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Vernacular Architecture of South Asia: Exploring Passive Design Strategies of Traditional Houses in Warm Humid Climate of Bangladesh and Sri Lanka

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Abstract
Vernacular architecture affects traditional house design decisions for different climatic zones. In this study, among South Asian countries, the vernacular practice of Bangladesh and Sri Lanka will be observed separately. As they share almost the same climatic conditions, rural parts of these countries build mud houses as their main living domain. In this study, construction techniques, passive design strategies, thermal comfort, etc of mud houses of both countries have been explored. Different methodologies such as site surveys, literature studies, software simulations, etc. have been applied to perceive and improve passive design strategies. Villages from Bangladesh and Sri Lanka are chosen to examine rural mud houses. The study of these houses provides insight for designing an energy-efficient rural house having thermally comfortable conditions, as well as leaving behind a very low environmental footprint. The existing realities of the mud house are investigated and a few reforms have been suggested to enhance passive energies and comfort of the occupants.

Keywords: Vernacular; Passive design strategies; Thermal comfort; Mudhouse; South Asian Village.

1. Introduction

Vernacular architecture is characterized by its reliance on needs, construction materials and traditions specific to its particular locality. It is indigenous to a specific time and place and not replicated from elsewhere. Historically, vernacular architecture has incorporated the skills and expertise of local builders as opposed to formally-trained architects. Since the late 19th century many professional architects worked in this style and now it has become the broadest interest in sustainable design. It depends on the functions that a building is required to perform and gradually the design gets evolved, becoming more refined and fits the context in which it exists. It includes the availability of resources and skilled workforce, local technology, a proper amount of sunshine, rain, humidity, wind, temperature profiles, local cultures, site surroundings, economic conditions, historic background and so on. The benefits of vernacular architecture include utilizing knowledge and traditions as well as taking advantage of local materials and resources, which are energy efficient and sustainable. As a result, it creates a vital connection between humans and the environment. Due to recent rises in energy costs, the trend has been sensibly utilized in many ways. Architects are embracing regionalism and cultural building traditions, as these structures have proven to be energy-efficient and altogether sustainable. In this time of rapid technological advancement and urbanization, there are still many things to learn from the traditional knowledge of vernacular construction. The vernacular practice has been seen globally and as a south Asian country, Bangladesh is no exception to that. The south Asian geographic region shares a common cultural landscape which is also evident in its vernacular practice. Bangladesh and Sri Lanka possess a rich tradition in the formation and development of its human settlement. It has some specific characteristics. Native people of both countries have hereditarily been practicing this sort of technology for years that reflect ecological and environmental concerns. There is a long history of environmentally strong, eco adaptive, self-sustaining traditional house form and technology in the various parts of Bangladesh and Sri Lanka. Mostly this housing technology depends on locally available materials: mud, mud bricks, bamboo, thatch, straw, timber, stone, etc. However, building forms, functional arrangements, materials vary in different parts of the country. Vernacular architecture and passive design strategy are closely related to each other. Passive design is a process taking advantage of the climate to maintain a comfortable temperature range for the occupants in the home. These strategies applied in traditional houses will give specific and unique identities of their vernacular design. The main material of the traditional rural houses of Bangladesh and Sri Lanka are made of mud. The paper tries to identify the age-old vernacular characteristics of local material mud and passive design strategies of built homesteads. It also analyses and suggests improvements to a more sustainable solution for a better living environment for local people of a warm humid climate.

2. Literature Review

Current trends of vernacular practice and different passive design elements have been identified through literature studies, which were not only confined in south Asian regions but also spread outside Asia. All regions have different climatic conditions and follow specific rules for passive design- this theme is mainly understood from the study. But one thing became common that all regions of the world have their own rich cultural identity and heritage and they follow specific vernacular styles. Rural areas of different countries maintain mud houses as their rich cultural root as well as for material availability. Such practice helps to maintain their vernacular style and also makes it cost-effective and environment friendly. Different study journals were followed to understand the overview of mud house pattern and its vernacular purpose.

Table 1. The significant findings of passive design-related research on mud house.

