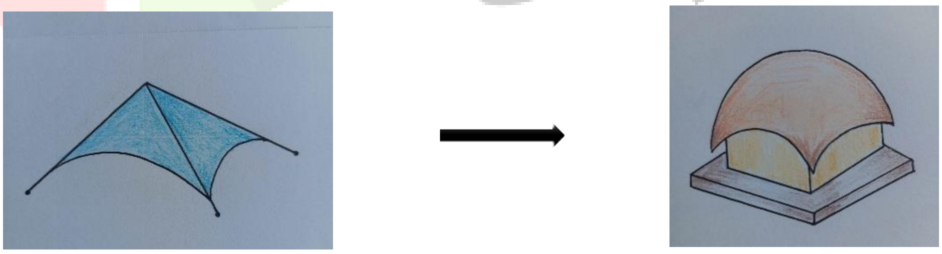


Figure 1.0 .Evolution of Bangla roof from tent to Dochal (Source: Author)

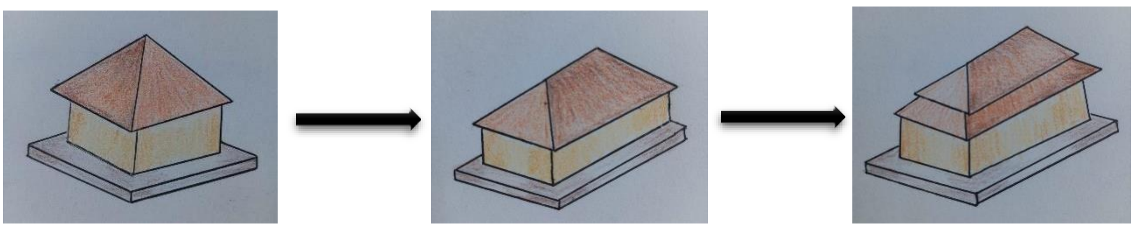


Figure 2.0 Evolution of Bangla roof from charchala to aatchala (Source: Author)

Sinha A., (2018) analyzed the passive cooling techniques in the vernacular architecture of Bengal. Different building techniques are adaptable for thermal comfort in a warm, humid climate, and the concept of building science is explained. Evolution of Bengal roof from tents to huts with dochala, charchala (having slopes in four sides), aatchala (double roofing system with eight slopes which helped in natural lighting and ventilation), and traditional huts transformation having veranda on all four sides is highlighted by Sinha A., 2018.

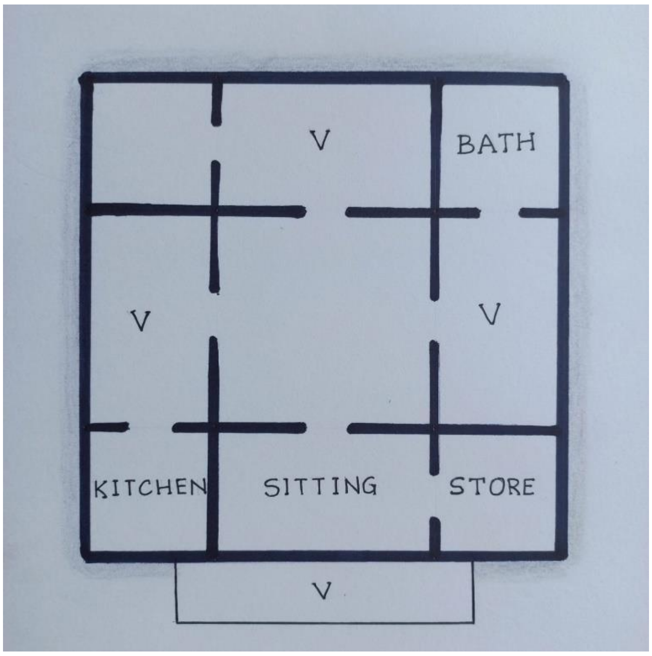


Figure 3.0 Typical plan of a traditional hut in Bengal *(Source: Author)*

Sinha A., (2018) analyses the major architectural aspects such as orientation, planning and spatial arrangements, building envelop, which includes walls, roofs, floors and fenestrations, building technique, and building materials used. Figure 3.3 illustrates the typical plan of a traditional hut in Bengal. Then it analyses the Bioclimatic aspects, including outdoor climatic conditions, air temperature, wind speed and direction, relative humidity, and solar radiation, and concludes with preferable design intervention for passive cooling in the region.

