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Climate Responsive Techniques of Vernacular Architecture: A Sustainable Approach



Abstract: - The economy, environment, and society are the three main parameters that make up sustainability. Vernacular architecture of any place instinctively takes into account each of these factors. India is recognized for its architecture, particularly its regional vernacular constructions. Vernacular structures have been constructed in response to local climates and human thermal comfort. The characteristics of Rajasthani havelis' vernacular architecture located in Jaisalmer have been examined in this study for its climatic responsiveness and further it demonstrates the model of economic, environmental & social sustainability. This vernacular structure in Jaisalmer possesses fascinating details regarding how they were built & how they coped with the dry, scorching climate of the region. It has also been discussed how the traditional building techniques can be incorporated into energy efficient contemporary architecture following examples from the vernacular architecture. The identified haveli has been documented on site and various practices have been identified which promote energy efficiency thus addressing the principles of sustainability. Various Parameters of energy efficiency, i.e., orientation of building block with respect to sun & wind, selection of building material, ventilation system and building form have been considered for analysis.

Keywords: - vernacular construction, energy efficiency, human thermal comfort, sustainability, climate

I. INTRODUCTION

Vernacular architecture describes buildings constructed from resources that were readily available nearby and that were functionally designed to fulfil the demands of the general populace during period [1]. Vernacular architecture is about creating built environments with available resources and inexpensive technology. Here, the locals constantly work to strike a balance among the climatic constraints, culture, social, economic, and religious aspects [2]. Climate responsive buildings are those that use passive and natural methods and are sensitive to the environment. There are several passive techniques used in vernacular architecture that are energy-efficient and help preserve the environment's natural resources [3]. Raw material and local technology are the pillars of vernacular architecture. It makes use of local resources & techniques and includes an ongoing human experimental process related to the spatial and temporal context. Vernacular architecture applies traditional techniques and material locally available to adapt to the socio-cultural traits and local climate [4]. Over the period of time, traditional homes are vanishing, and people are gradually losing understanding of ancient building construction techniques [5]. Therefore, the knowledge of vernacular construction methods needs to be documented so that age-old techniques which have been proved energy efficient can be transferred to the next generations. The energy consumption at buildings is consumed at two levels: construction cost and running cost. The construction cost can be controlled by adopting vernacular techniques which encourage the application of locally available materials & climate responsiveness. Further the running cost of the building shall be automatically controlled as uses shall not much depend upon cooling or heating devices.

There are effectively three climate zones in India: hot & dry, warm & humid, and composite. In India, Rajasthan region having hot & dry climate has been identified for analysing the vernacular architecture for climate responsiveness. Due to the region's intense climatic conditions, scalding summers and little precipitation, the documentation of construction practices of vernacular buildings shall provide a platform for understanding the fundamentals of climate responsive architecture. In addition to rich construction methodology, Rajasthan is also known as the 'Land of Kings' or 'Land of Kingdom'. Rajasthan has strong artistic and cultural traditions that reflect the traditional Indian way of life. Every city of Rajasthan has its own distinct music and dance accent. Grand havelis, amazing forts, and intricately carved temples are an essential part of Rajasthan's architectural legacy.

This article is about analysing the characteristics of vernacular buildings in settings of hot & dry climate. Patwa ki Haveli, a vernacular building of the city Jaisalmer, Rajasthan has been taken up as a case example for analysis. This haveli was built during the 18th century. Rajasthan, India. This haveli is famous for its skilful designs, historical importance, cultural legacy, beautiful architecture, fine carvings, ornate balconies, and delicate lattice work. The exteriors of the havelis are made of yellow sandstone, which is a characteristic of Jaisalmer's ancient

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building style [6]. In addition to making the structures more resilient, this material gives them a warm, golden colour that brilliantly reflects sunshine, which is how Jaisalmer got its moniker, "The Golden City". The region's rich heritage and expert craftsmanship are further demonstrated by the elaborate carvings and elaborate façade. Beautiful frescoes, mirror work, and paintings are found inside, highlighting the area's illustrious creative heritage. Visitors at Patwa ki Haveli are able to immerse themselves in Jaisalmer's rich past and architectural splendour of the ancient building.