Author	Year	Findings
Md. Nowrose Fatemi et al.	2011	Traditional house forms and technology in rural Bangladesh expresses regional, cultural, ecological and economic significance.
Khondokar Tariqul Islam et al.	2015	Mudhouse provides a better thermal comfort level Compare to Brick house and CI sheet house.
Nadia Manzur.	2018	House construction technique, socio-economic change, availability and preferences of material are reasons behind the gradual shift in the indigenous practices of a mud house.
M. Dhanasekaran et al.	2014	The utilization of solar passive methods and techniques in modern buildings to achieve thermal comfort allows the possibility of decreasing the dependence on fossil energy and sustainability.
Manori Wijesekera et al.	2012	Simple mud houses rapidly became a thing of the past but the techniques used, community bonding it created and minimal environmental impact of its construction quality should be valued and remembered.
Swasti Sthapak et al.	2017	Vernacular houses are more environment friendly as it is evolved through a continuous process.
Manjusha Misra et al.	2016	The continuity of vernacular architecture in the South Asian region and its shared cultural heritage and identity is evident in the fact that more than 90% of its people live in houses that they have built for themselves.
Avinash Gautam	2008	Designing energy-efficient houses promote thermal comfort by using passive solar techniques.
Rumana Haque.	2013	Bangladesh's traditional house reflects social, cultural heritage of peoples and also encapsulate traditional forms values and is designed by the owner according to occupants demand creatively based on low investment, local materials, combined with the assistance of relatives, friends, and neighbours.
Sayed Ahmed et al.	2017	The study is aimed to analyze the Thermo climate analysis in different mud houses of village Mauna at Gazipur district near the capital city of Dhaka.
Priyanvada, A.K.M.	2006	the thermally comfortable environment in the house located in tropical uplands can be created with the proper use of passive elements such as building material, roof, windows, sunshade, ceiling, interior, exterior finishing, etc.
A Madhumathi et al.	2014	Passive solar design techniques and the extent to which they promote high thermal comfort in a vernacular mud house in Madurai, Tamilnadu in India.
MTR Jayasinghe et al	1997	Proper use of orientation, shading devices, window sizes, roofing materials, insulation, the colour of the exterior and interior walls, etc. can ensure thermal comfort in a traditional house in Sri Lanka.

3. Methodology

The main purpose of the study is to identify and analyze various passive design and construction techniques applied in vernacular mud house settlements found in South Asian villages of Bangladesh and Sri Lanka. So this study is carried out by selecting a typical mud house in Bangladesh as a case study and analyzing its appropriateness in the existing context by using Ecotect Analysis 2011 software for simulation. In the case of Sri Lanka, various passive design features practiced in traditional settlements have been identified by going through various published journals and articles and finally some specific design decisions were taken based on climate and traditional vernacular practice.

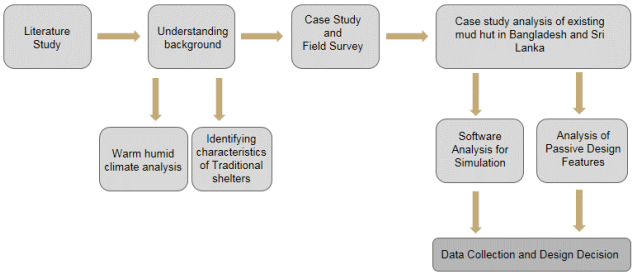


Figure 1. Methodology: A step by step process

3.1. Selection of case study

Savar is an Upazila of Dhaka district Dhaka division in Bangladesh. It is located at a distance of about 24 kilometres to the northwest of the capital Dhaka city. The land of Savar is composed of alluvium soil of the Pleistocene period. The height of the land gradually increases from the east to the west. For this paper, the site survey for mud houses has been taken in Sadullahpur village. The soil from this area is reddish and few of the lands are higher than the average land height. Savar Upazila has different types of dwellings in rural and urban areas. As it is a growing area closely attached to Dhaka, rural and urban places are in the process of development all around Savar. In the village Sadullahpur, two types of housing can be seen. One is a mud house which is representing the vernacular style. And the second one is a brick house or house made of CI sheet (Corrugated Iron sheet). Some inhabitants want to maintain their mud hut because of its sustainability, comfort, economic benefits and also for traditional values. However, many of them also want to replace their age-old traditional mud houses with brick or CI sheet house. Rural vernacular settlements in this village can be divided into two groups. One is the planned settlements, which are community-based, and the other one is the organically grown settlements which are occupation-based. In this paper, a survey of a typical mud hut settlement pattern was observed which belongs to a rose farmer and his family. From the questionnaire survey, it was found that such a house had its origin from a single space hut built by the owner with traditional skill and knowledge on available material and techniques. Later on, it has undergone various transformations at different stages for further development.

