

A Review of Energy Efficient Techniques in Vernacular Architecture of North Indian Plains

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Abstract: Objectives: This paper explores the building materials and construction techniques that have been used by the people of this region which are the successful examples of the Vernacular Architecture. **Methods/Statistical analysis:** As the importance of energy is increasing day by day, we keep on exploring new and better energy efficient techniques. In the process, we should also turn back to our past and understand how our ancestors lived a comfortable life in an age when there was no electricity and other modern age equipments. **Findings:** In India, Northern region is the most populated plain, people have been living there for ages and its architectural character has evolved over time with due understanding of the climate, customs, traditions of the region. This paper tries to identify some of the successful vernacular construction techniques of this region which can be suitably used in today's modern buildings for better comfort conditions. Today's modern buildings consume higher amount of energy and it is very important for us to reduce energy consumption and reserve it for future generations. The vernacular strategies discussed are not only traditional strategies creating good comfort conditions but also have the potential to reduce the energy consumption in buildings. **Application/Improvements:** Vernacular buildings are climatically responsive shelters and consume less energy for maintaining living conditions and this result to energy efficiency. The findings of this study suggest the possible integration of the vernacular strategies in the energy efficient building design guidelines.

Keywords: Energy efficient strategies, Vernacular Architecture, Indian Plains

I. INTRODUCTION

Vernacular is strongly tied to cultural and social traditions. It responds to ambient environmental conditions and it is in a way a naturally evolving process¹. As we are heading towards a more technological world, our energy needs are also increasing. But our sources of energy are still dependent on the conventional non-renewable resources mostly. If we have to keep the pace of developing, we shall also work on encouraging use of renewable resources and efficient usage of energy. As per the energy statistics 2016, electricity consumption in India is shown in fig 1 and household energy usage in India in Fig2. As per the charts it is evident that domestic, commercial and industrial building sectors are larger consumers of energy. Currently, the residential and commercial sectors account for 30% (22% residential and 8% commercial) of total electricity use and consumption in these sectors is rising at 8% annually². If our buildings achieve better energy efficiency, it will resultantly reduce the energy consumption of these sectors.

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From Chart 2 we can conclude that lighting and space cooling are the biggest consumers of electricity in India and if we provide sufficient natural lighting and ventilation to buildings, They may perform better the building performance and thereby decreasing energy consumption in buildings.

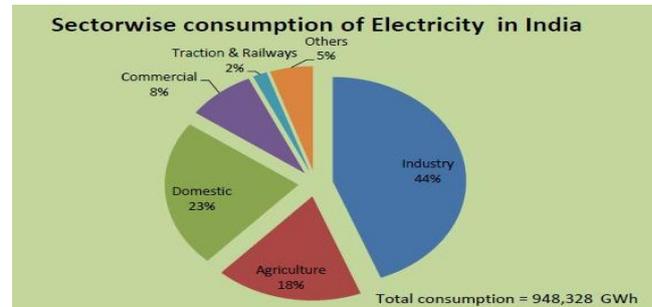


Fig 1.Total Energy consumption in India³

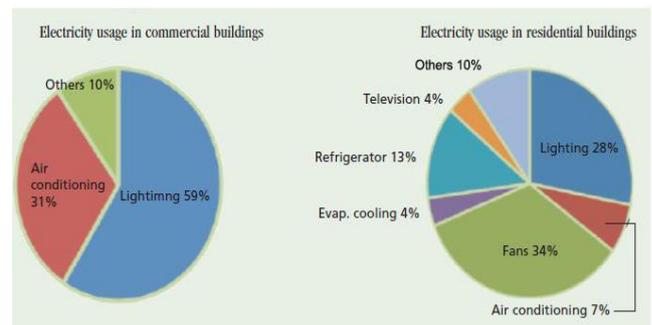


Fig 2.Total Energy usages in Resi. Buildings in India³

Architects always have been in search of techniques by which they can increase the energy efficiency of their buildings. But what about the time when we didn't depend on energy so much? , We still had buildings, which were able to provide better comfort and protection from harshness of nature. Vernacular buildings can create the most comfortable environment so far because they were constructed and people lived in a time when there were no electricity and other modern energy resources. This paper aims to discuss some of the vernacular building techniques proved for better comfort conditions and energy efficiency. With proper incorporation of these techniques can enhance the functioning and performance of present day contemporary buildings.

