International Journal of Technology Engineering Arts Mathematics Science
Special Issue 1, August 2023, pp. 112-117
ISSN: 2583-1224,

Analysis of vernacular architecture for response to climate in Indian climate zones

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Article Information

Article history:

Received Jun 10, 2023

Accepted Jun 25, 2023

ABSTRACT

Vernacular architecture is a type of construction which is local to the area or region of the building and is generally characterized by the use of local and traditional materials, resources, and construction techniques. Vernacular architecture complements its regional context, culture, and social life of the user. Vernacular architecture is competency practiced without any formal education and professional guidance. India has diverse climatic, social, and cultural conditions across the country. Every region has its unique peculiarities in the form of building design, materials, and techniques in the form of vernacular architecture. As per ECBC, India is divided into five climate zones. Climate responsive design with passive sun, wind and light strategies are one of the most effective methods to ensure that architectural designs are conscious to the geographical surroundings. This paper aims to study one example of vernacular architecture of the climate zones of India for its response to climate. The paper reviews the typical characteristics of the selected climate zones as hot and dry, warm, and humid and cold and sunny, various local materials used, building features of the vernacular architecture and their interrelation through bookcase study and literature review.

KEYWORDS: *vernacular, India, climate-responsive, architecture*.

1. INTRODUCTION

The term 'Vernacular' is derived from the Latin word "vernaculus" which means domestic, native, or indigenous [1]. Vernacular architecture is construction done using traditional construction materials which are available in the area. Vernacular architecture reacts consciously to its peculiar geographical surroundings, topography, culture, and social lifestyle. Vernacular architecture in India is outstanding and distinguished because of its varied climatic conditions. India has a remarkable history of traditional building methods and techniques that have evolved over time, with each region having its distinct style of vernacular architecture. Climate has been a dominant factor in determining the forms of vernacular architecture of India. India has a large variety of climates and as per ECBC, it is broadly classified into different climate zones as warm and humid ,hot and dry, temperate ,cold and composite. The climate zone is determined by certain variables like ambient temperature, solar radiation, wind direction and speed, air humidity, precipitation, and sky cover. The climate zone in which the building is situated will guide the design, construction materials, construction techniques and detailing of the systems of that building.

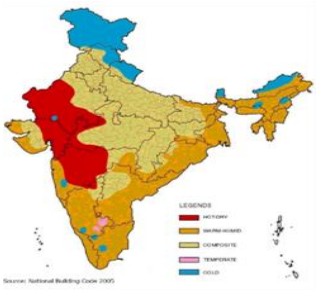

Fig. 1. Climate zone map of India

2.METHODOLOGY

Step 1: Study of Vernacular Architecture of India.
Step 2: A literature review.
Step 3: The climate zones of India were studied for their climatic parameters as per ECBC
Step 4: Three climate zones were selected due to their clear and specific climatic conditions.
Step 5: One example of the vernacular architecture of each climate zone was studied in detail through a literature review.
Step 6: The case studies were analyzed with respect to the plan form, building material, building technology, roof details, building envelope, and fenestrations.
Step 7: Inferences were based on the above parameters to understand the climate responsiveness of the building as a whole for the climate condition.

3.CLIMATE ZONES OF INDIA

For ECBC, a region that has similar conditions of the climatic variables and falls within their thresholds is grouped under one climatic zone. A region/place is earmarked to the first five climatic zones as shown in Table 1 only when the readings of climatic variables exist majorly for six months or more. The climate zone is a composite climate zone if the none of the defined parameters do not exist for six months.

Table 1 Classification of Indian climates Criteria at Bansal et al

Climate	Monthly mean temperature (˚C)	Relative Humidity (%)
Hot and dry	>30	<55
Warm and humid	>30	>55
Moderate	25-30	<75
Cold and cloudy	<25	>55
Cold and sunny	<25	<55
Composite	In case the climatic conditions do not prevail for six months or more within any of the above categories.	

Since the climate zone of hot and dry, warm and humid, and cold and sunny show distinct and clear climatic conditions, these zones were studied in detail for their specific climatic conditions.

