DOI: 10.23968/2500-0055-2024-9-4-33-48

ADAPTATION OF VERNACULAR WISDOM IN CONTEMPORARY ARCHITECTURE IN THE HOT-DRY CLIMATE IN THE CONTEXT OF INDIAN SUB-CONTINENT

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Abstract

Introduction: Globally there has been a paradigm shift in construction practices towards energy intensive building materials and design practices due to urbanization. Vernacular buildings and traditional knowledge are getting extinct although it has potential for adapting to changes and transforming for the changing needs of urban lifestyle. Some of the architects have tried to capture the principles of vernacular architecture and applied their own understanding in their contemporary designs with the contextual manifestation of the traditional principles for changing times. This type of architecture is known to be neo-vernacular architecture. **The purpose of research** is to see whether vernacular architecture is influencing the contemporary architects in designing sustainable buildings? How this traditional wisdom is getting transformed into a new dimension in a way to cater to the requirements and life style changes of modern times. Further, to know how far this traditional knowledge is successful in meeting the 21st century requirements of the people. **Methods:** Traditional architecture of selected buildings in the hot-dry climatic region in India were studied and compared with modern buildings designed using vernacular principles with respect to spatial configuration, form, building materials and passive solar strategies etc. **Results:** The research shown that architects of the modern era have modified the principles of vernacular architecture for it to be used in the modern context for better comfort and to suit to the modern life style of the people giving a new dimension to Vernacular Architecture.

Keywords: adaptation; hot-dry climate; neo-vernacular architecture; built environment.

Introduction

As the World enters the era of urban growth due to globalization and urbanization, there have been rapid changes in the built environment in terms of modernization of materials and construction techniques. It is often noticed that the changes in the built environment are not compatible with its surroundings (Thakkar and Routh, 2019). This depicts a paradigm shift in the construction industry and design practices. Extensive use of high-energy intensive material such as concrete, glass, cement, ceramics, metal etc. combined with the increased amount of construction activity is causing the emission levels of CO_2 gas, which is eventually causing global warming (Lall, 2007). Vernacular architecture of a region is the mirror of the people, place and its culture. The buildings influence the micro-climate around them as much as the micro-climate around the buildings influences the thermal performance of the buildings (Krishan, 1996). As it improves over time as per life style of people, it gets unique characteristics, which are symbiosis with the place and surroundings, and becomes the unique identity of that place and culture. Due to globalization, the identity of the place has been reduced to superficial decoration as foreign materials and technologies have been imported to get the global character (Moor, 2017). With the changing environment, vernacular architecture has evolved to keep pace with the changing life styles of the people by introducing better equipment and good craftsmanship (Jagatramka et al., 2020). Sustainability has often been an integral part of vernacular architecture as it has been developed for a group of people in a particular region with the available resources, which are limited by natural and economic factors. Yet it was successful in providing viable solutions for human shelter in harsh climatic conditions (Salman, 2018). Taking inspiration from vernacular architecture is a method for solving many environmntal problems in urban areas (Martinovic et al., 2023). Few people tried to achieve it with the help of elements, forms and motifs from vernacular architecture. Others tried to find essential principles of vernacular architecture and to adapt them in the modern context in the relevant manner. Involvement of properly schooled architects in the vernacular style of architecture has given birth to a new style of architecture known as "Neo-vernacular architecture". Architect Ashok Lall (2007), has argued that traditionally used construction materials and trades will result in several benefits contrary to the use of industrially manufactured materials. Salman (2018) has discussed that the use of vernacular principles in modern construction can improve identity and sustainability of a space. Architects

For citations: Nagarau, K., Sayak, B. (2024). Adaptation of vernacular wisdom in contemporary architecture in the hot-dry climate in the context of Indian sub-continent. Architecture and Engineering, No 4 (9), pp. 33–48. DOI: 10.23968/2500-0055-2024-9-4-33-48.

Vedamuthu et al. (2014) have discussed adaptive reuse of a vernacular house with an example of old Chettinad house. Cultural adherence, energy efficiency, vernacular influence, coherence with ongoing practices, and harmony with the site and surroundings are the five principles identified for creating neo-vernacular entity as per the study done on Indian neo-vernacular (Rajpu and Tiwari, 2020). Although there have been many studies undertaken to gain wisdom about vernacular architecture of different regions in India, very few only achieved proper implementation of them in modern context. This study aims to discuss about the traditional built forms in the hot-dry climatic region in India, to identify the principles associated in design and construction and how the same principles can be incorporated in the context of contemporary architectural context through suitable examples.

Vernacular architecture: its significance in 21st century

Vernacular architecture, by definition, refers to structures that are locally representative, and regionally differentiated. This concept encompasses the architecture of a precinct as well as a group of people or ethnic group who dwell in a certain geographical place (Olukoya and Atanda, 2020). Therefore, the most common understanding of vernacular architecture is the buildings constructed by the occupant himself or by the community as a group based on local wisdom and traditional knowledge gathered through generations. Thus, vernacular architecture is referred to as "Architecture without architects" to include structures built without any professional intervention and minimum or no use of industrial material of machines (Rudofsky, 1987). Vernacular architecture continues to be associated with past and often perceived as a symbol of poverty and is not being seen as a library of indigenous knowledge so the urge to replace them with modern buildings to portray a progressive image is visible in 21st century (Moor, 2017). The ICOMOS charter for built vernacular heritage has explained vernacular architecture as the expression of culture of a community as well as the world’s cultural diversity. Architects such as Hasan Fathy, Louis Kahn, B. V. Doshi, Charles Correa, and Raj Rewal also reinterpreted the principles of traditional architecture in their designs. Environmental sustainability as the first pillar of sustainable development focuses on human nature while being concerned about the pressures on the environment in terms of resource consumption, environmental pollution and climate change due to construction activities. Socio-cultural aspects focus on the restoring the cultural values of a community and through built environment reinforce opportunities to flourish and maintain the identity of a place. On the other hand, economic sustainability focuses on safeguarding and minimizing resource consumption. Therefore, the adaptability aspect of buildings to the changing climatic and social conditions are important with respect to economic sustainability. Simultaneously it also focuses on generation of income for local people or the building occupants (Tipnis, 2012). Vernacular buildings as well as neo-vernacular buildings in recent times are designed and built to satisfy all the aspect of sustainability in most cases. It must be recognised while many of the vernacular principles are sustainable and suitable even today, there are a couple of techniques that are no longer relevant in the context of modern life because of changed culture and ecological conditions. The key challenge in the 21st century is to take fundamental lessons from vernacular architecture and to find ways to integrate them for changing lifestyle and climate requirement to design new. Architects shall apply the strategies of vernacular techniques which were proven examples of energy efficient architecture with due consideration to climate (Nagaraju, 2017).

Methodology of the study

This study has been undertaken in the hot-dry climatic region in India with distinct vernacular architecture. As the first step, some of the traditional buildings with vernacular architectural style from this region have been identified and studied through secondary data from literature and internet sources. Important aspects like the culture, spatial organisation, building form, building materials, construction technique, bioclimatic attributes, and energy efficiency measures, which have been influenced by vernacular architecture, are identified as parameters of the study. As the second part of the study, few contemporary buildings have been identified from the same context which were built based on concepts of vernacular architecture in the modern context, which can become examples of neo-vernacular architecture. These buildings have been studied on the same identified parameters and analysed how the vernacular principles have been transformed and implemented in these contemporary buildings to meet the needs of modern life style with the help of latest technologies in construction.