Sri Lankan countryside shows a vast application of vernacular settlement patterns with greeneries all around. The country has different types of dwellings in rural and urban areas. These traditional houses are deep-rooted. In ancient times, there were strict rules about the building of private homes, and this may have influenced the simple plan and design of the houses. Villagers were not permitted to build their houses above one story high, neither they could cover their house with tiles, nor whiten their walls with lime. However, sometimes they use white clay. In this paper various mud house settlements found in the village areas of Bentota, Kandy, Colombo, etc. are observed. Simple mud houses and brick houses with a terracotta roof are common traditional dwellings. Most of them are either single or double story and follows Sinhala style traditional vernacular pattern which possesses passive design elements suitable for warm humid climates. Finally, documentation on mud house patterns, construction techniques, material, passive design techniques, etc. has been carried out.

3.2 Warm and humid climate

Climate is the average of long weather periods of around 30 years. It can be measured by an average variation of patterns of temperature, atmospheric pressure, humidity, wind, precipitation, atmospheric particle counts, etc. over a long period. A particular location's climate is usually affected by its altitude, latitude, nearby water bodies and their current and terrain as well.

Classification of climate:

The tropical regions of earth consist of three climatic zones: -

- The warm and humid equatorial climate
- The hot dry desert climate
- Composite or monsoon climate

High rainfall and high humidity are the main characteristics of warm humid climatic zones. The temperature range is high around 30-35°C and it remains even during the day and throughout the year. The wind is almost light or nonexistence for a longer period because of minimal difference in temperature. Such a climate does not have seasonal variation throughout the year and can be found in a belt near the equator. Countries having a warm humid climate are Colombo, Singapore, Hawaii, Malaysia, Kerala, and Meghalaya etc.

3.3 Climate of Bangladesh

Bangladesh has a subtropical monsoonal climate characterized by wide seasonal variations in rainfall, moderately warm temperatures, and high humidity. Three seasons are generally recognized:

- Hot, humid summer (March to June)
- Cool, rainy monsoon (June to October)
- Cool and dry winter (October to March)

The predominant characteristics of the climate are high solar radiation and heavy annual rainfall. In such a warm humid climate, thermal comfort in the built environment is extremely important and protection from rain and wetness is of high concern in the design and construction of the house structures.

3.4 Climate of Sri Lanka

The climate of the low altitude of Sri Lanka is predominantly warm humid having fairly a constant temperature, both over the day and over years. Humidity and cloudiness make diffuse solar radiation important. In tropical lowlands,

the annual average minimum and max temperatures are 24.6 and 32.4° respectively. Early in the morning relative humidity can be as high as to 100% whereas it drops to 60 to 70% in the afternoon.
Sri Lanka can be divided into three main climatic zones:

- Wet zone
- Dry zone
- Hill country

Climate is tropical monsoonal with a marked seasonal rhythm of rainfall. Distinct seasonal changes are much evident and the general requirements at low altitudes and high altitudes throughout the year are completely different. The dry and wet zone needs cooling and high altitude needs heating.

3.5 Traditional Shelter

In Bangladesh, vernacular type housing practices have been carried out for ages. It has developed a relationship with the physical environment, socio-economic and cultural setup. Most of the house forms of rural Bangladesh are based on the courtyard pattern to support agricultural activity. The factors that govern the choice of building materials are tradition, a function of the building, material cost, availability of building material and construction skills.
Depending upon the choice of material 3 types of houses is seen in rural areas:
1. Temporary type of houses. Materials: reed, thatch, mud
2. Semi-permanent house. Materials: bamboo mat, CI sheet
3. Permanent house types. Material: timber, brick, masonry

The courtyard is the most distinct feature of rural housing in Bangladesh. It has both physical and cultural aspects. It has a deep-rooted connection with rural people, their lifestyle and activities. Most of the traditional rural huts are arranged around a centrally located rectangular or square-shaped courtyard. Activities mostly take place in the outdoors except when it rains. Interiors are mostly used for sleeping and storage. The rural courtyard is introvert that it contributes to privacy for women in the homestead. This is a cultural attribute. Moreover, it allows thermal comfort allowing cross ventilation. Post-harvest activity is also a functional aspect of the courtyard.
On the other hand, vernacular housing is being practiced as traditional architecture in the villages of Sri Lanka. In the 19th century, the dwellings of the ordinary folk were of mud and straw where appearance is sacrificed for convenience and economy. These simple clay houses are built using the wattle and daub method. This style of building and the materials used have remained unchanged over the centuries. While natural decay and the development of building materials have left very few ancient wattle and daub houses, the process is being followed faithfully by the few who continue to live in these simple houses.
Two basic types of traditional shelters can be found in warm humid climates. Where timber is scarce, single-story earth walled houses are typical with the roof framed in timber, bamboo or palm and covered with thatch. Broad overhanging eaves shade the walls. There are several advantages and disadvantages to this form of shelter:

- The poor or non-existent air movement inside the dwelling will create unbearable conditions and damp.
- What little benefit may be gained from breezes is frequently prevented by the fenced walled compound.
- The intense heavy rains sometimes erode the bases and surfaces of earth walls. Therefore, annual maintenance is essential.
- Where the earth is unavailable, timber is used for building houses on stilts. This elevated position is better for security and free air movement.
- Thatched roof is excellent as a thermal insulator but may not be quite waterproof.
- The broad eaves shade the walls and openings protect from driving rain and sky glare.
- Sometimes it invites termites or other insects to breed.
- Both types of shelter perform well in their traditional rural context where materials and labours are available for construction purposes.