II. VERNACULAR ARCHITECTURE

Vernacular architecture is our starting point and is like the flora and fauna of any region. It also embodies the lifestyle of native and its process of evolution is completely unconscious⁴.



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The form and materials of the traditional building are selected as per the climatic conditions of the place to achieve comfortable environment for the inhabitants. It is the pure response to a particular person's or society's building needs and fulfils them because it is crafted by an individual and the society around. In addition, the building methods are tested through trial and error by the society until their building methods reach near perfection and are tailored to the climatic, aesthetic, functional, and sociological needs of the society. These buildings suits perfectly to that individual's personal requirements and needs as both the builder who constructs and the end user are the same. These traditional practices offer best suitable solutions for functional utility and liveability. Ritual beliefs, customs, social structure, profession, economic status and culture are often reflected in vernacular buildings through their form, scale, size, colour, materials and facades⁵.

III. VERNACULAR ARCHITECTURE AND ENERGY EFFICIENCY

Vernacular architecture, whose design decisions are influenced by the culture and traditions, had been developed through long periods of trial and error and the ingenuity of local builders who possess specific knowledge about their place on the planet, a commodity that is becoming increasingly scarce in our era of remote communication and outsourcing⁶. The local people possessing through knowledge about their place promote climate-specific passive building technologies. After the study of various aspects and characteristics of vernacular architecture in the context of energy efficiency, it is observed that most of the essential prerequisites for energy efficiency are already considered in the vernacular style without any technical support/ knowledge in different parts of the country. Sustainability is prerequisite for any successful Vernacular development is being followed through the ages. Unlike modern approach of making building's internal environment cool or warm, the intention was to give thermal comfort to the people with or without the building. In comparison to the historical buildings, our present day buildings are consuming more energy and resulting less comfortable habitation⁷. In hilly areas, vernacular settlements are built on the relatively flatter grounds so that the site development work will be minimal. One of the most important things to be considered while constructing a home is what spaces are important and where do you spend your time mostly, some people consider dining to be one of the most important timing of the day and so the preparation and eating of food becomes important in their lifestyle resulting in the form a larger kitchen and dining space. Some others may find that kitchen is only a basic necessity, and does not require much space where in they may require more living space. When a home is built to a person's needs as per the climate, space and energy are not wasted, which is the basic principle of Vernacular architecture. In many ways these are the principles of Sustainable building design.

Vernacular buildings are climatically responsive shelters and so minimum energy is required for maintaining living conditions within the buildings and these results in less

consumption of energy leading to energy efficiency. Natural day light is used for lighting purposes in the vernacular buildings. Various passive design features can also be incorporated easily to the vernacular architecture to make them energy efficient and to maintain the indoor comfort conditions. Though, the illumination level in vernacular buildings is usually less than desired, which can be improved easily. The use of locally available material with lower embodied energy is essential for sustainable development which is also one of the prominent features of vernacular styles prevailing in different regions.

IV. NORTHERN INDIAN PLAINS AND ITS ARCHITECTURE

The Northern plains comprise the Ganges basin states of Delhi, Uttar Pradesh and Bihar with Punjab and Haryana to their west. A vast area of rich alluvial land, this represents the most fertile, hence most populous, part of India. The climate is continental, ranging from little more than freezing of a January or February dawn to well over 40 centigrade (104 Fahrenheit) in May and June. This relentless summer heat is broken by the southwest monsoon which, from early July, waters the fields for some two months. Sometimes it fails; sometimes it is over generous. During the early days of man's presence, the Ganges Basin was richly forested, so timber played an important role in large-scale building, dictating its trabeate form of vertical posts and horizontal beams. A growing populace in search of agricultural land cleared the trees to till the soil. Sun-dried and kiln-baked bricks made up of alluvial clay was the prominent building material which has dominated the architecture of the region for decades.