An overview of the study region

The climate of India is diversified, with a wide range of weather conditions and varying topography. The Thar Desert throughout the North-West and the Himalayan range in the North work together to create a beautiful landscape and a variety of climate types in India's geography and geology. The Koppen system has classified this region as hot-dry climate where as India has another five climate types as per this classification. Bureau of energy efficiency (BEE), Govt of India has divided the country into 5 distinct climate types as shown in Fig. 1.

For this study, hot-dry climate has been selected which predominantly spread over central

Maharashtra, Eastern half of Gujarat, southern half of Rajasthan and the western border of Madhya Pradesh. The yearly rainfall in this area ranges from 300 to 750 millimetres (15.7–29.5 in). It is prone to dryness because of the South-West monsoon's occasional lateness or failure, which results in less consistent rainfall. March through May are hot and dry, with average monthly temperatures of 32–35 °C, while December, the coldest month, has average monthly temperatures of 14–20 °C. Madhya Pradesh is separated into three distinct regions (Table 1).

The area between the Narmada-Sone River and the Aravalli Mountain range is known as the Middle Highland ("India planted 66 million trees in 12 hours", on 3 July 2017). Burnt clay brick masonry and sandstone slabs are the most commonly used locally available material although locally produced clamp bricks are of bad quality. Wood and locally fired clay tiles are used for roof construction (DFID report, 2013). The plateau aspect of Maharashtra, which is separated from the Konkan coastline by Ghats, is its most prominent physical feature. The state has a small irrigation area, low natural soil fertility, and huge areas that are prone to drought. ("Western Ghats as world heritage site". The Times of India. 2 July 2012). Teak wood, grey granite, mud, straw, cow dung, burnt clay, sun dried bricks are the common materials available locally for construction (Biswas, 2009).

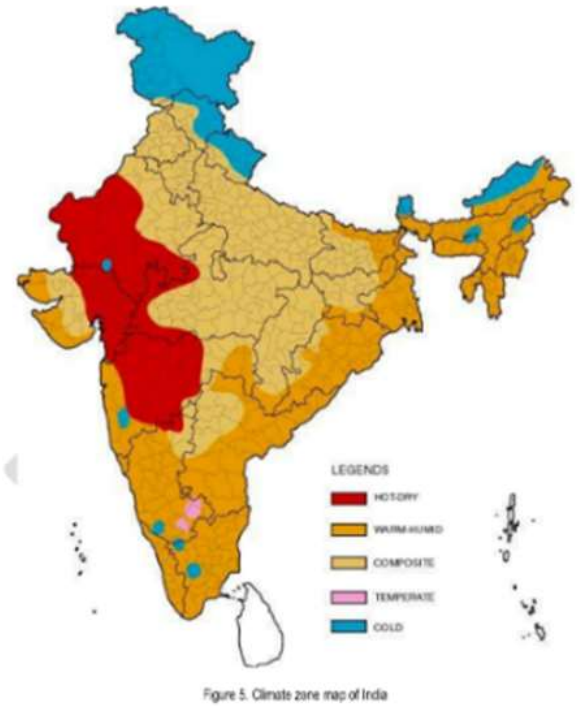

Fig. 1. Climatic map of India (Source: ECBC 2007)

The Thar Desert and the Aravalli Range, which stretches for more than 850 kilometres from southwest to northeast, practically from one end to the other, are two of Rajasthan's geographical features. The Northwest portion is sandy and barren, with little water, although it gradually improves from desert territory in the extreme west and northwest to a more fruitful and habitable area in the east. Mud, thatch, red/pink/yellow sand stone, limestone, lime, brick and cement blocks are most used material in this part of the country (Rathore et al., 2018). While the sea surrounds the state of Gujarat from the far South to the far North of the Peninsula, the state is primarily flat territory with low hills or minor mountains stretching from Rajasthan, Madhya Pradesh and Maharashtra. The state includes the Kutch region, which includes the Rann of Kutch, a significant tract of land (The Hindu World, Walker). Mud, bamboo, cane, bricks, stone are the main building materials, which we find in Kutch region of Gujarat (Lathiya, 2016).

Traditional Architecture of the region

Three vernacular buildings have been studied which falls in the hot-dry climate of the studied region and has shown characteristics of sustainability and thermal comfort. The identified cases are a (I) Haveli from Rajasthan, (II) Pol house of Ahmedabad and (III) Bhunga house of Kutch. Common characteristics of vernacular architecture have been identified to relate it to the contemporary trend of sustainable architecture. The selected cases were studied on parameters like (1) spatial configuration and building form, (2) materials and construction techniques, (3) passive strategies that are important for

Table 1. **Climate data of the study areas**

Parameter	Jodhpur, Rajasthan	Ahmedabad, Gujarat	Kutch (Bhuj), Gujarat
Average annual temperature	26 °C (78.8 °F)	27 °C (81 °F)	26.5 °C (79.7 °F)
Average annual rainfall	360 mm (14.2 inches)	800 mm (31.5 inches)	380 mm (15 inches)
Summer temperature range	25 °C to 45 °C (77 °F to 113 °F)	27 °C to 45 °C (81 °F to 113 °F)	28 °C to 44 °C (82 °F to 111 °F)
Winter temperature range	7 °C to 25 °C (45 °F to 77 °F)	12 °C to 25 °C (54 °F to 77 °F)	8 °C to 24 °C (46 °F to 75 °F)
Monsoon season	July to September	June to September	July to September
Summer months	April to June	March to June	March to June
Winter months	November to February	November to February	November to February
Humidity	–	57 %	55 %
Climate type	Arid/Semi-arid	Semi-Arid	Arid

creating good thermal comfort and energy efficiency in buildings.

Architecture of a haveli (Palace), Rajasthan

Spatial configuration and building form

As it was a male-dominated society with women kept to the home, there was a necessity for spatial segregation, as evidenced by the presence of at least two courtyards. Although, as the interaction between men and women has grown in recent years, the separated zones have become public and private. From the perception of environmental compatibility, courtyards are ideal for the function. During long wedding/festival celebrations, the courtyards become active with a lot of festivities. A back-basement room used for storage and the house is surrounded by the verandah. The plans of the palace are shown in Fig. 2. Due to lack of fenestrations and to break the monotony of flat facades, they were painted to create intriguing facades.

Materials and construction techniques

Stone was readily available in the area. Mud and clay were in little supply and were used sparingly in agriculture. Lime quarries were not close by, but accessing them was easy. Stone was a cost-effective and climatically acceptable material, therefore all of the buildings are made of stone and lime mortar. The roofs are flat, with stone slabs joined with lime mortar and resting on 10×10 cm timber beams separated at roughly 40 cm. Above that, an air layer of inverted earthen pots serves as insulation. On top of it, another layer of lime mortar is applied, this time finished with reflective smooth material such as shattered porcelain pots of white wash to reflect the majority of the sunlight landing on it.

Passive strategies

Sun is controlled by projections and building orientation, buildings receive the least amount of direct sun energy due to shadow patterns. This helps to reduce the peak heat flux into the building during the summer. For ventilation, a combination of the courtyard and internal vertical shafts was used. The courtyard, along with the glass vertical ducts and stair cases, are utilized to deflect wind down into the dwellings. The outside conditions are attenuated to create comfortable conditions inside the buildings due to the normal thermal lag present, as well as thick construction with good thermal capacity. Natural ventilation inside the building throughout the day is not desired due to hot and dusty breezes and so small apertures are provided. All the openings are shaded with projections which are surrounded by perforated stone screenings known as Jharookhas, which allow the air to cool due to Venturi effect. The staircase mumty was raised, and each chamber was given an opening through which forced ventilation could be conducted. This enables the nighttime convective cooling and daytime induced ventilation; these strategies are presented in Fig. 3.