4. Case study analysis of existing mud hut

4.1 Analysis of selected homestead at Savar, Bangladesh

The selected mud hut for the case study is situated in Sadullahpur village at Savar. This hut is amidst greeneries of Rose village known as ‘Golap gram’. The village home consists of a mud hut, a Kitchen, a storage hut, cattle/hen shade, etc. and they all are situated around a central courtyard.

Materials and techniques

The main material of the hut is mud. Cob method has been followed as a construction technique where locally available mud is mixed with clay, water and a lot of straw to avoid cracks. Such a mixture is used to spread in layers to construct the plinth and walls. Fresh lumps of mud (soil, water, and local fibre materials) stacked on each other. Thus the whole wall element is made by stacking lumps of mud. The roof is made of CI (Corrugated Iron) sheet with bamboo supports.

Figure 2, 3, 4. A mud hut, storage, and kitchen

Figure 5, 6. Cattle and hen shade, Roof with CI (Corrugated Iron) sheet, supported by bamboo.

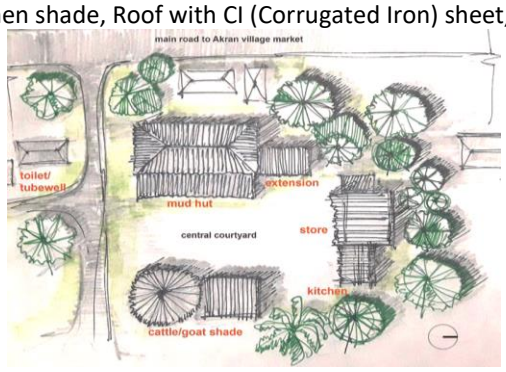


Figure 7. Top view of the homestead (Author)

Size and layout

The selected mud hut is 20’ wide and 15’ deep, with a height of about 4’6” at outside veranda space and increases to 6’0”-8’-0” at inner space. Generally, this hut has two activity zones, one is the sleeping zone, which is the inner space and another is the outdoor activity zone, which is the veranda space. Veranda space has a half wall boundary of around 2’6” height where dwellers can sleep or have a seat or rest. Mud Walls are 18” thick and plinth level is 1’0”-1’6” high.

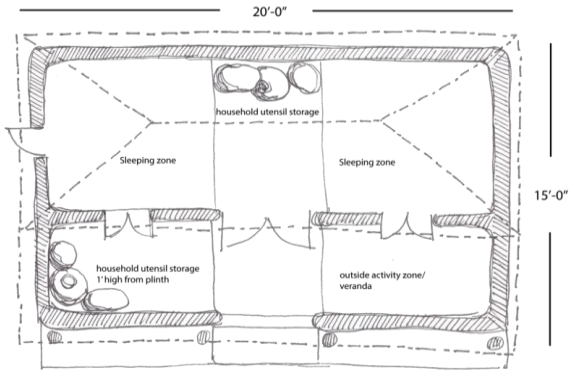


Figure 8. Existing floor plan (Author)

Orientation

Savar belongs to plain land area, where floodwater does not occasionally affect the locality. Therefore, the plinth level remains lower. The settlements of the village hut are scattered or open patterned which are ideal for warm humid climates to provide sufficient air circulation. They are separated with large free spaces between them to allow airflow which allows ventilation for cooling. The surveyed hut is East-West oriented. It has its long facade facing west and east. The main door and two narrow windows are also facing east. There is also an extra door on the north side.

There is no opening on the West facade to reduce the heat gain. Other structures like the store and kitchen are oriented around the north-south direction.