Henk M. Jonkersga et al., 2020 explore the usage of earth as a building material. Some of the traditional construction techniques with raw earth are COB technique, adobe technique, wattle, and daub technique. In contrast, modern construction technique uses CSEB (compressed stabilized earth blocks) and rammed earth construction. On one hand, earthen construction causes better indoor climate, easily recycled and reused but have poor resistance. There are a few advantages of using modern earthen construction over traditional earthen construction; the life span of modern building is more than 50years (approx.), whereas it is 5- 30 years for the conventional technique. Modern earthen construction provides more stabilization, weather resistance, termite resistance, compressive strength than traditional. Modern earthen construction also requires low maintenance. The use of earth as a building material is considered poor due to weathering and erosion. this can be improved with the help of stabilizers such as biomass. Cow dung and cactus extracts can help improve the earth's water-resistance characteristics.

Fatemi Md. Nawrose et al., 2011 discuss the eco-adaptability and sustainability of vernacular architecture. This is a study about Major building materials for the area that is locally available mud and bamboo. Most of the time, plinths made up of earth, walls majorly made up of earth or bamboo, and hatch roofs are observed are observed. Figure5.5 shows materials used in vernacular houses of Bengal

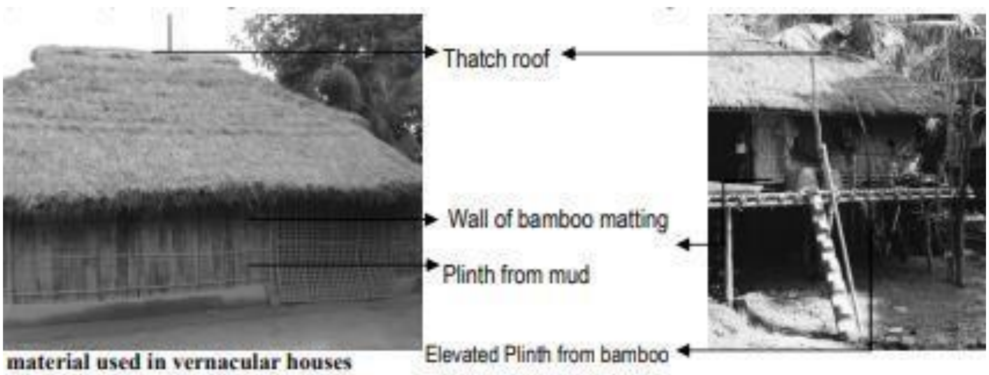


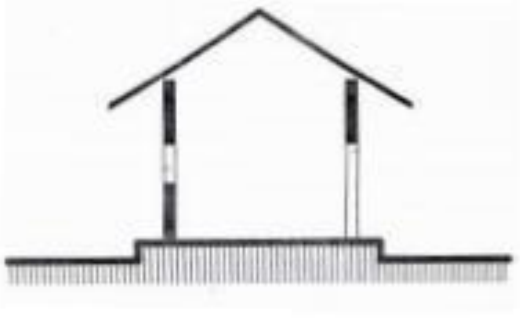
Figure 4.0 *Materials used in vernacular houses of Bengal*

(Source: A report on Sustainability and Eco-Adaptability in Vernacular architecture in Bangladesh)

This study also highlights the orientation of the building to be North-South and openings to be on the south to house the prevailing southern winds. The low height of the buildings and projected overhangs roof helps in reducing solar heat gain. The overhanging roof not only helps minimize the solar heat gain but also protects the building against rain. Holes are provided at the gable end of the top, which reduces heat.

Figure 5.0 The holes in the gable end of the roof

Figure 6.0 The air flow inside through roof and windows



(Source: A report on Sustainability and Eco-Adaptability in Vernacular architecture in Bangladesh)

Buildings are said to be sustainable when it is environment-friendly, cost-effective throughout the lifecycle of the building, is flexible and adaptable, and use locally available materials and tools.