Architecture of Pol houses from Gujarat

Following the communal riots in 1714, the Ahmedabad's houses were divided into tight neighbourhoods with a single entrance. Residents of each neighbourhood tended to have not only from the same religion, but also from the same caste or occupation group. These areas are known as "pols", which means "gate" or "entrance", and the buildings in these areas are known as *pol houses*.

Spatial configuration and building form

The houses are typically narrow with minimal frontage towards the neighbourhood street, two to four stories high with a small courtyard open to the sky and adjacent buildings (Fig. 4) share walls on either side. The relevance of the house's open spaces grows in the crowded urban fabric. The courtyard, also known as a chowk, is the main feature of the house that connects inside and outside of the house and functions as light well (Fig. 5). Parasol is the veranda space around the courtyard where most of the family life takes place. Otala, which is the front balcony that marks the extent of the house and is used for daily household activities and religious activities. The roofs of the pol houses were sloped to provide shade from the monsoon rains as a space for storage.

Materials and construction techniques

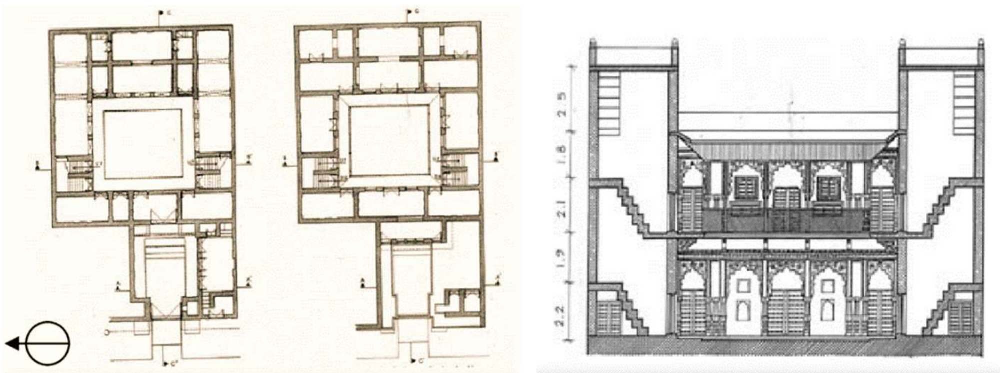

Fig. 2. Typical plans and section of Rajasthan Haveli (Source: Agarwal et. All, 2006)

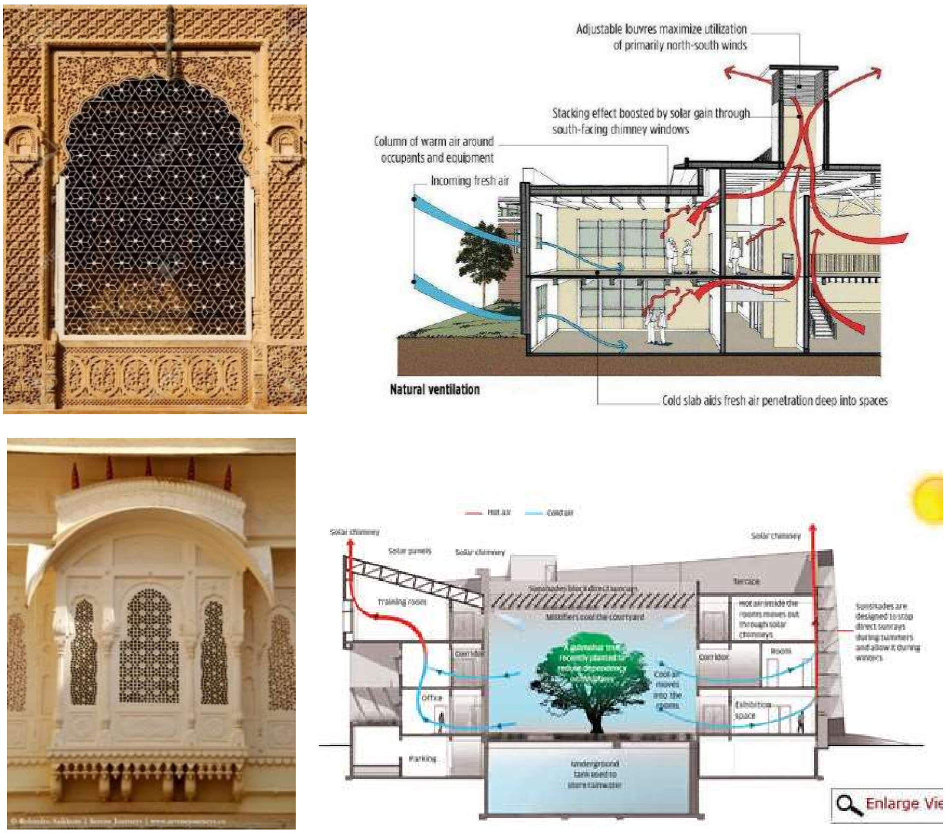

Fig. 3. Jharokha, Staircase mumpty working as stack ventilator, Jali & Courtyard in Rajasthani havelis (Source: google image)

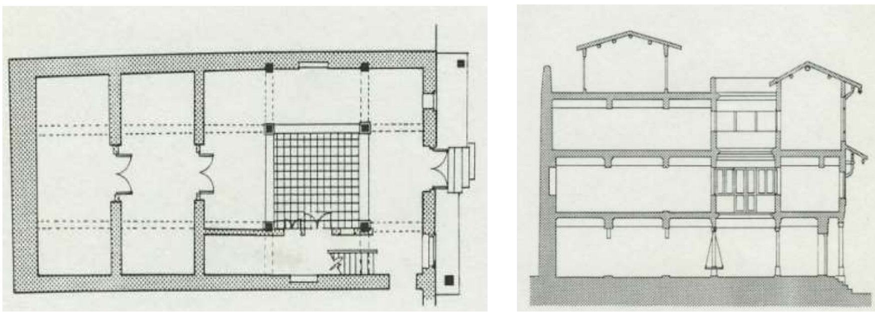

Fig. 4. Plan and section of a Pol house in Ahmedabad (Source: M. Susan Ubbelohde, George Loisos)

Fig. 5. Informal interaction in courtyard (Source: Gangwar and Kaur, 2020)

The construction of Pol houses is typically based on a wooden framework of posts and beams with 16'' brick infill walls (Fig. 6). The Foundation was the continuation of the parallel walls which goes up to 2–2.2 m deep while the width is same or twice the parallel wall. The brick walls were plastered on both the sides. The large flat bricks used in these Pol houses help to resist earthquakes because they are stable against overturning. The bonding materials used in brickwork were a mixture of mud and cow dung or lime, which gives sufficient bonding material large sized bricks. This brittle mortar allowed for some movement and plasticity in the wall. The flat slabs were constructed with timber joists and Coba slabs with lime mortar on top. Newly extended slabs have been made with RCC and sloping roofs are made with wooden beams and GI sheet covering. Structural and ornamental components, like carved columns, brackets, window shutters, and balconies made with wood. There is a provision for chimney over the fireplace (Chula) as an outlet for smoke from the kitchen. Stones are also used as the foundation for columns and doorframes in Pol homes. While the columns are properly pin-connected at the top and bottom, the building can somewhat shake back and forth during earthquakes.