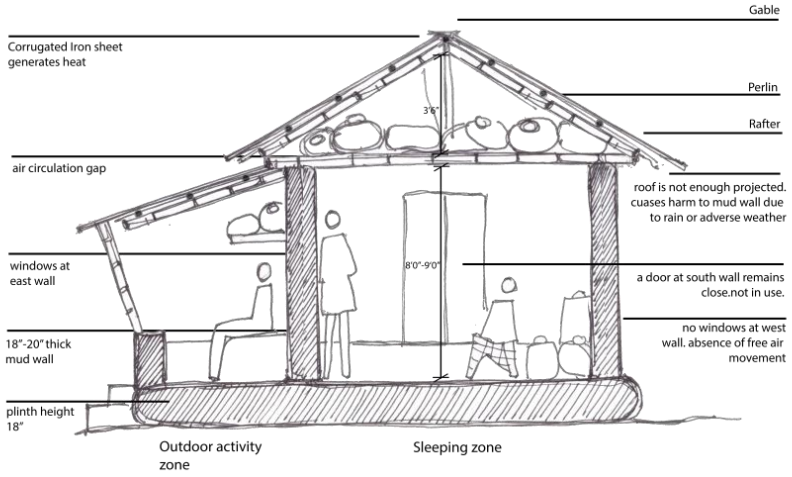


Figure 9. Sectional view showing zonal areas of the hut (Author)

4.2. Analysis of passive design elements of rural homestead in Sri Lanka

At present, one can hardly see any differences between rural houses and urban houses of Sri Lanka. People build houses with the concrete block with clay tile or asbestos roof covering and these are very much common in villages and urban areas alike. But till 50 years back, most of the rural house forms were built out of temporary materials such as clay for walls and coconut or Palmyra leaves for the roof covering. Sometimes various techniques are followed for construction which is suitable according to available skill and material and also suitable for warm humid climatic zones.

Figure 10, 11. Typical mud hut in Sri Lanka and wattle and daub technique

Material and construction techniques of a typical mud hut

The traditional countryside houses are built in such a manner that it is blended with the surrounding landscape. Openness is one of the defining features of these rural house forms. The rural people apply such construction technique which is eco-friendly and ideally suited to the local climate. A simple mud hut of the village area is constructed using the wattle and daub method (Warichchi). In this process, a framework of poles is sunk into the ground, with reeds or jungle vines woven horizontally between the poles to make mat-like screens (wattle or Warichchi in Sinhala). The spaces between the exterior and interior walls are then filled with mud. Both sides of these walls are then plastered (daubed) with a wet mud mixture of coarse sand, cow dung, and water. The roof is made with timber framing, thatched with coconut leaves. This type of house form is known as “matigeya” or clay house in Sinhala. These homes primarily used as a cool sheltered space for sleeping and storing tools. It is consisting of only a single enclosed space with little furniture, sleeping mats. But most of the daily activities would take place outside the veranda type area. Unfortunately, this type of mud hut is being fast replaced by the more modern materials of brick and cement. But its exceptional environmental advantages are still praised by home-owners and architectural experts.

Orientation

It is necessary to minimize solar gain into the building. Mud huts in various rural areas have large windows only on sides facing north and south. These large openings are provided with sufficient shading devices of light colours to minimize the solar gain without impairing the daylight. The need for ventilation can also be important in deciding the orientation of the building since it is necessary to improve ventilation conditions during daytime, evening and night. It is advisable to minimize the area of the wall facing the east and west which could be achieved by having the longitudinal axis of the building parallel to the east-west direction. In a rectangular-shaped mud hut, the front-facing

south side will receive sunlight from sunrise to sunset for nearly six months from the end of September to the end of March. The rear walls will receive sunlight from sunrise to sunset for about 5 months from mid-April to mid-September. The east-facing wall receives sunlight around 1100 hrs. The wall facing west will receive immense sunlight for 300 hrs.till sunset. Of all these solar gains, the sunlight falling on the eastern wall is considered less offensive as it falls in the morning when the external temperatures are low. The wall facing west is the most affected concerning thermal gain since it receives intense sunlight for about five hours when the external temperature is very high. Shading devices are possible to use to cut down the gain of solar radiation when the incidence sun angle is very high for about 1000 hrs.