TheRevivaloftraditionalbuildingmaterials(majorlyclay)tooffermoresustainability is done by Gheorghe D.etal., 2010. The use of conventional buildings reduces the overall carbon footprint and is more cost-effective. The study is about clay being a malleable material, and it can be used in various forms such as tiles and a ceramic brick. It is also completely recyclable. It also has a high thermal mass which causes less temperature fluctuation inside the building.

4. Summary of findings from literature reviews

Table 1 Summary of findings from Literature Reviews.

(Source: Author)

S. No.	Author & Year of publication.	Findings
1.	Cooper. I -et al., 1998.	Vernacular typology is associated with climatic, cultural and social factors. Construction Techniques depend on availability of materials: mud, bamboo etc for case of Bengal. the various building materials that are used for Pakka construction within the country It is not possible to go back to the traditional phase of construction, because it lacked structural stability and durability. The evolution of the chala roof of Bengal
	Gupta Janmejoy et al., 2018	Climate of lower Bengal. To understand the primary roots behind the architectural style and various factors that caused evolution. The evolution of the chala roof (traditional to contemporary architecture) Aatchala increases roof depth, also formation of clerestory for natural lighting as well as ventilation.
	Peter H., 2018	Understanding building science Understanding the interdependence of enclosures, mechanical systems and occupants Understanding evolution of architecture and its bioclimatic behaviour. Using durable and low maintenance products Efficient use of materials Renewable energy and energy/water efficiency Low impact operations (reduces- construction impact, operational

		pollution or waste. Stormwater pollution, pesticides treatment)
	Sinha A., (2018)	Climate Responsive principles appreciates the traditional and vernacular building science and its relevance in present context. Various passive cooling techniques feasible in a specific climatic condition was studied Identification of optimal technologies and design solutions from vernacular architecture for a warm humid climate of the same kind. Orientation, fenestrations. Materials to be used in building envelop, form of the building and spatial organization with respect to warm and humid climate.
	Henk M. Jonkersga et al., 2020	investigates the potential of earthen materials as a low-cost alternative for contemporary architectural building material. Various construction techniques on basis of bioclimatic region and typical construction technique and materials. Use of CSEB, rammed earth construction, poured earth construction. The high cost of modern (stabilised) earthen material can be reduced by minimising the use of cement and hydraulic lime in favour of bio-based alternatives.
	Fatemi Md. Nawrose et al., 2011	sustainability and eco-adaptability of our vernacular architecture Explores traditional housing Interpretation of the environmental behaviour. Environmental considerations such as orientation, solar heat gain minimization, ventilation. Use of locally available building materials Ensure cost effectiveness in the construction Use Flexible design so that it is easy to upgrade.
	Gheorghiu D.etal., 2010	Revival of traditional building materials to offer more sustainability. Uses of clay in many ways such as ceramic brick and tiles etc Clay not only have traditional values but also aesthetic values.

5. Secondary case studies

5.1. Asha Niketan

Laurent Fournier designed Asha Niketan in Kolkata in the year 1995. It is a meditation room for the mentally challenged. It is an example of climate-responsive architecture, considering both the vernacular and ecological aspects. The use of local materials like exposed brick for walls, terracotta tiles which are burnt clay tiles for the roof, and huge windows and ceilings with bamboo mesh can be seen. The plan of the building takes up a zig-zag shape as no surrounding trees were removed. The space inside is small, but the openings are huge compared to the size of the building. South Bengal's predominant southern winds were used in the design.

5.2. A House in Baruipur

It is located in Baruipur, West Bengal, designed by Laurent Fournier in 2017. The total area of the house is 1800sq.ft. It is two and a half storey tall building which is 10 feet approx. It is constructed with the help of both conventional building materials (such as reinforced-concrete frames cemented floors) and sustainable materials (such as bamboo, thatch, and mud). The use of locally available and eco-friendly materials reduces the overall carbon footprint can be seen. Although the ground floor is constructed with the help of the RCC framework, the top floor is majorly constructed with the help of a mud-supported bamboo frame. Ropes were used to join the bamboo frame. There was no use of iron and steel to weld them together.

Curtain walls are used that bulges out the concrete frame. The house was plastered with the help of mud, and these bamboo-mud walls help maintain a constant temperature inside the house. The floor and roof are made up of shallow, unreinforced brick domes (except kitchen and bathroom where there is more water usage), making it 10% to 20 % cheaper than conventional concrete and more resilient and quicker to build overall cost of raw materials is also low.