Passive strategies

In the summer season the house act like a protective shell which keeps the heat away and creates a microclimatic cooler in the house through the intervention of the Chowk. Thermal capacity of thick walls varying from 12–24” is the key for indoor thermal comfort. Shading is the second most important aspect, due to its tall and narrow structure, the chowk or courtyard lowers solar radiation in summers through reciprocal shadowing. The surrounding walls of the chawl are also shaded with wooden details to shade it from the high-altitude sun (Fig. 7). The rainwater-collecting tank is always beneath the courtyard, and the courtyards specifically constructed floor tiles absorb heat.

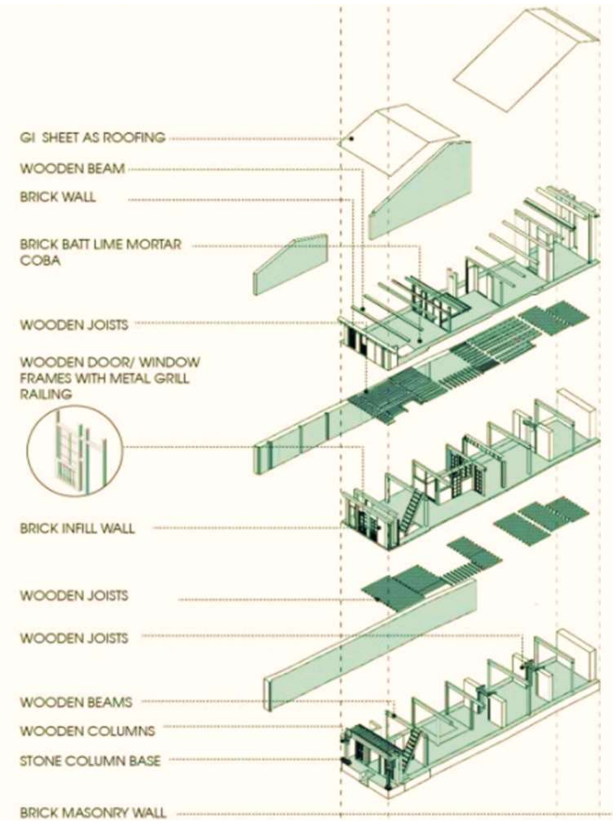

Fig. 6. Exploded axonometric view of construction technique of Pol houses (Source: M. Susan Ubbelohde, George Loisos)

The household activities takes place in the chawl making it a wet place, which eventually allows for evaporative cooling during the summer. Windows are opened at night and are closed by 8 in the morning to allow the night ventilation to cool the house.

Architecture of Bhunga houses

Bhunga houses are one of the vernacular dwellings that have developed in response to the prevailing weather conditions by the locales. They are single cylindrical buildings that are stacked close together to form a dwelling for nomadic and seminomadic pastoral communities to live in. Following the earthquake of 1819, building craftsmen in Sindh and Kutch devised the circular house-form design. Even after the earthquake of 2001, it was discovered that the majority of Bhunga houses had survived the disaster, whereas many other structures had collapsed.

Spatial configuration and building form

The locals construct circular mud dwellings with thatch roofs, materials that are perfectly adapted to their harsh desert environment. The community of the villages is made up of many vandas. Every varandah is made up of vaases. A vaas is a unified family unit in which everyone stays together and shares one or more shared areas. A single family can start a vaas by building a big plinth on an empty plot, and this plinth usually covers the vaas’ future expansion. In most cases, the cooking space is shared by two or more Bhungas. A single plinth connects all of the structures in a vaas (Fig. 8).

The platform of a Bhunga connects the different, separate individual residential units that are not connected to one another. The modulating and flexible surface of the platform naturally maps the

Fig. 7. Façade with wooden carving (Source: Gangwar and Kaur, 2020)

Fig. 8. Development stages of typical Bhunga house (Source: Inside and out, NID, 2019)

growth and multiplicity of individual units. When the family's needs for another unit emerge, an additional Bhunga is built and connected to the house by extending the platform to include the new space within the house's jurisdiction.

As a result, individual privacy is respected and protected. The household may be made up of two or more bhungas, each of them is assigned to one of the same family's married spouses. Bathing and storage are sometimes done in smaller, enclosed chambers that are undefined in shape and lack a roof. The vandh is a polycentric structure in which the middle courtyard spaces are left unoccupied to allow for cross ventilation and daily activities. The courtyard is large enough to accommodate a variety of activities while being small enough to provide shady areas. Aangan, room, cooking area, otta, veranda, and backyard are typical house layouts (Fig. 9). The aangan, or front yard, is a common meeting place for relatives and visitors. A typical Bhungas have three or four little, low height windows arranged symmetrically around the door.

Materials and construction techniques

Bhunga materials are readily available in the Banni region's surroundings (Fig. 10). Chikani Matti (clay) and cow/camel/horse manure are used for the walls and flooring. The roof is made of bamboo from the Babul tree. The term "COB" was commonly used in construction techniques. A big lump is roughly fashioned into the shape of a huge elongated egg, standard size ranges from 12 to 18 inches. These mud cobs are stacked virtually side by side in a row. The sides are smoothened to eliminate the holes and fissures. The wall is constructed of sun dried bricks and compacted stabilised earth blocks.

The beam-adi is hung from the wall horizontally, perpendicular to the door's axis. The ends of the

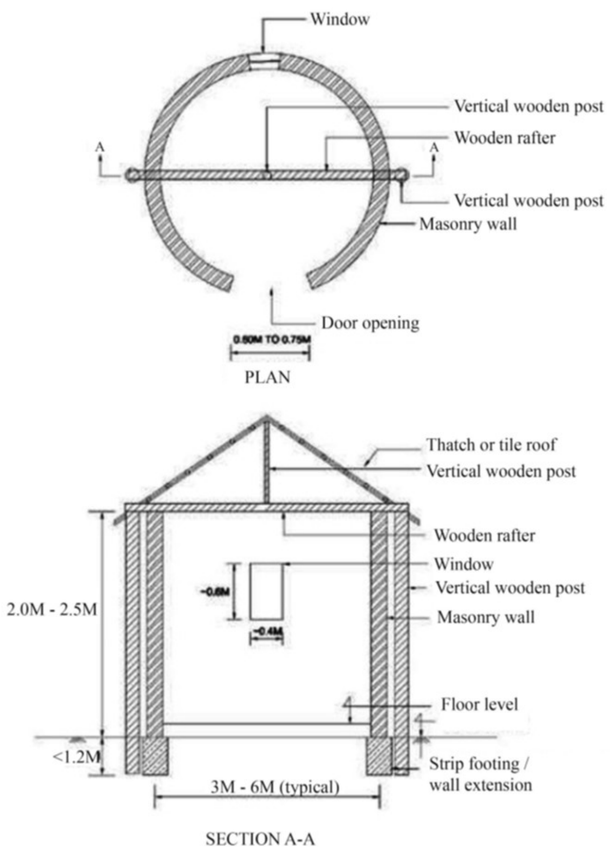

Fig. 9. Plans and sections of Bhunga house (Source: aina. wikidot.com)

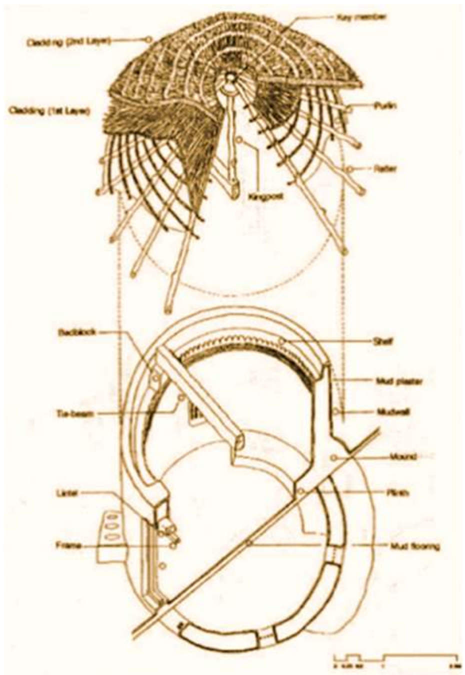

Fig. 10. Exploded view of construction detail (Source: Lathiya, 2016)

beams are attached with pegs to slightly higher parts of the wall. The vertical kingpost's base, patli, rests on the centre of the beam, adi, while the Kingpost stands on the middle of the patli. The kingpost is topped with a cone. Rope is used to secure the joints (vali) at the top of the cone and between them (Kathi). Split bamboo culms (khapatis) occupy the space between the valis and are attached to them. Starting at the bottom, straw bundles (kheep) are connected to the roof framework. The straw bundles are then held in place by a rope net dropped from the roof's top (Fig. 11).