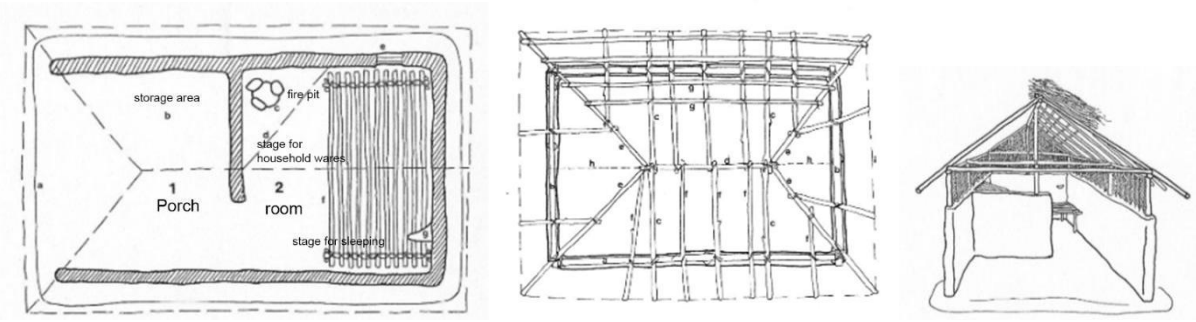


Figure 12, 13, 14. Typical floor plan, typical roof plan, perspective view

Shading

Many traditional mud huts in Sri Lankan village has extended thatched roof that is important to protect mud walls from rain, wind, dust. Many huts have bamboo mesh windows of 3' height just under the roof to allow light and air into indoor. The use of more insulation is not very effective in warm and humid areas, especially where there is a chance that condensation would occur, which greatly degrades the thermal performance of the building environment. On the other hand, shading devices cut part of the solar heat gain so that the total heat flow is reduced. Hence, roof construction with adequate eaves could be extremely useful. It should also be noted that shading devices have the added advantage of cutting down the direct sunshine. It is advisable to use adequate shading devices of light colours for the windows provided for improving ventilation and lighting. The shading devices can be in the form of fixed overhangs or vertical fins.

Ventilation

Since Sri Lanka is an island with monsoons blowing in the south-west and north-east directions, the windows placed in the western face could be extremely useful in maximizing natural ventilation. The ventilation could be maximized with minimum solar heat gain by having very short windows provided with an overhang of considerable projection. Courtyards maximize ventilation. Since Sri Lanka has its main winds blowing in the south-west and north-east directions, the provision of courtyards in western and eastern sides could be highly desirable. However, the courtyards facing west should be carefully planned to minimize the gain of solar radiation.

5. Software simulation

5.1. Study in the existing condition of the selected case study of Bangladesh

Autodesk Ecotect Analysis 2011 software has been used for the thermal comfort analysis of existing study mud hut. The survey has been done in April and the annual average highest temperature of this month during 2019 was 33.70°C and the lowest average temperature was 23.60° C. The existing study mud hut is East-West oriented. At first comfort analysis (mean radiant temperature) has been explored with the existing position of the hut. All the walls and floors are assigned to mud material. The CI sheet is assigned as the roofing material. The openings (door and windows) are assigned to wooden material.

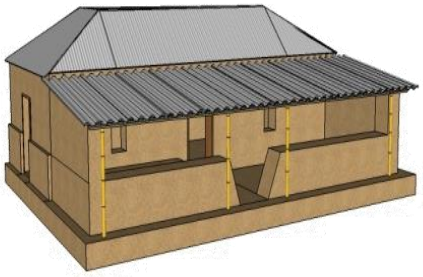


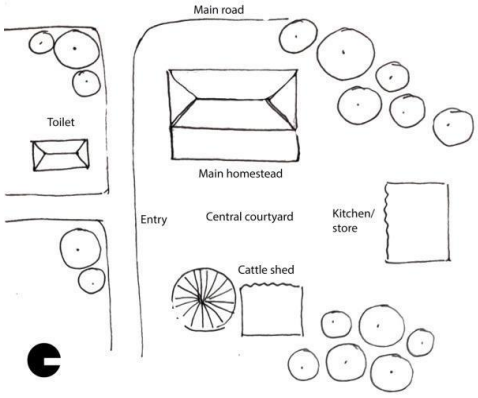
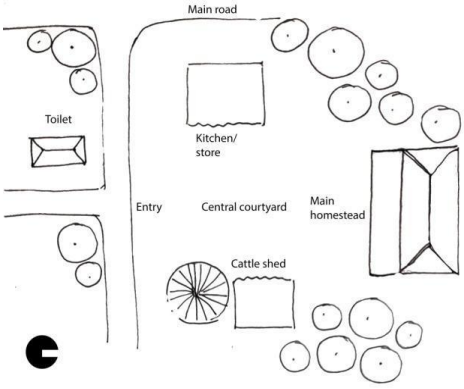
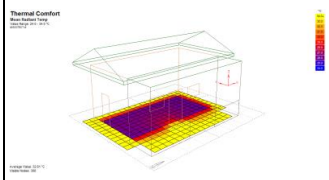
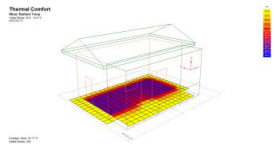
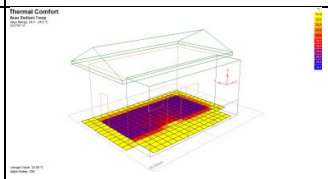
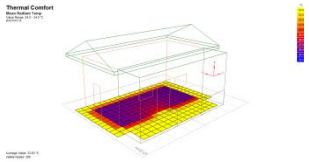
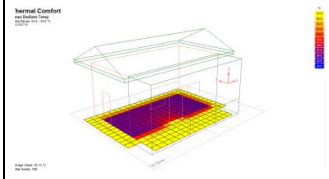
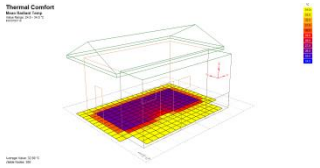
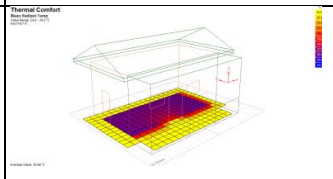
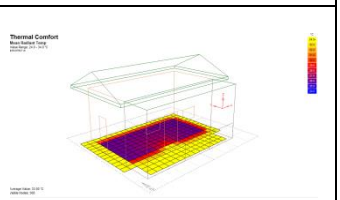
Figure 15. 3D visualization of existing mud hut situated in Savar.