Sewage water is filtered through sand, gravel, and a planted bed and reused except for direct consumption. The toilets are dry composting eco-san toilets that need no water, and the accumulated waste is turned into compost which the farmers can later use. The thick thatched roofs of the house can withstand rain, sand, and summer heat for approx. 10 years (which is much longer when compared to conventional thatched roofs). This thatch must be strewn on the ground with 1.5 ft (approx.) thick straw reinforcements. The roof also serves as overhangs which protect the mud walls from rainwater.

Instead of using artificial emulsions of various chemicals in painting the exterior of the house, a simple lime wash is used on all sides. Using lime wash helps protecting the walls against weathering and allows air to travel in and out. Thus, helping in regulating the indoor humidity. Using mud as a primary building material makes the building thermally comfortable both during summers and winters. Doors, windows, and large verandas open up in the south to welcome prevalent southern winds. They only allow reflected light, so no direct heat is generated within. The house has solar–power setups that supply approx50% of the electricity. The house has intense beams made up of locally available materials supporting the pillars, making the house earthquake-proof.

5.3. Handmade School in Bangladesh

It is located in Rudrapur, Dinajpur District, Bangladesh. It was designed by Anna Heringer and Eike Roswag and built in the year 2007. It is a primary and secondary school with a 325sq.m area. The ground floor has three classrooms and is made up using thick earth walls and to the back of each classroom is an organically formed series of caves. Upper floor is light and open. The walls are made up of bamboo with openings where one can enjoy the view of the surrounding. Because of the use of these bamboo strips on the top floor, light and shadows can be observed across the floor that contrast with the multicolored saris on the ceiling. The foundation of the building is 50 cm deep, made up of brick masonry with cement plastered over it. A double layer of PE- film (easily locally sourced) is provided as a damp-proof course. It makes the building last longer and reduces its requirement of maintenance. The ground floor uses a method similar to cob walling to create load-bearing walls. A straw earth mixture was heaped to a height of 65cm on top of the foundation wall. The next layer of cob was added after around a week. Door and window lintels and jambs were introduced during the third and fourth layers, and also airing beam made of thick bamboo canes that served as a ceiling wall plate. A three-layer bamboo cane ceiling on the ground floor provides lateral stabilization and link between the supporting beams, with the central layer arranged perpendicular to the other two layers. On the base of the central layer, a layer of split bamboo cane planking was laid and packed with the earthen mix. The frame structure on the top floor is made up of four-layer bamboo beams with longitudinal and diagonal members that are at right angles to the building. The framing at the building's short ends and the stairs help to stiffen the structure. Bamboo rafters at half the frame building intervals underneath provide support for the corrugated iron roof structure and are covered with timber paneling. The outer surfaces are exposed earth walls with lime plastered window frames. The bamboo can esseated in old good pipe footings, with split horizontal timber as lattice work, form the frame work of the green façade on the back side. Clay is used for plastering the inner surface, which is then coated with lime-based paint.

The top floor's façade consists of window frames, and bamboo strips were used to cover these window frames. A parapet around the top floor is provided using the fifth layer of cob walling. It acts as a wind anchor for the upper-story framed structure and roof. Under the roof is a textile ceiling. The cavity behind the textiles ventilates thereof space.

5.4. Pani Community Centre

It is located in Rajarhat, Bangladesh. It was designed by Shidler Scholte Architects. It was built in 2014. It is an educational building with 910 sq.m. Bamboo, mud bricks, mango wood, reclaimed steel, local mortar, and wafer-thin recycled corrugated panels were used to build the structure. There was no electricity or fossil fuels used during construction. The roof consists of large bamboo construction. The roof is lifted high, which helps in reducing the heat build-up within the spaces.

Cooling is also provided with the help of cross ventilation, surrounding vegetation, and a nearby pond. The ground floor has a covered plaza with lavatories next to them, and at the first level, there are freely accessible floors for public meetings. The workshops have bamboo cladding on the wall sand French doors. The structure's orientation allows for optimal cross-ventilation, which makes it thermally comfortable. The roof is overhanging on both sides, which provides shade and protection against rain. It is designed so that the direct sunlight inside the classroom is minimized but provides optimal day light. Nearby pond helps in passive cooling of the classroom.