Passive strategies

These are compact modules with a low surface to volume ratio to provide the best possible thermal comfort. The thick mud walls and little openings keep inside of the bhungas cool during the day in the summer and somewhat comfortable in the evenings in the winter. This is because the daytime heat is stored in its high-thermal-capacity mud walls. Bhungas have small holes that keep the hot desert breezes at bay. The bhungas' climate-responsiveness is enhanced by thatch, which has high insulating characteristics. A bhunga's roof overhang casts shadows and shields the walls from direct sunlight. Because of its round form, the majority of the surface is shaded and heat is reflected away, making it more convenient for the summer. Thatch is inherently resistant to the elements and does not absorb a lot of water. During the limited rainy season, the bhunga roof's steep slope (minimum 50 degrees) lets rainwater to slip down swiftly. The bhungas' thatched roofs have air spaces that keep them warm in the winter and cool in the summer.

Contemporary architecture with vernacular principles

Contemporary houses have been identified in the hot-dry climatic zone of India, which were designed according to the vernacular principles and intended to implement those principles with a twist of modernization. Methodology for selecting the buildings have been described below:

1. As vernacular architecture is very much region specific, case studies have been selected from the hot-dry climatic region of India.
2. Buildings, which have used local material and traditional construction techniques and contemporary technology, have been identified.

These buildings have been studied based on four parameters such as: (1) spatial organisation; (2) built form; (3) material and construction technique; (4) passive strategies adapted for energy efficiency. These studies helped in identification of probable simple and advanced strategies, which can be adapted in contemporary context.

Case study 1: Shunyam residence, Jodhpur, Rajasthan

Shunyam is a single-family retirement home set on a 2-acre site on the outskirts of the "blue city", Jodhpur in Rajasthan. This building echoing the grandeur of Jodhpur's historic palaces through an explorative merging of the vernacular with the contemporary (Fig. 12). The design's main goal was to create an architectural solution that responded to the local culture, aesthetics, and environment while also meeting modern living needs by incorporating traditional construction processes.

Spatial configuration and building form

In this single storied house, living areas are free flowing spaces set around two courtyards in a simple geometric pattern. Utilities and service areas are designed along the periphery as an insulating barrier against the weather. Jaalis separate the building masses and open them up to the outside through sandstone arches. First floor houses only meditation room with a pyramidal roof (Fig. 13).

Materials and construction techniques

The entire edifice was built using traditional stone construction (Fig. 14). In the load bearing RCC foundations (the only use of RCC in the entire

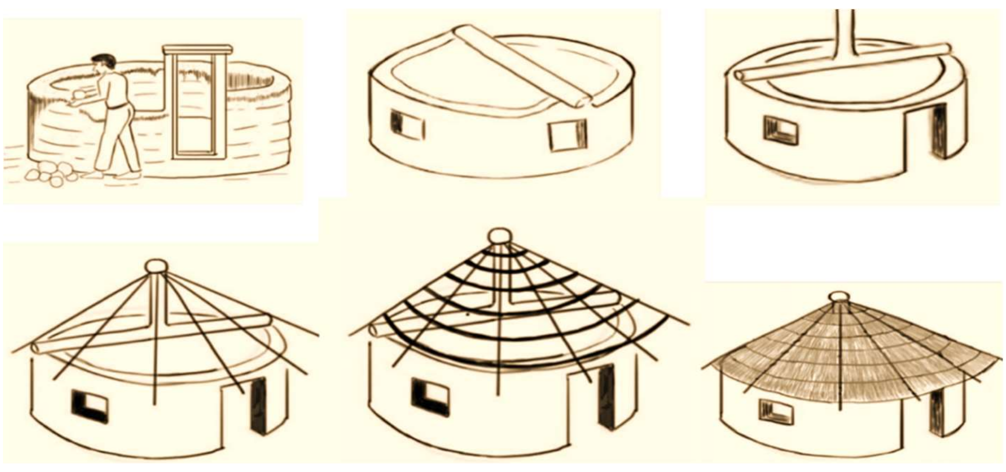

Fig. 11. Stages of construction of Bhunga House (Source: Inside and out, NID, 2019)

Fig. 12. Entrance of Shunyam residence (Source: archiol.com)

project) three layers of 100 mm stone masonry were used. It was constructed with stone on both faces and a middle layer of stone pieces and filled with mortar (Fig. 15). Mild steel (MS) I sections were used as beams and columns. Lime and sand were used for waterproofing and as mortar for stonework.

Toilet walls are Lime plastered with organic blue colour pigment. For the bedroom flooring, ceiling, doors and for furniture, local Sisam wood was used. Glass was used for door panels, light fittings and crockery cabinets. Printed and woven textiles were used for curtains, furniture, and carpets locally. A roof top was finished with China mosaic. Earthen pots were used as an air barrier over a stone slab on the terrace. Traditional Rajasthani architectural motifs such as jaalis, arches, circular apertures, and jharokhas are carved into Sandstone. Handcrafted wood, glass, and metal doors, furniture, and accessories reinvigorate local crafts while connecting residents to their traditional heritage. The house's materials were all sourced within a 200-kilometer radius of Jodhpur town.

Passive strategies

The dual courtyards create positive and negative pressure zones, which aid in the house's passive cross ventilation (Fig. 16). The cooling towers funnel fresh air into the building, chilling it with spray and incorporating it with the cross-ventilation loop to keep the house cosy. Turbo vents just above exhaust spindles extract warm air from living spaces. Earthen pots serve as an insulator on the ceilings, shielding

Fig. 13. Spatial zoning & bird's eye view of the house

Fig. 14. Exploded Isometric view & external views of the house (Source: Archiol.com)

