CLIMATE-CONSCIOUS DESIGN: RETHINKING BUILDING DESIGN FOR THE FUTURE IN HOT AND DRY REGION OF RAJASTHAN

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**Abstract** -Vernacular methods, often rooted in local knowledge and materials, have historically provided effective solutions to the challenges posed by extreme heat and dry conditions. These techniques, such as passive cooling strategies, thick walls and courtyard design, have been adapted over centuries to optimize thermal comfort and energy efficiency. In recent decades, modern technology have emerged as alternative or compliments to traditional approaches. These includes advanced materials, and modern architectural designs.

This study explores the evolution of housing design and modern construction practices in Hot and Dry climates. This study also considers few case studies of buildings located in the area of Hot and Dry region of Rajasthan. The study focuses on the thermal comfort index of the buildings with modern construction practices and provides the insights on the future construction technology in hot and dry region of Rajasthan.

**Keywords:** Hot and Dry Region, sustainability, Vernacular construction, modern technologies.

1. Introduction

Building typology is a classification system used to categorize buildings based on their function, form, and construction. It is a way of grouping similar types of buildings together and analyzing their characteristics and features. Building typologies are used in a variety of contexts, including architectural design, urban planning, and building science. In architectural design, building typologies help architects to understand the characteristics and needs of different types of buildings and make informed design decisions. India has a rich tradition of vernacular architecture, with a distinct range of building typologies and techniques. For this purpose, the prior step is to understand the vernacular architecture, envelope of building plans, traditional and new construction techniques, type of materials used in building construction, etc. in order to illustrate the sustainability of the building to make the building climate resilient for its life-time.

During its life span, a sustainable building aims to reduce the building impacts on human health as well as natural environment. It can be done only through good design, construction, operation and maintenance practices.

By incorporating sustainable practices, we can reduce the negative impacts of construction on our planet while creating healthier and more comfortable living spaces.

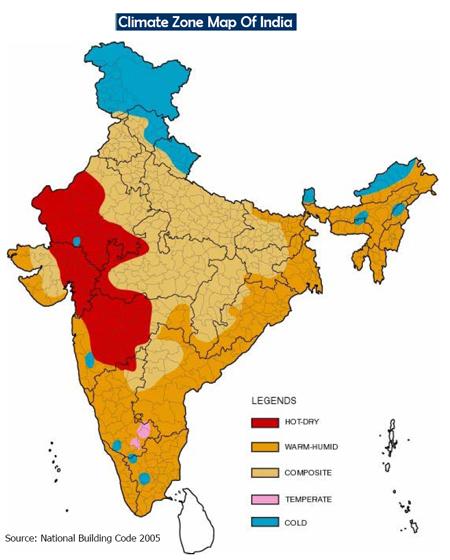
The present climate changes are directly linked to the human activities and also the concerns regarding exploitation of the fossil fuel have reached a level where the negative effect are having impact on the life of a common man. This resource intensive development model posed problems like rising of costs, loss of productivity and disruption of economic activity for a developing country. With the advancement of technology, the consumption of energy has increased and thus even technology is seen as a factor of environmental degradation. As we are aware that there is a limit to the natural resources available on earth we need to conserve these by judicially utilizing these. In the case of India reducing the consumption of energy may be linked to slowing down the development rate which surely may not be appreciated by many. It is need of the hour therefore to look into the aspects and methods which shall help to reduce the consumption of energy without hampering the development rate.

This study explores the evolution of housing design and modern construction practices in Hot and Dry climates. This study also considers few case studies of buildings located in the area of Hot and Dry region of Rajasthan.

2. Study area and Built Environment

2.1 Study Area

The climate of the India divided into five zones namely: Hot and Dry climate, Warm and humid climate, Composite climate, Temperate/Moderate climate and Cold climate (Fig. 1). Hot and dry climate zone lies in the western part of India predominantly in the state of Rajasthan [1]. This zone experiences a scorching weather in summer and cold in winter. There is high-temperature difference between Day and Night. High Solar Radiation in this regions causes glare effect [3]. Hot and dry climate zone experiences minimal rainfall during the monsoon season, low Relative Humidity and dry sandy or rocky ground with less vegetation. Thus, requires special provisions in the functional design of buildings with respect to human thermal comfort and energy efficiency. This paper focuses on traditional and modern construction practices adopted the hot and Dry area of Jaisalmer and Khuri area. The paper presents the findings from the field study on building typologies in the regions of Khuri and Jaisalmer. The study presents the data of 43 traditional buildings and 20 conventional buildings.



**Fig. 1.** Climatic zones of India

2.2 Built Environment

2.2.1 Case Study 1: Jaisalmer

(a)Traditional Houses (b) Present Construction

**Fig. 2.** Typical Jaisalmer Houses

Jaisalmer often called as the Golden city, famous for its unique sandstone architecture. The house of Jaisalmer hold significant value in the contest of dessert architecture, reflecting countries of adaptation to the harsh Thar dessert environment. The traditional houses of Jaisalmer are characterized by the use of local materials for the adaptation to the climate. The buildings are made of sandstone, which is abundant in the region. The sandstone is durable, and its color blends with the natural surroundings [4]. The houses are provided with the courtyard at the centre of the building having walls around it and open sky from the top. The walls of the traditional houses are found to be non-plastered. The thickness of the sandstone wall is twice or thrice as that of brick walls. The roofs of these houses are typically flat, designed to maximize space usage. The roofs were often used for various domestic activities, such as drying grains or enjoying the cool evening breeze. No projections are provided in the traditional houses as there is very less or no rainfall occurs in Rajasthan. The size of the openings (doors and windows) are very less and only few number of openings are provided in the traditional houses. Lime mortar is used for masonry in the traditional houses. Underground tanks are provided in the building for water storage purpose.