6. Summary of findings from secondary case studies

Table 2 Summary of findings from Secondary Case Studies

(Source: Author)

S.No.:	BUILDING	FUNCTION	ARCH. STYLE	DESIGN ELEMENTS	MATERIAL USED	INFERENCE
1.	Asha Niketan, 1995	Meditation Centre	Vernacular & Ecological	Climate Responsive: Huge openings, Zig zag shape, Use of Site potential (trees),	Exposed Brickwork, Terracotta Tiles, Bamboo.	Climate responsive architecture making the building thermally comfortable. Use of locally available materials.
2.	House in Baruipur, 2017	Residence	Vernacular	Mud walls, Mud plaster, Shallow brick domes, Curtain walls.	RCC, Bamboo, Thatch & Mud.	Climate responsive architecture making the building thermally comfortable. Use of both Conventional (RCC framework) and sustainable (bamboo, mud) building materials which are locally available.
3.	Handmade school in Bangladesh, 2007	School	Vernacular	Earth Walls, Caves, Bamboo Strips, Load bearing walls, Timber Lattice, Textile Ceiling, Cavity.	RCC, Bamboo, Thatch & Mud.	Climate responsive architecture making the building thermally comfortable. Use of locally available sustainable building materials.
4.	Pani Community Centre, 2008	Community Centre	Vernacular	Earth Walls, Caves, Bamboo Strips, Load bearing walls, Timber Lattice, Textile Ceiling, Cavity.	RCC, Bamboo, Thatch & Mud.	Climate responsive architecture making the building thermally comfortable. Use of locally available sustainable building materials.

7.Conclusion

Adapting sustainable and local techniques and building materials of architecture can be done by implementing aspects of vernacular architecture in contemporary architecture.

Vernacular architecture is greatly influenced by the availability of local building materials. Building materials should be available locally and sustainable (making them more cost –effective).

However, to achieve thermal comfort, choice of building materials plays an important role. To achieve thermal comfort while designing a space, factors such as solar radiation, air humidity, overall temperature of the place, precipitation and wind flow should be taken care of.

Taking the above factors into consideration, for Bengal:

- orientation of the building should be preferably along the east-west axis.
- In warm humid climatic zones, courtyard planning is preferred.
- For South Bengal, wind flow is majorly south and south- west during summer months
- Fenestrations should be comparatively bigger in size for proper ventilation thus reducing the effect of humidity and at the same time should be properly shaded to reduce the heat gain inside the buildings through solar radiations. Windows should be provided in a way that they let summer wind for cross ventilation but stop the winter winds. Fenestrations should also be designed in a way that it cuts off the glare and allows diffused sunlight.

- Walls should have low heat storage capacity and preferably shaded with overhang roofs so that it is not directly exposed to the sun. For walls, brick masonry with earth infill could be used. Exposed brick work cladded with mud or lime wash or bamboo- mud brick walls cladded with mud could be used. Lime wash is used as it protects the wall from weathering and makes the wall breathable.
- If the structure is not more than 2 floors, load bearing walls could be used. Bamboo framework could also be used for structural frame.
- Roof receives maximum solar radiation. Use of pitched roof can help reducing the heat effect as on one part of the roof will be heated at a time.

  For roof, use of terracotta tiles, bamboo thatched roofs or shallow unreinforced brick domes could be used. Foe ceiling, bamboo mesh in different forms could be used.
- Use of mud as it has low thermal conductivity. Although traditional mud is not considered as high-end material. Instead, mud could be used with modern techniques.

8.Acknowledgement

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Last but not the least, I would like to thank all of them who have knowingly and unknowingly helped in completing this paper.