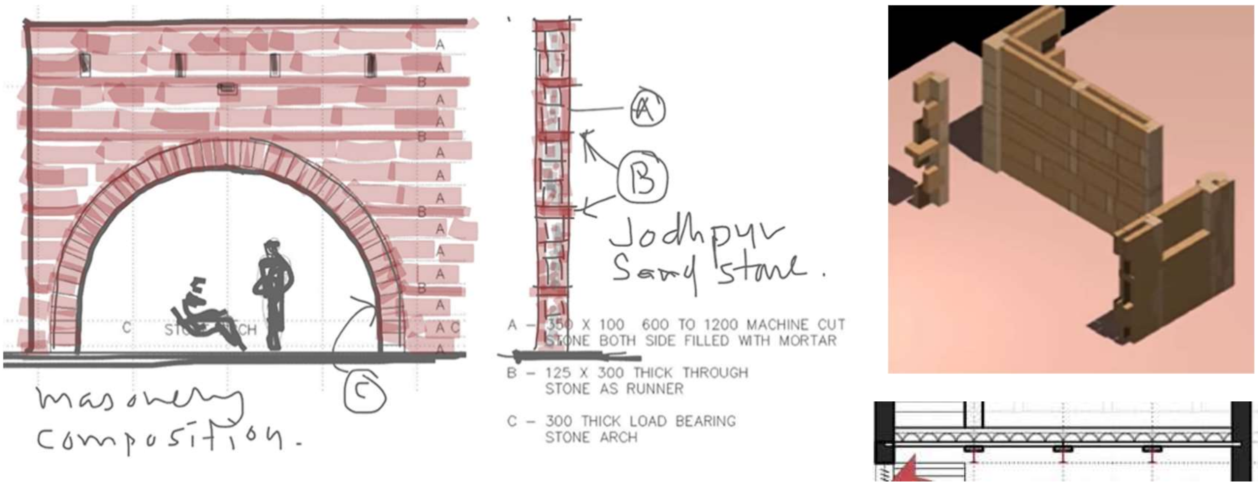

Fig. 15. Load bearing wall with stone and wall & roof details (Source: taoarchitecture.com)

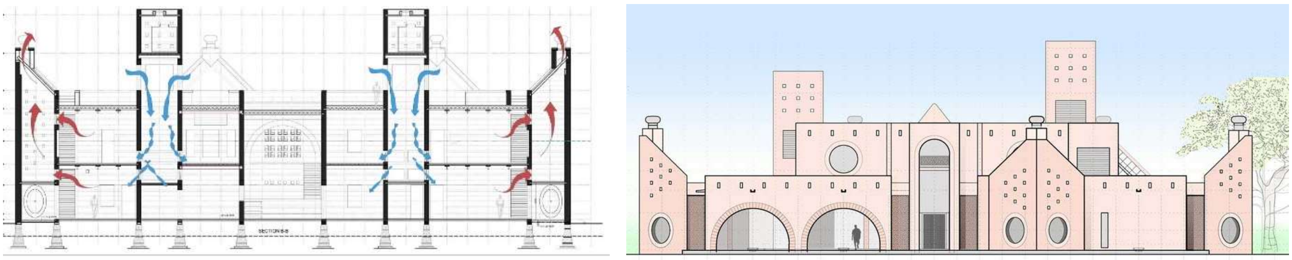

Fig. 16. Natural ventilation through solar chimney and wind catcher & North side elevation (Source: taoarchitecture.com)

Fig. 17. View of stone house

the interior spaces from solar radiation, while China mosaic tiles serve as a roof finish, reflecting sunlight and preventing heat absorption. Gaps in the parapet wall allow air to circulate above the terrace, cooling the surface. All of the confined spaces are on the southern and northern facades, while 90 % of the semi-covered and open areas are on the east-west axis, allowing for continuous air circulation.

Case study 2: Stone house, Jaipur, Rajasthan

The house in Jaipur, Rajasthan with a built up of 8000 sft was designed and constructed using traditional wisdom in architecture. Construction method used in this building has been used in traditional structures in India for ages. Stone was used mostly in the building (Fig. 17). Craft's scope, which had previously been limited to ornamentation, artifice, and an object, was broadened to include architecture. In a space that is both ancient and contemporary, easily consumable symbolism is replaced by the primal and vital deployment of material resources and craft.

Spatial configuration and building form

It is three storied building with a semi basement (Figs. 18–19). The house is built around a small courtyard that leads to even smaller openings. Traditional homes' void proportions as a means of mitigating the effects of the scorching summer heat. The ground floor is living areas with bed rooms on the upper two floors. The basement is dedicated to servants' room along with other recreational activities.

Materials and construction techniques

The load-bearing building method relies on the thickness of the wall (Fig. 20). This was reengineered

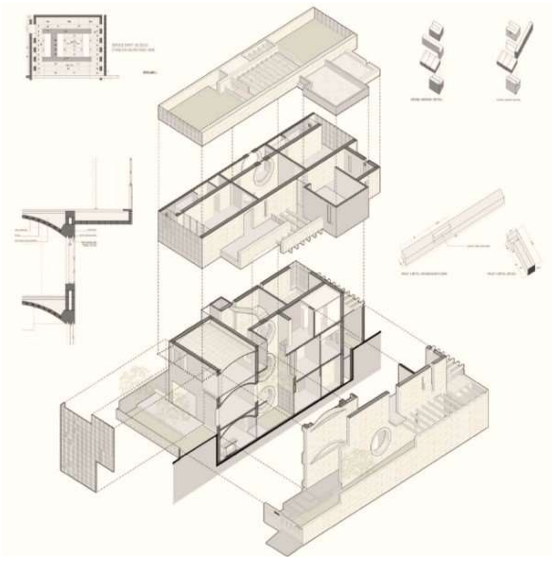

Fig. 18. Exploded Isometric view of the construction technique (Source: archdaily.com)

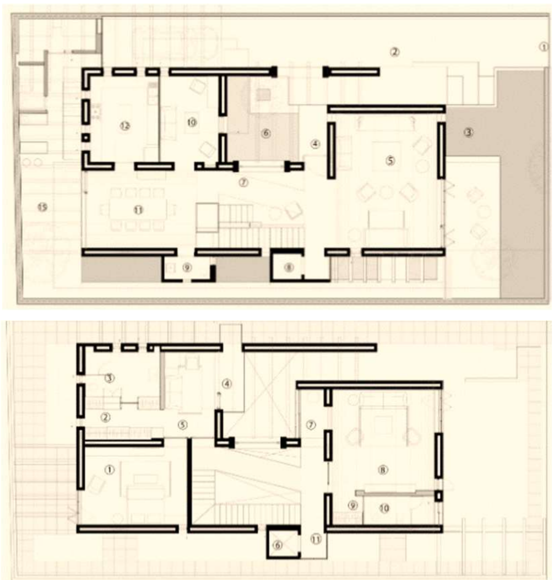

Fig. 19. Floor plans (Source: archdaily.com)

by developing a hollow interlocking structural wall system, which creates an effective thermal break, provides space to integrate services within the wall cavity, and effectively reduces the material consumption by 30 %. Vaults and massive single-span stone pieces alternate as floor systems. All the elements from the basement raft/retaining walls/lintels/door and window jambs/reveals/stairs/screens etc. have been made from stone blocks, either from the quarry (superstructure elements) or excavated from the site (substructure elements). For a seismic response, a small amount of steel, such as tie-rods and shear pins, were used to support the stone. Only the outside joints are sealed with lime mortar.

Passive strategies

The longer surfaces are towards north and south direction. To control light, privacy, and views, large wide overhangs and moveable shade front and back glass, hand-cut stone screens (Fig. 21). Caused by the thermal mass of the material and the "cavity" structure, there is a 5–7 °C difference between the exterior and interior. Finishing of external stone surfaces are kept rough for self-shading as well as for radiative cooling at night due to the increased surface area. A narrow courtyard in the building controls the microclimate as well as cuts off the extra solar radiation. Basement rooms tend to use the cooling from the earth.

Case study 3: Meethi Mishti Nu Mati Ghar, Ahmedabad, Gujrat

Meethi-Misthti nu Mati Ghar is a 440 m^2 residence in Ahmedabad designed by Ar. Naman Shah. Meethi (3 years old) and Mishti (3 years old) are the two young patrons of this project. The built-up area of the building is 4 736 sft constructed in a plot of 18 000 sft. Local materials and techniques are used throughout the house, as well as recycling and upcycling, resulting in a low carbon footprint

Spatial configuration and building form

The house has two wings of private spaces connected with a double height living space overlooking the veranda (Figs. 22–23). Backside of the house is open to the Sun throughout the day therefore services are placed there. The living room has a sloping glass roof towards the north that caters to the requirement of clients changing the ceiling. Since Ahmedabad gets hot in the summer playground was brought inside the house.