The analysis of the study demonstrates how planning procedures can greatly improve natural resource conservation by taking local climate factors into account. Utilising local materials, maximising natural ventilation, and utilising renewable energy sources are all ways to design buildings and spaces that are in harmony with the climate of the area. This strategy lowers energy use, promotes sustainable development principles, and lessens reliance on artificial heating or cooling systems.

The architecture of a place can be analysed with the help of understanding the shape of the building, the effective & creative use of building materials in consideration of the desired time lag of the place, the size and position of the openings, etc. Some of the significant characteristics of vernacular architecture can be listed as [7]:

- Consideration of climatic & locally obtainable materials.
- Application of construction methods that have been passed down through the centuries, frequently making use of regional craftsmanship and expertise.
- Serves as a reflection of a community's cultural and social values. It has been created to satisfy the distinct functional requirements of society.

By using such methods, a building can become more energy efficient while simultaneously reducing its reliance on artificial comfort measures.

II. METHODOLOGY

Documentation of the identified haveli has been the basis to understand the features of vernacular architecture which are climate-responsive in nature. It entails the methodical gathering and examination of data pertaining to the conception, development, and functionality of vernacular buildings under certain climatic circumstances.

Following mentioned factors have been considered to comprehend how vernacular architecture responds to climate of the place [3] [8][9]:

1. **Field investigations and observations:** Perform on-site investigations to record a variety of factors including building shape, materials, construction methods, orientation, shading devices, natural ventilation systems, and any other climate-responsive features. Investigating the relationships between these elements and the local climate as well as how they affect thermal comfort.
2. **Gathering of climate data:** Compile climate data, including information on temperature, humidity, wind patterns, sun radiation, and rainfall. These facts will aid in identifying the climatic setting in which the structures were designed.
3. **Performance of a building analysis:** Analyse how vernacular structures behave in relation to the environment. To understand how the design elements affect thermal comfort, natural lighting, and ventilation, analyse airflow and other pertinent factors.

The conclusion of the study explains that economic and environmental sustainability can be achieved by adopting climate responsive strategies.

III. LITERATURE REVIEW

Lot of researchers have explored the climate responsiveness of vernacular architecture. Referring to ANZSRC 2020, the most relevant publications fall under the category of 'built environment & design' and 'architecture'. By fostering awareness of the past and enhancing the surrounding landscape, traditional structures significantly improve people's quality of life [10]. The utilization of passive and natural methods in Havelis was successful in creating a thermally comfortable environment that was comparatively cold in the summer and warm in the winter. The desired thermal comfort conditions were achieved without the use of any mechanical devices [11].

The aim of this research is to examine the Havelis' built shape and characteristics in relation to its climate-responsive features. All possible range of parameters are included into the analysis of Rajasthani Havelis' vernacular architecture which ensured passive and practical design while also making it aesthetically beautiful and climatic responsive. The study focuses upon the architectural elements which could potentially be able to withstand the region's harsh climate without compromising with the thermal comfort of the occupants. A comprehensive review of the literature has been applied to identify the research parameters (fig 1).