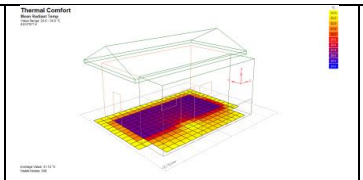
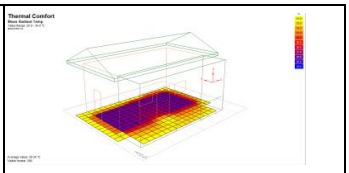
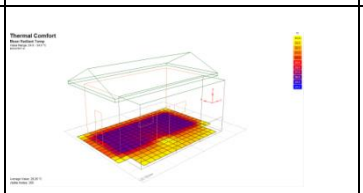
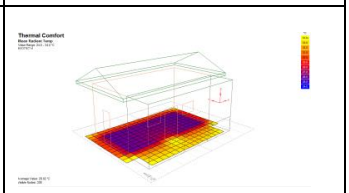
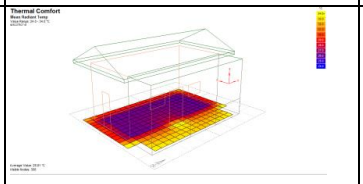
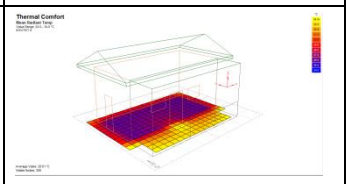
Average mean radiant temperatures of different times of a specific day (15th April) have been achieved by the simulation process. As a result, it is observed that the average mean radiant temperature is 32.41°C of exposed mud hut which can be even lesser if proper orientation is applied.

5.2 Study in repositioned condition

From the analysis, it is clearly shown that by repositioning the mud hut in a north-south orientation, the average mean radiant temperature becomes 31.38 °C which is less than the average means a radiant temperature of the existing condition.

Table 2. Comparative simulation analysis images for thermal comfort in existing and repositioned condition

Comparative analysis of thermal comfort in existing and repositioned condition					
Existing plan			Repositioned plan		
					
Time: 15th April	Average Mean Radiant Temperature	Software simulation	Time: 15th April	Average Mean Radiant Temperature	Software simulation
9.00 AM	32.61°C		9.00AM	32.17°C	
11.00 AM	34.09°C		11.00 AM	33.63°C	
12.30PM	35.13°C		12.30 PM	32.89°C	
2.00 PM	35.90°C		2.00 PM	33.00°C	

4.00 PM	31.12°C		4.00 PM	30.34°C	
5.30PM	29.26°C		5.30PM	29.02°C	
7.30PM	28.81°C		7.30PM	28.61°C	
Average value	32.41°C		Average value	31.38°C	

6. Design recommendations

6.1 From case study analysis

From the above studies on traditional rural houses of Bangladesh and Sri Lanka, some basic passive design points can be highlighted to understand vernacular strategies in warm humid climates. These are:

- Maximum ventilation and free air movement by large openings should be provided
- Maximum shading of direct and diffuse solar radiation is important
- Heat storage should be avoided
- Reflective outer surfaces should be used
- Ventilated double roofs should be used
- Vegetation should be counted as it helps to moderate the solar impact.
- Topographical location with maximum air velocity and shade.
- Better orientation to minimize solar radiation impact.
- Better orientation to maximize natural ventilation by winds.
- The scattered pattern of buildings should be preferred
- Hazards, mainly floods and storms, to be considered.
- Buildings should be spread out with large open spaces in between for unrestricted air movement
- To provide shelter from rain and heat, the form of the building should be planned to promote airflow.