Materials and construction techniques

By ramming soil extracted from the site itself into 16” thick structural walls for the house, diverse

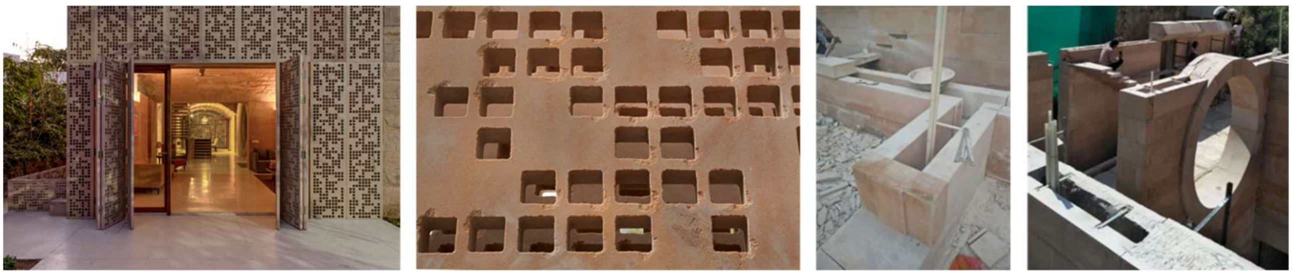

Fig 20. Detail of stone used for different types of construction (Source: archdaily.com)

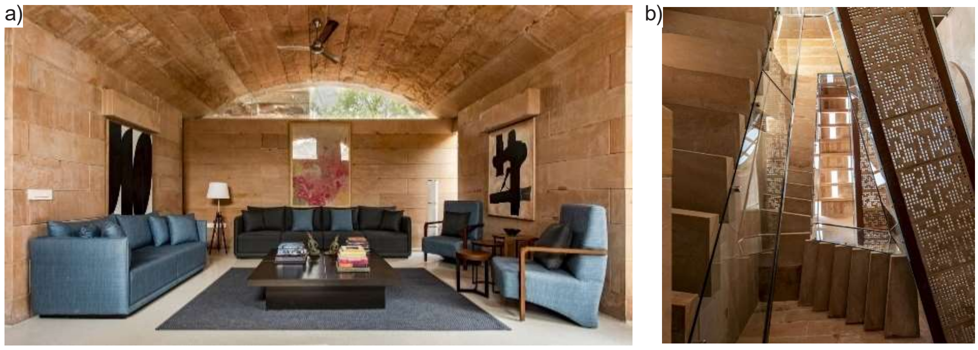

Fig. 21. Vaulted roof with clearstory (a) & Ventilation shaft in hall (b) (Source: archdaily.com)

Fig. 22. Floor Plans (Source: archdaily.com)

Fig. 23. External view of the house (Source: archdaily.com)

natural oxides are used to create layered fluid patterns. It is the largest rammed earth wall built in India. Additionally, few RCC column has been added to the structure. Roofing with RCC slabs supported on the columns and rammed earth walls. Walls other than rammed earth are 9-inch brick with lime plaster. An old building's wood was repurposed. Wooden pergolas over the veranda are made from packing wood. A glass broken on the site has been used in the terrazzo flooring in the verandah. Toilets are plastered with lime to give a monolithic finish (Fig. 24).

Passive strategies

16" thick rammed earth wall on East, West and South side gives thermal insulation from Solar radiation to the habitable spaces due to its high thermal mass capacity. The glass roof over the living room lets in cold north light, which illuminates the house throughout the day and cuts down on electricity use. Blinds have been provided to close the glass roof if the internal temperature rises beyond certain level. Long overhangs have been provided to shade the glazing surfaces. The roof has been covered with white tile to reflect the maximum amount of solar radiation. Solar panels have been added to offset the required energy demand while shading the roof surface (Fig. 25).

Inferences from the study

Comparison between the traditional and contemporary architecture

Good Architecture of a building shall be suitable for its environmental context, and should adequately protect the inhabitants from the climate. Further, it should safe guard the environment from potential pollution and degradation caused by human habitation (Bennetts et al, 2004). The architecture of today is radically different from the images of the vernacular associated with space. The change in the economy and globalization has paved way for

Fig. 24. Flooring in lobby (a) & Wash room with lime plaster (b) (Source: archdaily.com)

Fig. 25. Roof top solar panels (a), Large overhangs (b) and Rammed earth wall (c)

manufactured materials and has caused a profound change in the vernacular architecture.

I. Orientation. Contemporary and traditional houses of the region have followed the same concept of East-west as longer axis.

II. Building form. Rajasthan havelis used the concept of twin courtyards and the architect for designing Shunyam residence adapted the same system. The stone house located in Jaipur; Rajasthan also followed the concept of a narrow courtyard just like the Pol houses of Ahmedabad.

III. Roof system. All the traditional houses selected were constructed with either a flat roof or sloped roof, whereas all the selected modern houses were constructed either with flat roof or with combination of flat roof and sloped roof.

IV. Spatial configuration. All the traditional houses were designed with activities around the courtyard with public activities either in the verandah or in courtyard. Whereas the contemporary houses followed the similar concept by designing all the public activities around the courtyard with private spaces separated for privacy. It is mainly due to the change in life style over the period as human beings are giving emphasis on private spaces for individuals over and above the family spaces.

V. Walls. Traditional houses had used the wall assemblies like stone, Adobe, COB and burnt clay brick. In the similar lines, architects of the contemporary buildings also used materials like dressed sandstone, rammed earth and burnt clay brick and used glass. The difference may be the clay brick that is now manufactured with using straw along with mud and use of glass.

VI. Roofs. Stone slabs, flat slabs with timber joists/ steel "I" sections and Coba slabs with lime mortar, split bamboo with wooden beams were used in traditional buildings whereas in contemporary structures, RCC roofs, vaulted roof and an earthen pot are used.

VII. Passive strategies. High thermal mass walls, courtyards for evaporative cooling, Mumty walls as wind catcher, shading through Jalis and projections, and balconies were used predominantly in traditional buildings. In contemporary houses, latest technologies like reflective tiles for roofs, sloped glass roofs, movable blinds along with vernacular elements like Jalis in modern designs, modernized Jharokhas were.

The comparisons between the studied buildings of vernacular architecture and modern architecture is presented in table 2.