3.1 HOT AND DRY

The hot and dry climate zone is located generally in the western and central parts of India. This zone is characterized by very hot weather in summer and cold in winter. The temperature range in summer varies from 40-45 deg C and in winters ranges from – 5 to 25 deg C. High Solar Radiation causes glare and there is a significant presence of hot winds. There is minimal rainfall and low relative humidity thus making the region dry. Dusty winds often develop into sandstorms. Generally sparse vegetation is observed, and the ground cover is rocky or dry sandy. The sky condition is almost cloudless. On the surface, there are very less sources of water and the level of underground water is also very low. In this climate zone, it is important to control the movement of hot winds from entering inside the building and to also control solar radiation. The passive design strategies therefore should focus on reducing the exposed external area to the solar radiation and provide shading which would resist heat gain. The orientation and openings should be designed to control the ventilation. To help increase the humidity, a water body could be placed which will in turn help to reduce air temperatures.

3.2 WARM AND HUMID

The warm and humid zone is located generally in the coastal parts of the country. Heavy vegetation is seen because of high humidity levels. Generally, a high presence of cloud cover is seen. Due to the presence of clouds, heat which is trapped in the land is marginally dissipated to the night sky. Thus, there is very little difference in the diurnal range of temperature. The temperature range in summer varies between 30 – 35 ºC during the day, and 25 – 30 ºC during the night and the temperature range in winter varies between 25 to 30 ºC during the day and 20 to 25 ºC during the night. Although the temperature ranges are not too extreme, high humidity is experienced in this climate zone which leads to discomfort. High to very high level of humidity is generally recorded throughout the year which could go to about 90% at times. To achieve comfort in this zone passive strategies which aid in cross ventilation are desirable. Cross ventilation can be achieved by the winds flowing from one or more predominant directions with varying speeds. Air movement also helps in dissipating high levels of humidity which reduces discomfort. Reducing heat gain by shading also aids in achieving comfort in this zone.

3.3 COLD AND SUNNY

The cold climate is located generally in the India's Himalayas and the Thar desert regions which are at higher altitudes. They largely influence the climate of India. Ladakh is in a cold and sunny type of climate zone. In this climate zone, the temperatures range in summer varies between 20°- 30° C and from -3°-8° C, in winters making it quite cold. The precipitation level is very low which makes the climate cold. No vegetation or at most a very scanty shrub is seen. January is the coldest month with temperature falling as low as -29.4° C. August has the highest average low temperature of -1.4° C. The relative humidity ranges between 65% - 87%. This region also experiences snowfall with the highest of 301mm in August and lowest 105mm in December. This region is

characterized by a cold desert climate and so it is necessary to trap solar radiation for heat gain. Also, heat loss should be avoided with the help of insulation and prevent loss through infiltration.

4. CASE STUDY

4.1 BHUNGA HOUSE- HOT AND DRY

Bhungas are the traditional houses found mainly in the northern parts of the Kutch region of Gujrat, especially Abnni and Pachham.