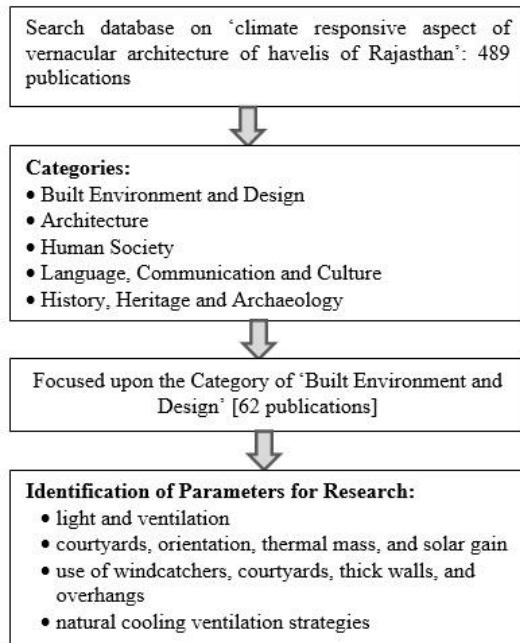


Fig. 1. Sequence of Comprehensive Literature Review from ANZSRC 2020

IV. CLIMATE RESPONSIVE TECHNIQUES IN VERNACULAR ARCHITECTURE

It is essential to comprehend the significance of climate responsive architecture, which examines how structures may adjust to changing weather patterns across the year. The focus of this study is the passive design strategies of vernacular architecture, which include understanding different passive techniques that have been used to create thermal comfort with the help of natural ventilation and thermal mass utilization. The potential of vernacular architecture to lower carbon footprints and achieve sustainability is explored in relation to its function in climatology. By combining innovation and tradition, this thorough approach provides a full grasp of climate-responsive strategies in vernacular architecture.

The study commences with an overview of the climate, with special attention to the hot, dry climate of Jaisalmer, India.

4.1 Climate of Jaisalmer

Hot & dry climate prevails around 15°-30° from equator in the northern and southern hemisphere. In this climate, daytime air temperatures range from 27°C to 49°C, while lows at night normally reach 22°C. During the day, solar radiation is direct and of high intensity, while at night, it escapes into the clear, nighttime sky. Due to solar radiation with a high intensity, humidity is extremely low. The annual precipitation ranges from 50 to 150 mm [12]. Localized winds frequently bring in dust storms. This location typically features flat, sandy, and rocky terrain, which leads to limited vegetation with few plants other than brushes.

At 26°55'N latitude and 75°55'E longitude, the town of Jaisalmer is situated 241.7m above mean sea level. Here, rainfall is scarce and unpredictable (the average yearly amount is less than 200mm). There are primarily two seasons: summer and winter. Summertime temperatures range from 25°C at night to 45°C during the day. In the winter, the temperature ranges from 25°C to 5°C. The daily temperature range is between 15°C and 20°C [13] (fig:2).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Month av. max T _a	21.9	26.5	32	36.5	40.2	40.3	35.9	34.4	34.7	34.3	28.8	23.6
Month av. min T _a	10.4	14.1	21	25.8	29.3	30.4	28.5	27.2	26.9	25.1	19.4	12.3
Rainfall	2.1	1.2	2.6	1.5	5.2	6.8	89.5	85.8	13.9	1.3	4.9	2.2

Fig. 2. Monthly Temperature and Rainfall Details of Jaisalmer [14]

4.2 About Patwa ki Haveli

Patwon ki haveli is one of the main and most important mansions in Jaisalmer. The affluent Guman Chand Patwa built the cluster of five havelis in 1805 for his five sons. This haveli is one of the five havelis of the cluster

and is situated in approximately the center of the city. The haveli is approached through a narrow path. This is five storied and its main gate is located on a high plinth of roughly 7'0" to 8'0" high and is accessible via steps. The semi basement of haveli maintains the coolness based upon the concept that the earth being a good thermal insulator does not transfer the heat to the indoors. The ground-level chambers were primarily used for storage as they easily allow the loading & unloading of materials. In order to maintain privacy, the upper floors were designated for family members' residential use. The entrance lobby at the ground level used to be lavishly decorated which also denotes as a status symbol of the family. The central courtyard of the haveli gives access to the rooms.