Fig 3. Map showing the areas under Northern Indian Plains

Ganges Basin: Rural housing in this region has not changed much in the last millennium. Two thousand year old carved reliefs show circular and rectangular thatched huts much like those of today. Near rivers, the flood-plain villagers adapt to circumstances. Houses were of thatched shelters built up of brushwood, bamboo and straw, lashed with twine and plastered with mud,



they were destroyed by the floods easily. The fragments are salvaged; the structures were re erected without much difficulty and financial loss. Truly vernacular, these buildings utilize only the materials available in nearby.

Higher Grounds: On higher grounds it is possible to build permanent structures as there is no threat of floods. Here, the houses were constructed with Sun or kiln baked bricks, or with courses of mud and dung in some cases. The roof is pitched, tiled or thatched with paddy straw. The *jhonpri* (hut) provides shelter from the elements, for night privacy and storage. It is an ill-lit refuge, an area of darkness. There are no windows, but sometimes ventilators. An archetypal northern Indian town house is *chaukband* (built around at least one courtyard).

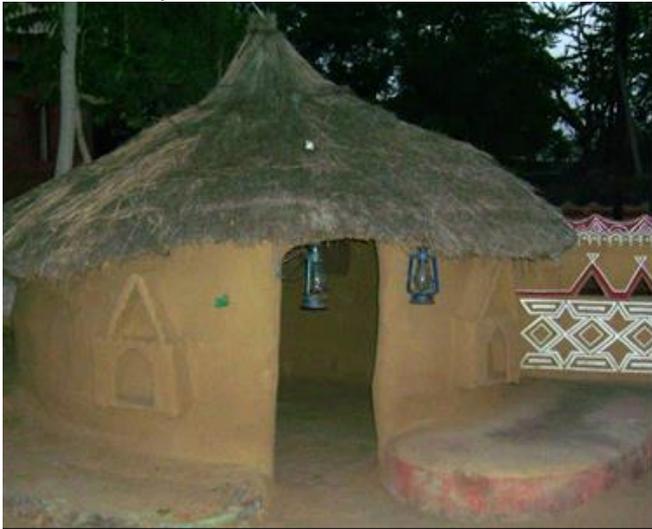


Fig 4. A view of Jhonpuri house



Fig 5. Courtyard of a Haveli

The concept of courtyard, an enclosed private space open to the sky, is basic to Indian urban housing. A building turns inwards onto this secret interior into which few are privileged to pass. There is a second, semi-private space where guests can be entertained easily. In the plains, *havelis* are built of brick consolidated with lime plaster. The roof system consists of beams which support the closely spaced joists. The gap bridged by flat bricks on which a thick layer of mortar and rubble is laid and is finished with fine lime. The lower floors will have very minimum openings to the external side in the form of ventilators. Upper rooms have shuttered windows. The facade is decorative, its surface

divided by relief stuccowork in the form of plasters and cusped arches. The traditional *haveli features* remain in place, a wide *chajja* (eave) supported on the stone brackets shading both doorway and courtyard, open three arched *dalans*, a carved wooden door surround with iron inlaid shutters.

Punjab and Haryana: In this region, roofs are generally flat, surrounded by a low parapet walls. Most of the houses consists an open semi-private area. The smaller houses consists a slightly raised adjoining piece of open space, surrounded by bamboo wattle or a hedge of brushwood. Wealthier farmers enclose the area with mud walls, sometimes topped with thatch or tile to protect it from rain, mostly like an inward facing building. This place is helpful for the housemates for socializing. Irrespective of the life style differences across various regions, compounds or courtyards are one of the important features of Indian housing.

A rare Mughal ruin at Sirhind (Punjab) is rectangular in plan, consisting of two blocks of rooms linked by high curtain walls to enclose a courtyard. Externally it presents a forbidding expanse of blank brick wall broken by a pattern of rectangular recessed panels. At the southwest end of the house, we find full height of the building, covered by a curved, vaulted *bangla* (Bengali style) roof.