Fig. 2. Typical bhunga house

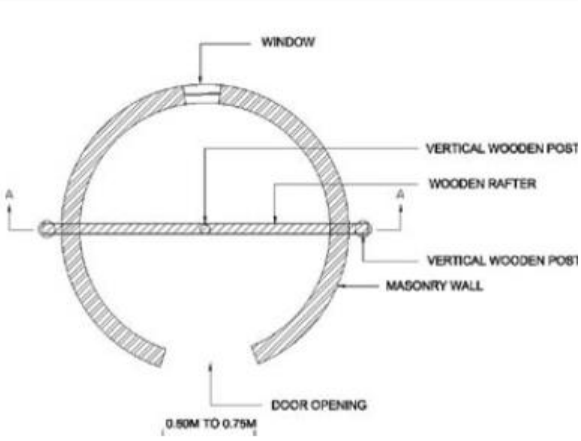

Fig. 3. Bhunga house plan

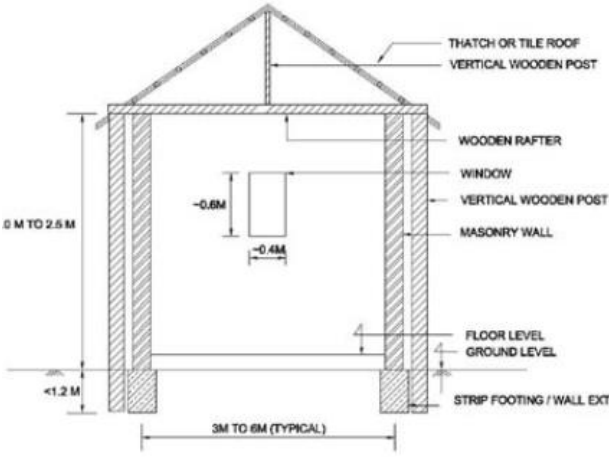

Fig. 4. Typical bhunga section

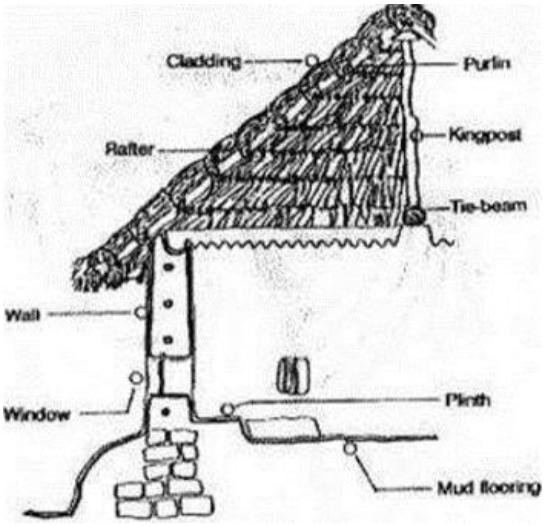

Fig.5. Typical bhunga cross-sectional view

Commonly used local construction materials are mud and thatch as the land has unavailability of stones or aggregates for construction. Silty clay type of soil with flat plain area is there. At times, for foundation limestone in uncoursed rubble masonry is used.

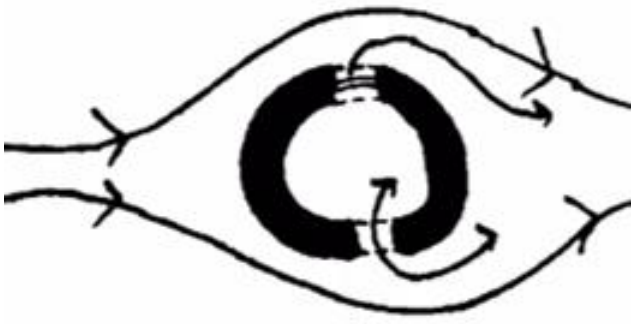

Fig.6. Circular plan form of bhunga and the Bernoullis effect

Inertial forces developed in the wall are resisted because of the circular plan form through shell action which provide resistance to lateral forces. The thick walls which are designed for thermal insulation perform under lateral loads as they have high in-plane stiffness.

4.2 KERALA HOUSE – WARM AND HUMID

A house in Kerala is generally called Veddu. The traditional house is called Nalukettu.

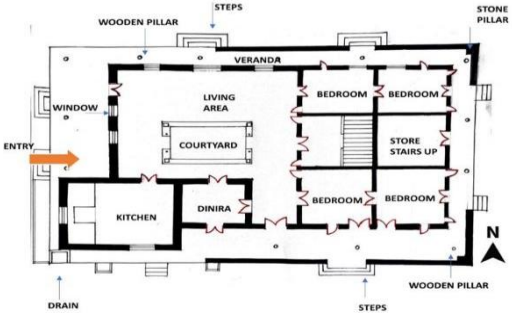

Fig.7. Kerala house plan

Fig. 8. Traditional Kerala house

A traditional Kerala house is established by four rectangular blocks. These blocks connect to one another by intermediary structures having high-pitched roofs. Courtyards are kept open to bring natural light and ventilation to indoor areas. The courtyard acts as a focal point for the family space as well as various household activities. Internal and external veranda acts as an area which protects indoor spaces from rain and sun, also it functions as an interactive space towards the surrounding. The veranda width varies from 2ft to 12ft. Veranda all around the building protects the external walls of the surface from sun and rain. External walls are built in exposed laterite bricks which have a rough surface. It also has self-shading properties, which reduces the radiation falling on walls. Double layer of laterite masonry with a cavity having sand filling increases thermal mass of the external wall. It helps in insulating the interiors. Cooling loads are reduced by using cavity in wall. White or light colors Facades are painted to minimize heat absorption. In a typical Kerala house, openings are provided on two opposite walls which helps in achieving cross ventilation.