4.3 Orientation of Haveli

One of the first steps to achieve climate-responsive design is orienting a building block with respect to the sun and wind. In this regard, it is important to comprehend the solar chart² and the wind direction for a specific location. Solar charts define the azimuth angle and altitude angle of the sun w.r.t day & time in specific latitude. Azimuth angle depicts the sun's horizontal position through the focusing point, while altitude angle depicts the sun's elevation angle [12]. Insolation (incident solar radiation) reduction is essential for climate-responsive buildings in hot-dry climate since incident solar radiation is a major contributor to consumption of building energy in order to achieve the thermal comfort. One of the key elements that raises the needs for space cooling is the amount of incident solar radiation (insolation) that strikes building surfaces [15]. The architectural layout of Jaisalmer's traditional structures, especially those with south-facing facades, is greatly influenced by the sun's position throughout the summer. The sun is at its most intense between 9:30 AM and 2:30 PM, shining straight on the south façade with higher altitude angle (fig 3 & 4). Even little horizontal overhangs, chhajjas (sloping eaves), or balconies, are capable of offering shade during this period because the solar altitude angle varies from roughly 54° to 86° (Fig.4).

The longest axis of haveli runs through northeast/ southwest which cuts the courtyard approximately into two parts (fig. 3). When the sun is positioned in the section plane, it is possible to calculate the sun's movements, which are the main indicator to understand the details of shading devices and positioning of openings. The longer side of the haveli is designed to be least exposed to the sun and winds from the east & west (fig 3). As the haveli abuts the narrow street, it acts as a shield from the sun's intense rays through the concept of mutual shading.

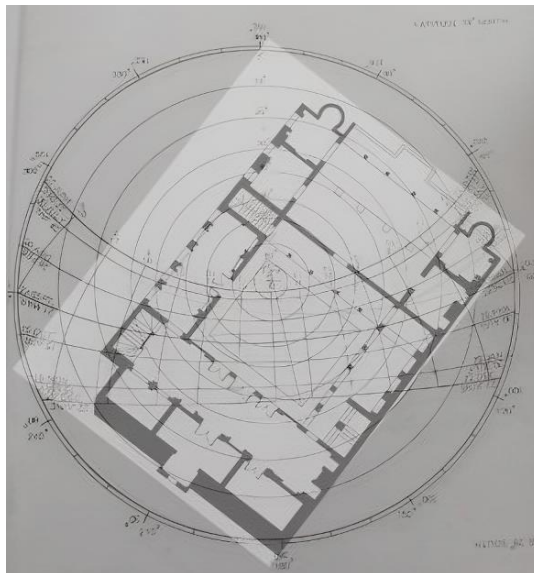


Fig. 3. Sketch showing the orientation of Haveli with respect to solar chart of given place.

² A graph depicting the sun's ecliptic passage through the sky over the course of a year at a certain latitude is known as a sun chart.

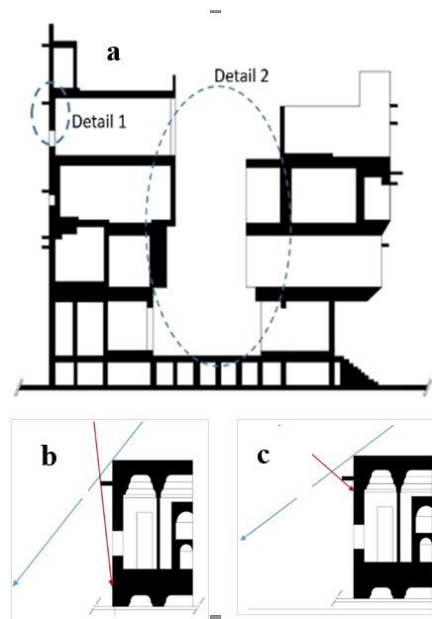


Fig. 4. a-showing the key section of Haveli. b. Detail 1 showing solar radiation on May at 10 hrs. (vertical angle: 35°/ horizontal angle: 143°) c. Detail 1: Solar radiation on Jan at 10 hrs. (vertical angle: 61°/ horizontal angle: 93°)

The correlation between windows' strategic orientation and solar altitude angles is evident from figure 4. The sun is higher in the sky during the summer because the solar altitude angle is much higher. With the meticulous positioning of windows on a building's north and south faces, this aspect enables efficient control of solar radiation. These orientations aid in reducing the amount of direct sunlight that enters a space when combined with minor projections like overhangs or blinds. By lowering glare and keeping interior spaces colder, this method not only reduces heat gain but also improves indoor thermal comfort. These projections allow diffused natural light to illuminate the interiors while reducing direct sunlight penetration by absorbing the strong solar radiation. This well-considered design, which is based on the ideas of climate-responsive architecture, shows how energy efficiency can be enhanced and the need for artificial cooling can be decreased by integrating appropriate orientation of the building block. A distinctive feature of Jaisalmer's vernacular architecture is the application of such passive design techniques, which demonstrate a thorough comprehension of solar patterns and how they affect building performance.