Discussion

The use of red sandstone and elaborate carvings define Jodhpur's traditional architecture. Along with materials like stone, brick and lime plaster. Traditional buildings were designed with courtyards, thick walls, Jharokhas and flat roofs. The indoor temperatures were kept low even during the

Table 2. **Comparison of traditional and contemporary dwelling studies in this research**

Si. No.	Strategies	Rajasthani Haveli	Pol Houses	Bhunga Houses	Shunyam Residence	Stone House	Meethi Mishthi Nu Residence
I	Orientation	E-W longer axis	E-W longer axis	No particular orientation	E-W longer axis	E-W longer axis	E-W longer axis
II	Building Form	Compact with twin Courtyard	Linear with narrow central Courtyard	Individual circular units	Compact with twin Courtyard	Compact with narrow central Courtyard	Compact without Courtyard
III	Roof form	Flat roof	Flat & sloped roof	sloped roof	Flat roof	Flat & Vault roof	Flat & sloped roof
IV	Spatial configuration	Spaces around courtyard with Verandah	Linear spatial planning, public spaces around courtyard	Separate circular rooms connected with a common plinth	Habitable Spaces around courtyard, buffer spaces in the periphery	Public & living Spaces around courtyard, private spaces separated	Two wings of private spaces connected with living space
V	Wall Materials	Sandstone, RR masonry	Wooden frame, brick infill	COB/Adobe/ burnt Brick	Dressed Sandstone masonry	Cavity wall with Sandstone	Rammed earth and burnt Brick
VI	Roof Materials	Stone slab Earthen pot + + Lime mortar & Porcelain finish	Wooden beam + COB + +Lime mortar/GI roof/RCC	Wooden beam + + split bamboo+ +straw	Stone slab Earthen pot + + Lime mortar & China mosaic	Stone vault + light weight filling + + PCC/stone slabs + PCC	Exposed RCC frame structure
VII	Passive Strategies	Shading through Jali/ Jharokha/ wooden lovers/ vegetation/Sun shades	Shading through wooden details, projected balconies	Low surface to volume ratio	Reflective tiles as roof covering & Jalis for shading	Extensive use of hand cut stone jalis & modern Jharokhas	Reflective tiles as roof covering & sloped glass roof
		Mumty and tall shafts as wind catcher	Courtyard as a ventilating and lighting shaft	Long roof overhang for shading	Three wind towers over habitable spaces	Stair case space for stack ventilation	Large overhangs and movable blinds
		Evaporative cooling through courtyard	Evaporative cooling through courtyard	Thermal mass of the walls and insulation for the roof	Six solar chimneys	Shading with Jali/ self-shading	Vegetation for shading

most intense heat seasons by using architectural features like high ceilings, courtyards, Jharokhas and Jaalis. In the contemporary residential building, blends both modern and traditional elements were observed. Vernacular features like courtyard and Jalis and materials such as stone and brick were used in modern buildings mimicking the traditional architecture of the place. They have also used modern materials like concrete, glass and steel along sandstone to offers utility as per modern life style yet with traditional looks. Ahmedabad is known for its traditional Pol houses, which have compact and inward-facing dwellings with internal courtyard. These provide natural ventilation and cooling in the hot and dry climate of Gujarat. They used locally available materials like mud, brick, and clay and intricate wooden carvings can be seen, these features promote cooling and airflow. The studied buildings from Ahmedabad were designed with internal courtyards, thick walls for better cooling and thermal comfort inside the residence. They are aesthetically contemporary with minimalist, functional, and sleek designs. The use of mud, clay, cow dung and straw characterise the traditional residential architecture of Kutch. Bhungas that had thick mud walls and thatched or tiled roofs could be seen all around. These were well insulated to withstand heat and earthquake. It used to be decorated with local art making it simple yet functional. These were sustainable and were clustered in villages reflecting a strong sense of community and mutual support. The contemporary buildings in the present study have used modern construction strategies to improve sustainability, ventilation and cooling techniques with large windows with sunshades. But with the use of intricate woodwork and colourful facades, they portray the aesthetics of the traditional architecture of the place. They were designed with modern designs fused with traditional materials to create unique living spaces that cater to modern lifestyles. The use of wood in interiors with modern elements gives the look of traditional buildings. These modern buildings utilises concrete and steel as the main materials in addition to bamboo, COB etc. Hybrid designs incorporating traditional styles is used to maintain a comfortable indoor temperature apart from the ACs and enhance earthquake resistance while retaining traditional aesthetic elements. Minimalistic approach can be seen in contemporary architecture. In Kutch, reconstruction efforts post-natural disasters have integrated modern, resilient building techniques. This architectural evolution not only enriches the cultural and visual landscape of these regions but also ensures their adaptability and growth in a rapidly changing world.

Conclusions

Jodhpur, Ahmedabad, and Kutch's residential architecture is a testament to the artistic prowess, innovative architectural techniques, and a rich cultural legacy of the respective regions belonging to the same climate. It reflects the historical practices and adapts to local climatic conditions. While contemporary architecture demonstrated how architects used these classic aspects in the current designs, traditional architecture displays historical workmanship and environmentally friendly building techniques. The blend of traditional and contemporary elements in residential architecture results in aesthetically pleasing and functionally efficient homes. This fusion caters to modern lifestyles while respecting historical and cultural contexts. The study tried to focus on the integration of some of the aspects of vernacular architecture into contemporary architecture. The effects of globalization and westernization influences the architectural practices leading to the loss of the unique characteristics of vernacular architecture. Aesthetics of contemporary architecture does not have continuity with its surroundings because it suffers from diverse and foreign elements and materials. In modern construction industry as the use of rigid modular elements increases, we should also recall that entropy works fastest on the most unnatural shapes. Till now the architectural vocabulary in India is greatly influenced by the West which does not necessarily respond to the dictates of the context in terms of climate, related lifestyle responses, technological appropriateness and aesthetic relevance. In order to re-orient architectural responses for the local, architects are looking at the sources of inspiration from the traditional buildings from the past to make the buildings more meaningful. The works of many contemporary architects have shown innovation in technology in combination with sustainable materials to create new vernacular architecture. The nature of sustainability and that of vernacular architecture in the modern form are discussed with the help of identified case studies. The study analysed the vernacular and contemporary architecture in three different regions under the same climatic context in India. This study highlighted the importance of adopting vernacular architecture in contemporary needs while maintaining cultural identity, sustainability and response to climate. It demonstrated how traditional construction techniques can be integrated with modern design to create functional and aesthetically pleasing spaces.

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АДАПТАЦИЯ МЕСТНЫХ АРХИТЕКТУРНЫХ ОСОБЕННОСТЕЙ В СОВРЕМЕННОЙ АРХИТЕКТУРЕ В УСЛОВИЯХ ЖАРКОГО И СУХОГО КЛИМАТА В КОНТЕКСТЕ ИНДИЙСКОГО СУБКОНТИНЕНТА

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Аннотация
Введение. В связи с урбанизацией во всем мире происходит смена парадигмы строительной практики в сторону энергоемких строительных материалов и методов проектирования. Здания, построенные с учетом местных архитектурных особенностей, и традиционные знания исчезают, хотя у них есть потенциал для адаптации к изменениям и трансформации в соответствии с меняющимися потребностями городского образа жизни. Некоторые архитекторы пытаются уловить принципы местных архитектурных особенностей и применить свое собственное понимание в современных проектах с контекстуальным проявлением традиционных принципов в условиях изменяющегося времени. Этот тип архитектуры известен как новая национальная архитектура. **Цель исследования:** выяснить, оказывает ли местная национальная архитектура влияние на современных архитекторов при проектировании устойчивых зданий? Как эта традиционная мудрость трансформируется в новое измерение, чтобы удовлетворить требования и изменения в стиле жизни в наши дни. Кроме этого, чтобы узнать, насколько эти традиционные знания успешны в удовлетворении потребностей людей 21-го века. **Методы.** Традиционная архитектура выбранных зданий в жарком и сухом климатическом регионе Индии была изучена и сравнена с современными зданиями, спроектированными с использованием принципов народной архитектуры в отношении пространственной конфигурации, формы, строительных материалов, пассивных солнечных стратегий и т. д. **Результаты.** Исследование показало, что архитекторы современной эпохи изменили принципы местной архитектуры, чтобы использовать ее в современном контексте для большего комфорта и соответствия современному стилю жизни людей, придав новое измерение народной архитектуре.

Ключевые слова: адаптация; жаркий и сухой климат; новая национальная архитектура; строительная среда.