ANNEXURE A

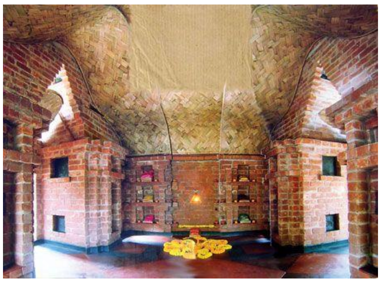

Figure 1.1 Meditating Hall of Asha Niketan (Source: downtoearth.org.in)

Figure 2.1 A house at Baruipur, West Bengal
(Source: wether.com)

Figure 2.2 Bathroom at first floor
(Source: downtoearth.org.in)

Figure 2.3 and **Figure 2.4** First floor of the Baruipur House supported on bamboos
(Source: downtoearth.org.in)

Figure 3.1 and **Figure 3.2** Bulging walls and the thatch roof of the house
(Source: thebetterindia.com)

Figure 3.3
Balinese- style thatch roof
(Source: downtoearth.org.in)

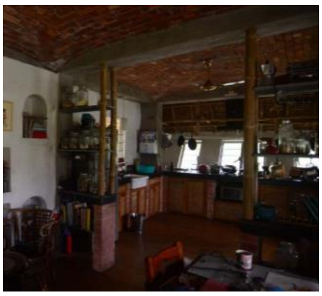

Figure 3.4 Beams that supports the pillars
(Source: downtoearth.org.in)

Figure 3.5 Solar panels at the roof
(Source: downtoearth.org.in)

Figure 4.1 Handmade school in Bangladesh
(Source: Arch Daily)

Figure 4.2 Upper floor walls are made up of bamboo and lower floor using Cob technique
(Source: Arch Daily)

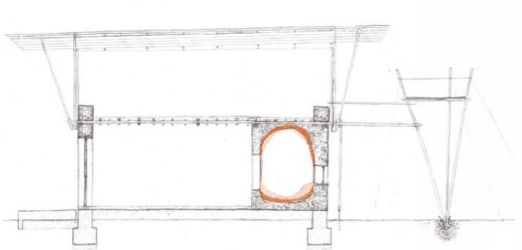

Figure 4.3 Cave like structure at the end of the class room and **Figure 4.4** Section of the classroom
(Source: Arch Daily)

Figure 4.5 School at night with contrast ceiling color with help of saris
(Source: Arch Daily)

Figure 4.6
Bamboo frame structure
(Source: Arch Daily)

Figure 4.7 Pani Community Centre, Bangladesh
(Source: Arch Daily)

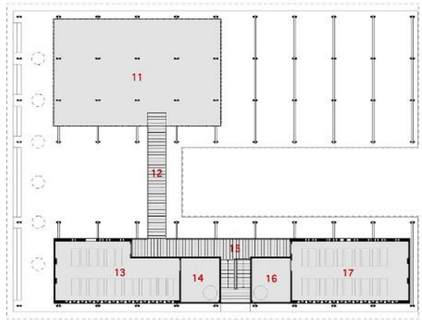

Figure 4.8 First floor plan of Pani Community Centre, Bangladesh
(Source: Arch Daily)

Figure 4.9 and **Figure 4.10** Covered courtyard of Pani Community Centre (Source: Arch Daily)

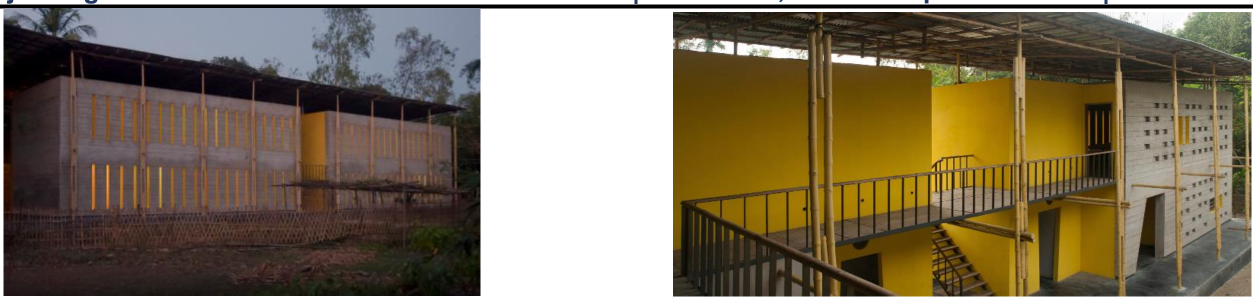

Figure 4.11 and **Figure 4.12** Fenestration for proper cross ventilation at Pani Community Centre (Source: Arch Daily)

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