Due to high solar radiation, shading was crucial for exterior walls as well as windows. Thus, appropriate shading has been provided with the help of overhangs. In addition to overhangs, mutual shading by the articulation in the elevation (fig:5). The daytime effects of solar radiation on indoor spaces are significant and one can see different patterns of light & shade varying during the length of time.

The orientation of the building is also ideal for the predominant wind patterns. The winds are primarily from the southwest for the majority of the year, but they move to the northeast and north in the winter. While summer winds, especially those from May to July, are strong, winter winds are typically low and erratic. These winds are often unwanted in Jaisalmer's harsh climate, which is hot & dusty in the summer and extremely cold in the winter. However, the inside of the haveli is naturally protected from these severe winds by its longer sides, which are orientated northwest and southeast. This design ensures increased comfort all year round by successfully blocking the chilly winter winds and the dusty summer winds.

4.4 Time lag and Selection of Material

The temporal delay brought on by thermal mass is referred to as a time lag. The period of time it takes for solar radiation to pass through a thicker, more resistant material increases the time lag. Jaisalmer has a hot & dry climate and diurnal range is about 11°C. In this situation, long time-lag is desired to prevent the daytime temperature from rising above a certain point. Keeping the same in mind, the exterior facade has fewer openings and thicker walls with more insulating properties have been provided. According to the desired time lag requirement, the rooms are arranged in distinct patterns i.e. the rooms to be used during daytime are kept in a western direction and rooms to be used during daytime are kept in an eastern & southern direction. The living areas are typically positioned in the western half of a house since the western facades are warmer in the evenings while the east facade is warmer in the morning. Sandstone and terracotta bricks, which are often used as building materials in Jaisalmer havelis, are well-known for having a high thermal capacity, or the ability to store heat without releasing it to the environment. This

Jaisalmer haveli was constructed from locally sourced yellow sandstone since it has the ability to reflect the majority of solar radiation thus leaving only less heat to penetrate indoors during the day. As per the climatic data, Jaisalmer has a high diurnal range thus the building block gently radiates heat at night when temperatures drop. The walls measure up to 70 cm thick which increases their thermal capacity as a thermal reservoir thus increasing the overall time lag. This phenomenon helps to divert the excessive heat gained during the day to the night when there is sudden dip in the temperature. Due to higher thermal capacity of the materials, in winter, it prevents heat from escaping from indoor spaces whereas in summer, it lessens the inward flow of heat from solar radiation.

A lime-based coating known as *ghotmakali* has been used to insulate the interior of the haveli's walls. Additionally, the lime-based plaster guarantees effective heat conduction in the winter and reduces overheating in the summer. Furthermore, it enhances humidity evaporation by preventing capillary rise. Lime's microporosity, which permits a significant amount of water vapor to travel through the wall without deteriorating it, is one of its very special properties.

The haveli's roof is flat and has a thickness of about 30 cm. As nearly 60 percent of heat intake during summer is from the roof, thus detailing of roof and thickness helps in achieving the desired time lag.

4.5 Ventilation

In the hot-dry climate of Jaisalmer, ventilation of indoors becomes very crucial. Making openings everywhere in these spaces is not a solution for ventilation as windows shall be the route of outside hot air. There is a requirement for the strategic placing of openings, appropriate size of the opening and adequate shading of opening. These openings are protected from the weather conditions with the help of *Jharokhas*³, Approximately sixty *Jharokhas* look out onto the street and inner courtyard in this haveli. In comparison to the lower floors, the upper floors have a greater concentration of *Jharokha*. From top to bottom, *Jharokhas* are arranged in descending order, which is based upon the concept that cool air being heavier in weight tries to settle down [16]. Rooms are well lit and ventilated through star-shaped openings. Small apertures are provided which allows cool air with high pressure to enter indoors. The point to ponder here is that the openings are very small in size and further these are being screened with the help of *Jharokhas* and also open into the shaded areas i.e. narrow street & courtyard.