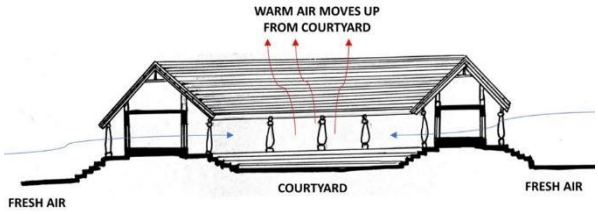

Fig.9. Kerala house typical section

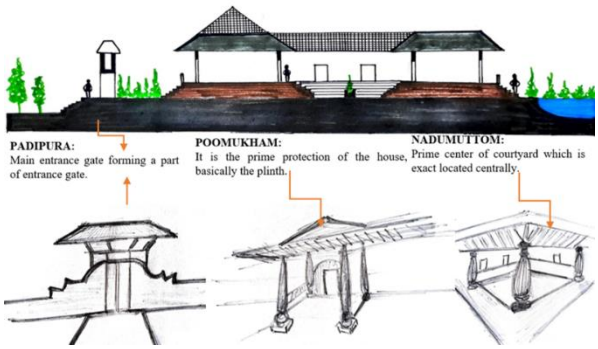

Fig.10. Kerala house section with elements

The arrangement of the wooden jailis is such that they are placed closely. This helps to cut the glare and bring in diffused light. the wooden jalis also help improving the air movement. The small hole pattern created in the jalis increases the speed of air which passes through them and increases the effect of the mild breeze outside by allowing wind to flow further by creating required air movement which is very important to achieve thermal comfort in the warm and humid.

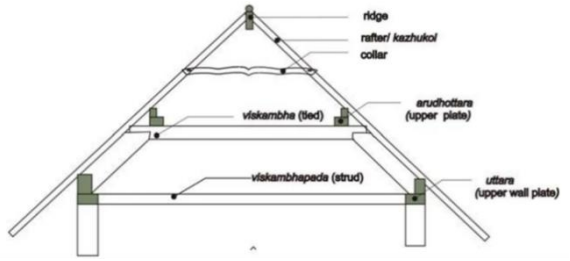

Fig.11. Kerala house roof details

High-pitched roofs and roofs with large extended over hangs are used. The pitched roof also has a roof beneath which creates a large air space. The large air space has openings which are created to escape hot air. Due to this, below provided roof remains cooler than the above pitched roof. Since Kerala experiences heavy rains, the steeped roof pattern and deep eaves are used which helps in rainwater discharge.

Fig.12. Kerala house construction materials

The construction materials used for construction differs as per different parts of Kerala. Mostly the materials used for construction are locally available like clay roof tiles, laterite stone, granite stone for foundations, bamboo, and wood. The exposed laterite stone masonry is most used in typical Kerala houses.

4.3 LADAKH HOUSE- COLD AND SUNNY

The Ladakh house is mostly built on two stories. The ground storey is reserved for animals, wood, and storage like fodder for winters. The upper storey has habitable spaces like the Hall, Guest rooms etc.