The layout typifies that of a nineteenth-century mansion with courtyard forms the focus. External walls, although decorated, give an air of defence and privacy and a shading eave (*chhajja*) supported on stone brackets runs the length of the facade, sheltering the only entrance. This is through a large arched gateway closed by two massive, metal-reinforced doors, hinged on stone sockets, with a little wicket door in one or both the shutters allowing access without opening the main gates. Rooms giving onto the courtyard function as bedrooms and stores. Those of the lower storey are open *dalans* behind which are closed rooms. Internal masonry stairs lead to the upper storey and the flat roof. The upper rooms are reached by a narrow projecting walkway supported by stone brackets set in the wall. The floor of bathrooms are covered with fine waterproof lime plaster, slope towards a drain. The flat roof is an important space in the house for the family gatherings and even for sleeping in the nights. Sockets fixed around the roof are used for fixing the *shamianas* during functions.



Fig 6.A Village house in Punjab

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Delhi, Agra, Fatehpur Sikri and Agra:

The impact on traditional architecture of seventeenth century by Mughal technology was powerful. The hierarchical positions of courtyard, veranda and inner spaces in Mughal buildings provide an organization of activities from one place to the other in relation to climate. For example, the Panchmahal at Fatehpur Sikri was built for Akbar's wives to enjoy their summer evenings⁸. Under British rule, wealthy merchants patronised *haveli* building in the ancestors footsteps. The *haveli* construction has reached its zenith under the new regime. Despite their size and opulence they were traditional structures, planned and put up by a team of local builders drawing on materials available from the surrounding Countryside.



Fig 7. View of Fatehpur Sikri, Agra

V. ENERGY EFFICIENT TECHNIQUES AND THEIR WORKING

- 1.1. **Town Layout:** Most of the buildings were joined together having common walls which helps these buildings shade one another and also reduces the surface area which gets exposed to the hot Sun. The Courtyards in the buildings gets more sunlight and gets heated up by mid afternoon. Once the heated up air starts moving up. The cooler air from the trees in the streets starts filling up the courtyard.
- 1.2. **Massive Walls:** Traditional buildings in many areas were constructed with massive walls of over 60 cm thicknesses with various materials as explained below.
 - i. **Mud:** Mud with sufficient cohesion of particles is a better used material for masonry construction. It becomes much stronger when straw is mixed. These walls consists a fairly low R-value of 0.4, making the heat transfer through these walls slower. Because of its higher thermal mass it holds up heat in afternoons and releases it slowly after sunset. This phenomena helps to keep the houses warmer during winter season and d During summer, Sun is kept off the walls to stay cool during the day and night.
 - ii. **Lime and Clay:** Lime was used as plaster materials both for the interiors and exteriors of the houses. It was also used as a pigment to bring white and bluish shades.
Clay and lime plaster on walls and ceilings help in creating cooling environment and a stable climate

conditions for the room, holding the temperature and humidity in balance. Lime-based plasters dry hard and continue to cure for months by absorbing carbon dioxide from the air, and reverting back to the original limestone state.



Fig 8. Mud Wall Plastered with clay



Fig 9. Wood used for Doors and Windows

- 1.3. **Timber:** Timber is used extensively in these traditional housing, as structural members like columns, doors and windows. Dressed timber was used for doors and windows. Windows were provided with wooden shutters for privacy as well as to keep off the dust from outside. On the top of timber poles, mangrove slats are used for roof frame work, a mixture of mud and straw are used on top of it as roof covering. Since wood products and mud are good insulating materials, it keeps of external heat from the house makes it comfortable for the inhabitants.
- 1.4. **Courtyards**
The courtyards in traditional buildings are surrounded by rooms with windows opening in to the courtyard. Many times they are not with any sunshades opening directly to the sky. As per the geographical location and climatic conditions, the size and shape of the opening may change. It is not common to see fountains in courtyards of rich which helps in evaporative cooling within the building.

Courtyards moderate the climatic conditions in many ways:

- (i) The cool air of the summer nights are kept undisturbed for many hours from hot and dusty winds when surrounded by walls
- (ii) The rooms draw more day lighting and ventilation from these spaces

Courtyards help the micro climate in three ways; (i) cool the air during the night time spreads in to the rooms around the courtyard. (ii) Induces convective currents during afternoon for better comfort (iii) Dissipates heat rapidly by radiation in to the night sky.