Jharokhas are also screened with the help of '*jalis*'⁴. The jail's main function is to conceal the family's women from exterior as it has ability to see outside while remaining unseen (fig.5). The tight mesh of the *jalis* has the effect of accelerating the passage of the wind, providing additional natural ventilation. Due to small openings which are recessed with arches and *jalis*, the interiors are not directly exposed to the solar radiation. The building's interiors are efficiently protected from the sun, guaranteeing thermal comfort to the inhabitants. But the effect results in poorly illuminated indoors. This is addressed by carefully placing mosaic patterns and tiny mirrors onto the walls and ceilings. These components increase brightness and provide the interiors a charming decorative touch by reflecting and distributing light. Numerous tiny mirror and mosaic pieces reflect light in even the darkest nooks and crannies of rooms. Mirrors multiply light, illuminating interiors with the proper level of illumination.

One of another unique architectural elements that greatly improves the building's natural ventilation and cooling systems is the wind tower (fig. 6). It creates a cosy and well-ventilated atmosphere by directing fresh breezes into the interior spaces during the day. Due to the clear sky, solar radiation easily escapes from the clear sky, thus dipping in the night temperature. Convective cooling is made possible at night by the wind tower, which draws in cooler air from the outside while allowing the heated air within to rise and escape. By regulating internal temperatures, this constant airflow relieves heat and preserves a comfortable ambiance. An inventive method of passive climate management in traditional architecture is demonstrated by the wind tower's dual purpose of providing cooling at night and ventilation during the day.

³ An architectural element that hangs over and offers a view of an open area is called a *jharokha*.

⁴ Jali is latticed screen, usually with an ornamental pattern



Fig. 5. View of Patwon ki Haveli; Ref: <https://rajputanacabs.in/jaisalmer/patwon-ki-haveli/>.

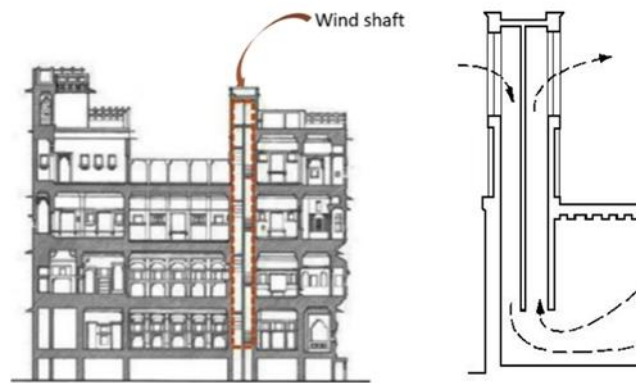


Fig. 6. Section through Wind shaft

4.6 Building Form

The amount of heat gain or loss from the surrounding environment is largely determined by the building envelope's construction and design [17]. Thermal performance is directly impacted by the envelope, which serves as a barrier between the interior and exterior environments and comprises building forms, roof forms, etc. The amount of heat that is absorbed, maintained, or discharged is greatly influenced by its shape, material composition, insulation, and direction. By minimising undesired heat transfer, a well-designed building envelope preserves indoor comfort while using less energy for heating or cooling. The envelope may efficiently control temperature by incorporating elements like thermal mass, reflecting surfaces, and shading devices, guaranteeing a harmonious relationship with the outside world.

The local climate, religious sentiments, and beliefs all had a significant impact on the building form of a place. The internal courtyard is a very significant aspect of the haveli, and it serves as the focal point for all the activities that take place (fig. 3 & 7). Additionally, it is utilized for social gatherings and events.