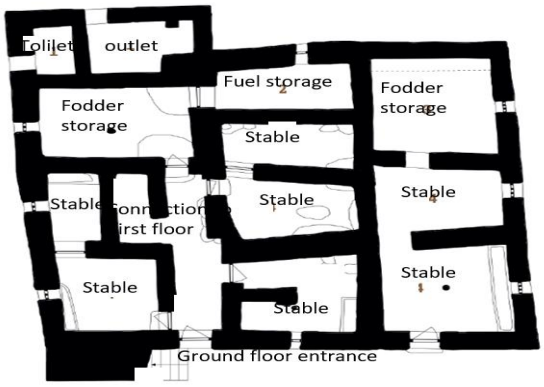

Fig.13. Ladakh house ground floor

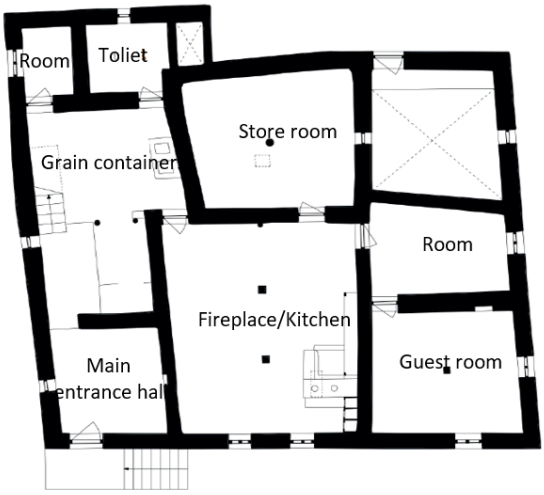

Fig.14. Ladakh house first floor

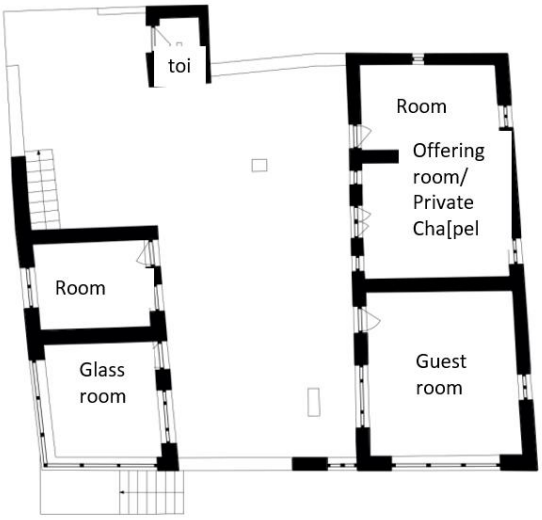

Fig.15. Ladakh house second floor

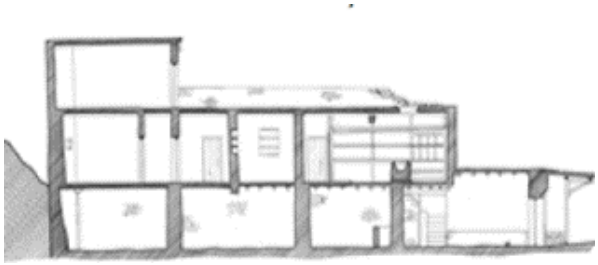

Fig.16. Ladakh house east west section

Fig.17. Ladakh house east elevation

For cooling and heating of the interior spaces an oven is provided in the corner of a large room. The Ladakh house is constructed by using mud, along with the use of timber, which is placed horizontally, and timber members are used as reinforcement. The wall material used is either sun-dried bricks or rammed earth. The walls are provided with mud plaster and flooring is provided with either mud or wood. The low ceiling height is beneficial for the required insulation. So, it is provided in all areas. The material used for the ceiling is generally mud and wood as it has good insulating properties. Also, these are easily available. This helps to trap the heat which in turn aids in maintaining the temperature inside to provide thermal comfort to the occupants.

5. RESULTS AND DISCUSSION

Table 2 Summary of case studies

Climate zone	**Hot-Dry**	**Warm-Humid**	**Cold-Sunny**
Vernacular architecture case study	Bhunga House	Kerala House	Ladakh House

Location	Kutch - Gujarat	Kerala	Ladakh- Jammu & Kashmir
Plan form	Circular	Rectangular	Rectangular
Wall Material & technology	Thick Mud walls for thermal insulation	Laterite Stone, wood, and bamboo	Thicker walls, walls with glass surfaces, Trombe walls Sun-dried earth blocks, rammed earth, mud for the ground floor, and Timber for the upper floor.
Roofing Form	Conical roofs to resist earthquake	High-pitched roofs and roofs with large extended over hangs are used. Below that air space with an opening to escape hot air is provided. Stepped roof with deep eaves to discharge heavy rain.	Roofs are constructed in flat spans by using the trunk of a local tree.
Roofing Material	Bamboo,straw-thatched Roof	Palm leaves, wood, clay roofing tiles	The wood of local trees is used
Flooring/ Ceiling Material	Bamboo, straw	Beaten earth, polished with cow dung	The ceiling height of the interior spaces is low. It is made mud and wood because of their insulating properties.
Plaster Material	Cow dung and mud	No plastering	Mud plaster
Fenestration/ Opening	Three openings one door and two small windows	Windows are very small or timber jalis to give timber to give diffused light without glare	Main living has a large window facing the sun

6. CONCLUSION

Achieving human comfort conditions is the most important outcome of climate responsive architecture. The passive strategies and building materials and techniques of climate responsive architecture help in achieving maximum human comfort conditions and aids in minimizing the use of energy. The vernacular architecture of climate zones studied here helps us to understand the passive sun and wind strategies, orientation, form, materials used, building techniques and details that could help us achieve climate responsive architectural design.

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