6.2 From simulation analysis

Orientation

The suitable orientation for the least heat gain for a rectangular built form is to reposition the mud hut in the north-south orientation where the longer side will face the N-S direction. In this proper orientation thermal gain would be lesser.

Ventilation

In the studied mud hut, internal temperatures remain high because of the absence of convection process of airflow. There is no opening in the top portion of the wall as rainwater often enters inside the hut during rainy days and through which cool air at night could come in and warm air can go out. Thus proper ventilation is blocked in summer in the evening and night. A probable solution is to use openings at the top and cover them by bamboo mesh-like surface to stop rainwater coming in monsoons but at the same time allowing free air movements. Existing mud hut is scattered around a central courtyard which will maximize ventilation with the help of surrounding vast green.

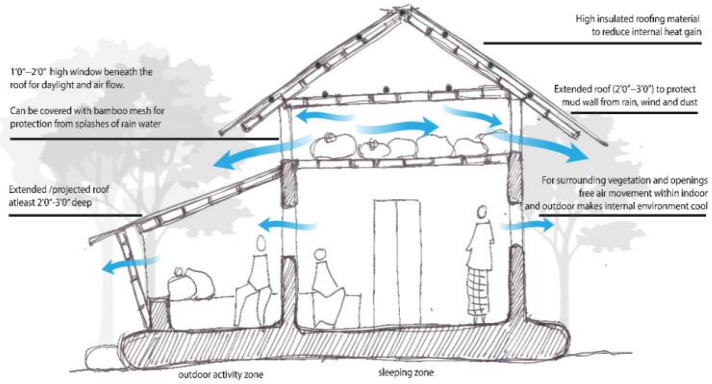


Figure 15. Conceptual sectional view showing probable ventilation (Author).

Building material

The building material for the walls is mud and the roof material is CI sheet. The U value for mud is 3.44 W/sq. m K & the U value for CI sheet is less than 1 W/sq. m K. (U values: U-values measure how quickly energy will pass through one square meter of a barrier when the air temperatures on either side differ by one degree. U values are expressed in units of watts per square meter per degree of temperature difference W/m2K). Though the U value of the CI sheet used is not that high and it is a low insulating material. The insulating property of thatch is much higher, as its U value is even lesser than the CI sheet. As a result, in summer, thatch will keep the inside of the hut even cooler than the CI sheet does. Modern-day thatch is treated and improved industrially thus can be utilized for mass use in rural areas, being low cost and having very good thermal properties. Thatch is a natural reed and grass which, when properly cut, dried, and installed, forms a waterproof roof. The most durable thatching material is water reed which can last up to 60 years. A water reed thatched roof, 12 inches thick at a pitch angle of 45 degrees meets the most modern insulation standards.

Shading

For proper shading, eave projected roof is a very important fact. Due to the high solar elevation angle around noon time during the summer period, solar radiation on south-facing facades is lower and direct sunlight is easier to shade. Besides a projected roof can protect mud wall from direct winds. Rain splashes also can be avoided by deterioration. If shading is increased by having greater eave projections and sunken window, then heat gained can be considerably reduced.

7. Limitations of the study

The Mud hut in Savar Bangladesh was studied in April when the climate was at a most critical stage due to excessive heat. However, mean radiant temperatures for thermal performance of studied hut found in the analysis will not be applicable for the rest of the months because of changes in the weather pattern and seasonal variation. For time constraints other relative thermal data were unable to be collected. Besides case space analysis for Sri Lanka was confined only in literature studies without any physical survey. Several studies have been done on passive design techniques previously. However, it is difficult to find a comparative analysis of similar vernacular designs of two countries with a similar climate. In this paper mainly vernacular culture of the South Asian region has been analyzed. Such a study will help to understand different countries own passive design rules and improve their practice through technological advancement.

8. Conclusions

This Mud house study reveals that mud as a building envelope keeps the Indoor environment of the hut cooler in summer. However, the cooling effect of these traditional mud houses can be further improved and living conditions inside the huts can be improved by proper design considerations. For a warm humid and tropical country like Bangladesh and Sri Lanka, the minimization of solar radiation gain of a building is the key to the effective use of passive techniques. Both these countries' vernacular practice follows a specific passive rule which ensures thermally comfortable living. Some thumb rules have been identified in this paper, which can vary from country to country according to climate variations. The vernacular design suggests that if these passive techniques, with proper local materials, are appropriately applied, the environment of our homesteads will become more comfortable to live in.

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