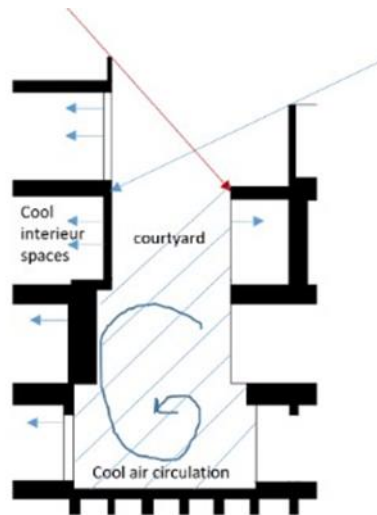


Fig. 7. Section through courtyard (detail 2 from figure 4) showing that the lower portion of courtyard is always in shade.

As already discussed, thermal transfers take place on the building's façade which is directly exposed to the solar radiation. Thus, increasing surface area also increases thermal transfer. The aspect ratio of the structure determines the amount of surface area from which heat will be transmitted between the environment and the building block. By lowering the surface area, energy transfer is decreased. It is possible to compare the surface area of various building designs by using the aspect ratio, which is a measurement of a structure's footprint in terms of length and width (x:y). The aspect ratio of the given haveli in the east-west or north-south axis has been carefully decided. The shorter sides of this traditional haveli's rectangle are situated to the NE and SW thus lowering the surface area which is exposed to the direct solar radiation. The courtyard was added for the purpose of making the interior space cooler and enhancing the quality of living (fig: 7). This courtyard is a highly effective way to block the sun, and the size of the courtyard adds to its effectiveness. The courtyard's width-to-height ratio of haveli is carefully planned to minimise direct solar exposure to its lower levels, maximising its thermal performance. This deliberate adjustment guarantees that, throughout the day, the lower parts of the courtyard walls are shaded while the top parts are largely illuminated by the sun's beams. The courtyard's microclimate is made more comfortable and colder by this design, which also minimises heat accumulation. The lower level that is shaded provides a thermally comfortable place, particularly in the hot hours of the day. Furthermore, by reducing glare and preventing nearby interior rooms from warming, this calculated ratio improves the courtyard's overall thermal efficiency and year-round usability.

V. ENERGY EFFICIENT TECHNIQUES FOR BUILDING CONSTRUCTION: LESSONS FROM THE PAST

The thermal exchange between the body and the environment takes place in four different ways: conduction, convection, radiation, and evaporation (perspiration and respiration) (fig. 8)

The thermal balance equation further explains the heat exchanges happening between building and atmosphere.

$$+Q_i + Q_s \pm Q_c \pm Q_v \pm Q_m - Q_e = 0 \dots \text{Thermal balance equation}$$

Q_c : heat exchange due to conduction

Q_v : heat exchange due to convection

Q_s : heat gain from solar radiation

Q_e : heat loss from evaporation

Q_m : energy load on mechanical devices

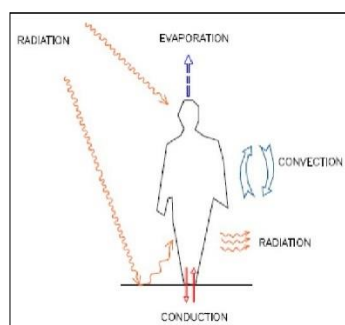


Fig. 8. Heat exchange between human being and atmosphere Ref. [12].