Fig 10. View of Traditional Courtyard

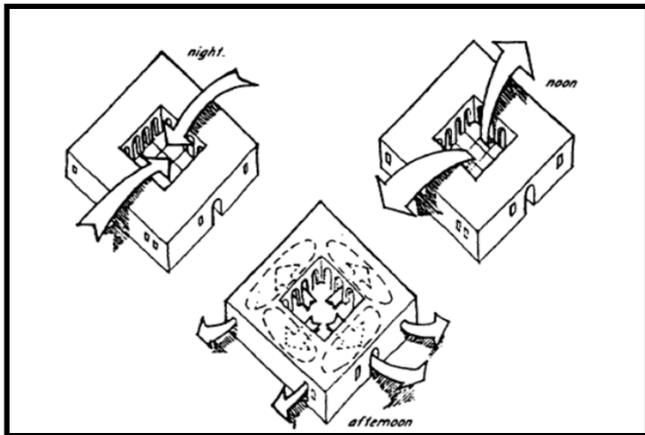


Fig 11. Functions of the Courtyard in a day

In Mughal buildings, the courtyards are added with vegetation and water bodies most of the time which enhance the humidity, cool the air by evaporation, keep dust down and provide shade for comfortable living in hot dry seasons⁹

1.5. The Wind Tower (Badgir)

The wind towers are an important feature of traditional buildings in some parts of Northern Indian plains. They are vertical shafts with vents on top to lead desired wind to the interior spaces and provide thermal comfort¹⁰. It consist two parts, the catching device and the tower. It is opened into either upstairs or downstairs rooms or stops about two meters above the floor level. The operation of the wind tower changes with wind conditions in a day, this basically happens in two ways.

- (i) When there is not much of wind movement during nights, it acts as chimneys and sends out the hot air trapped in the building thus helping the circulation of cooler air in to the rooms.
- (ii) When there is no wind movement during the day time, the tower works opposite to that of a

chimney and the hot air outside of the building pulled inside through it.

It is most effective in dry arid regions of the Country where the diurnal variation is large and night air temperatures are low.

1.6. Lattice Screen (Jaali)

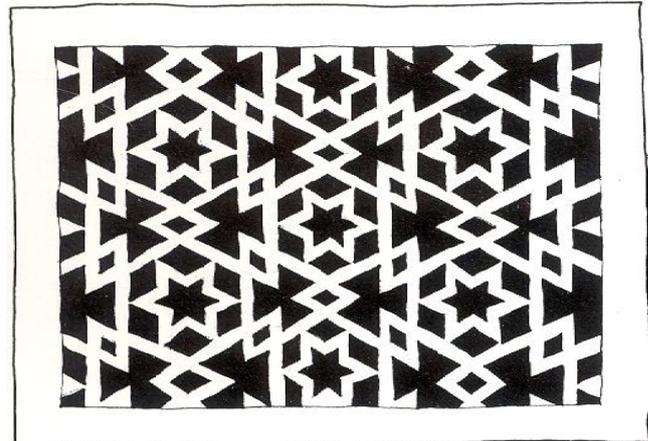


Fig 12.Lattice screen (Jaali)

Another important feature of traditional architecture in this region is lattice screens called them as *jaalis*. These Jalis not only provide privacy to the inhabitants but also controls the air movement in to the building reducing the indoor air temperatures. Harsh sun light during mid afternoons will be controlled by allowing only diffused light. To get a clear outside view, a cut-out is provided at eye level for the viewer sitting on the floor (Figure 11). Jaali in Mughal buildings mostly have a low sill or sometimes without sill so that the air could move near the floor⁹

VI. CONCLUSION

This paper tried to examine the vernacular building techniques which were used for providing comfortable indoor built spaces by our ancestors. These techniques not only provided better comfort but also reduced dependence artificial lighting and ventilation systems thus by saving energy. Apart from being energy efficient these techniques also were economical as dependent more on locally available materials and techniques. Further they help us in preserving our identity as we stand out because of our indigenous architecture. We can conclude from the above mentioned studies that techniques like courtyard, natural ventilation etc. are easily applicable and they help in meeting our lighting and ventilation requirement to great extent and also in maintaining a proper internal temperatures. They keep our built spaces comfortable throughout the year and resultantly cut down the energy wastage. The findings of this study suggests that architects shall apply the strategies of vernacular energy efficient techniques which were proven examples of energy efficient architecture with due consideration to climate.



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