The sole purpose of designing climatic responsive architecture is to ultimately reduce energy consumption. Key heat transfer components, including Q_c (conduction heat transfer), Q_v (ventilation heat transfer), and Q_s (solar heat gain), can be controlled to maximise a building's thermal performance and response to climate changes. By choosing suitable materials with advantageous thermal properties, it is possible to efficiently regulate the value of Q_c , or the heat transmission via building materials. By reducing undesired heat transfer, materials with high thermal resistance (low conductivity) contribute to indoor comfort. For example, thick walls composed of sandstone or adobe are chosen in hot areas because of their thermal mass, which moderates temperature variations and inhibits heat conduction. In order to maintain adequate air circulation, the location, dimensions, and orientation of air inlets and outlets can be carefully planned. This will help control the Q_v value, which indicates heat transfer through ventilation. To improve air quality and lower indoor temperatures, strategically placed windows, courtyards, and jalis (latticed screens) increase cross-ventilation by using natural wind movement. In this case, the location, dimensions, and composition of the windows affect the Q_s value, which takes into consideration solar heat gain through windows. A small or shaded window lowers heat gain, while proper orientation minimises direct exposure to strong sunlight. The entry of solar radiation can also be further controlled by choosing the appropriate glazing materials, such as tinted or double-glazed glass, which allow light indoors while keeping out too much heat. When combined, these elements allow architects to create structures that maximise thermal comfort while lowering energy use by adapting well to their climatic setting.

Cities are believed to use 75% of the world's energy and produce 70% of the carbon footprints, and a large portion of this is a result of building construction [18]. Therefore, it is vital to develop sustainable building solutions that are applicable to conserve energy without compromising with thermal comfort. The needs and demands of society and the human person are also drastically changing and are completely distinct nowadays than they were in the past, when cities like Jaisalmer were founded. As a result, architects and planners play a crucial role in helping to plan cities and design buildings that use nature and natural features as their primary inspiration in order to make cities more sustainable, habitable, and energy efficient. An energy-efficient structure may be more comfortable to live in and less expensive to maintain with favorable thermal comfort conditions. The fundamental philosophy of the approach is to achieve climate responsive architecture. Desired building orientation is the first step towards adopting passive techniques. A significant part of passive systems also depends upon appropriate ventilation systems. In order to prevent direct sunlight and maintain appropriate ventilation, it is required to understand the climatic data and follow the appropriate design parameters as listed below:

- Orientation of Building w.r.t sun & wind
- Properly ventilating the buildings
- Appropriate roof and wall treatments keep in mind the desired time lag.
- Adopting solar passive cooling/heating techniques.

VI. CONCLUSION

The research emphasizes upon the complex interrelationship between climate and design of vernacular buildings by analysing the haveli of Jaisalmer as a case study. These buildings are good examples of how contemporary issues like sustainability and energy efficiency may be addressed by using age-old methods that are based on local knowledge. The study highlights upon how vernacular practices can serve as inspiration for modern design through these examples, especially in areas with comparable climate. The purpose of study of Jaisalmer's havelis is to understand the difficulties imposed on by the desert climate and how the ancient people handled the same with the traditional practices. To maintain the indoor thermal comfort, they have applied thick sandstone walls that served as thermal mass with a property of decreasing heat gain during the day and releasing the stored heat at night. Intricately carved jalis, or latticed stone screens, are used on windows to provide airflow and filter strong sunlight, guaranteeing thermal comfort and seclusion. A crucial component of these havelis are courtyards, which encourage natural ventilation and produce a desired microclimate inside the building that is frequently colder than the outside air.

Researchers working in the fields of energy efficiency and sustainable design are taking inspiration from vernacular structures in various parts of the world to extract the tried-and-true sustainable design methods ingrained in ancient architecture. The inhabitants enjoy very energy-efficient, thermally comfortable indoors because of the adopted passive control system from traditional climate responsive practices. Intelligent application of acceptable techniques with appropriate materials is crucial for a sustainable, energy-efficient, and comfortable human lifestyle. So, it's time to recover the traditional wisdom that was probably forgotten in the rush to mindlessly adopt the latest fashions. The shape of the building, the materials used in its construction, and its position in relation to the sun and

wind all affect how energy-efficient it is. We must first fully understand all of these factors and adopt a thorough strategy in order to make building more energy efficient. Understanding the position of the sun and the direction of the wind makes it crucial to examine the location of structures at a given latitude. There is a dire need to thoroughly study vernacular building for more optimal solutions. The designers can certainly extract environmentally friendly and economically sustainable solutions from vernacular architecture.

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