Whereas, the present construction consists of well surface finished sandstone, being used for walling in the present construction. Nowadays, one masonry unit of sandstone is very much larger in length as compared to its lateral dimensions. Cement mortar is used instead of lime mortar. No need of plaster required in the walls as the standstone itself gives a well finished surface. Courtyards are not necessarily provided at the centre of the building. Courtyards are provided at the entrance where Jharokha and Jalis are provided for ventilation and light [4]. Projections are provided in the buildings these days. The buildings are also designed with the use of terraces and balconies that provide views of the surrounding area. Most of our buildings had grills and fenestration/façade work done to control and manipulate light by means of strategies like Jalis or double windows with wooden Louvers etc. Stone carving in the buildings seems to be common in traditional houses and present construction. Underground tanks are provided in order to store the water as there is a scarcity of water in the area. The roofs of the houses are made up of famous Jaisalmer stone with a concrete slab poured over it and wooden logs under the stone [4].

2.2.2 Case Study 2: Khuri Village

(a) Traditional Bhonga houses(b) Present construction **Fig. 3.** Typical Houses in Khuri Village

Khuri Village is in the Thar Desert, approximately 40 KM southwest of Jaisalmer, Rajasthan. The Bhonga house in Khuri are designed to withstand the harsh desert conditions and provide a comfortable living environment. The Bhonga has a conical roof supported by cylindrical walls. The roof is thatched and made up of dry grass and wood. The walls are made up of thick rammed earth material [1]. The thickness of the walls is generally taken as 0.50 m. The wall is plastered with mud or lime. The floor is also made up of mud [4]. Bhonga construction has existed for several hundred years. This type of house is quite durable and appropriate for prevalent desert conditions. Due to its robustness against natural hazards as well as its pleasant aesthetics, this housing is also known as “Architecture without Architects.” It performed very well in Bhuj earthquake with a magnitude of 7.6 in 2001. Very few Bhongas experienced significant damage in the epicentral region, and the damage that did occur can be mainly attributed to poor quality of the construction materials or improper maintenance of the structure.

Whereas, the present construction consists in Khuri consists of the houses that are made sandstone as the sandstone is readily available in the region. Courtyard is provided in the centre as shown in Fig. 4. This space is used for various activities, including cooking, dining, and socializing. It also provides natural light and ventilation. The walls are plastered with lime or mud. There are no projections provided in the building. Floor is made up of cement concrete or mud. Slabs are made up of stones with the concrete poured over it. Bhonga houses are still constructed in Khuri, but very less in number. These days, the walls of the Bhonga houses are made up of sandstone instead of rammed earth.



**Fig. 4.** Courtyards of Khuri Houses

2.3 Key Takeaways from Rajasthan’s Vernacular Architecture

Vernacular construction techniques in Jaisalmer and Khuri highlight the use of locally sourced yellow sandstone, which not only harmonizes with the desert landscape but also provides effective insulation against extreme temperatures. The architecture incorporates features for rainwater harvesting and thick walls with small windows to regulate indoor climates, show casing sustainability and adaptability to arid conditions. The courtyard act as a natural cooler. The common space allows air circulation, which helps in reducing indoor temperatures during the hot days. Intricate carvings and Jharokhas reflect local customs and artistic expression, while the knowledge of these techniques is passed down through generations, emphasizing community craftsmanship and cultural heritage. Overall, traditional building methods offer valuable insights into sustainable architecture that prioritizes environmental harmony and social significance.

2.4 Present construction: A Critical Look at Its Drawbacks

The study of the housing techniques in Rajasthan shows that it is necessary to make the buildings more sustainable and thermally comfortable. The orientation of some buildings in Jaisalmer and Khuri are not according to the design criteria of the building alignment which led to increase in heat inside the buildings. It has been noticed that nowadays, the people of Rajasthan are changing their interest from courtyard houses to non-courtyard houses, moving with the current lifestyle and design techniques. Only few traditional houses are left over with the courtyards in Jaisalmer and Khuri. The main reason behind not providing courtyard is the scarcity of land.

Most of the present construction in Jaisalmer and Khuri are willing shift towards the use of reinforced concrete, standardized designs, and materials like glass and steel, which aim for durability and aesthetic appeal but come with significant drawbacks. These contemporary methods often neglect the region's harsh climate, resulting in increased energy consumption for cooling due to poor insulation compared to traditional thick sandstone walls. Additionally, the loss of unique cultural heritage and craftsmanship is a concern, as modern buildings may lack traditional features essential for effective water management, further exacerbating vulnerabilities in water-scarce conditions. This shift also disrupts the aesthetic harmony of the city, as uniform and industrial designs clash with the historical and cultural landscape, highlighting the need for a balanced approach that integrates modern needs with traditional architectural wisdom.

(a) Out of plumb wall (b) Non-plastered Wall

**Fig. 5.** Construction Practices

The ventilation and openings in the houses of Rajasthan are found to be inadequate for cross-circular of the air inside the house. Several reasons why people might not provide proper ventilation and openings in their buildings are Lack of Awareness, Ignorance, Outdated Information, Cost Concerns, Initial Investment, Maintenance Expenses, Aesthetic Preferences, Design Constraints, Visual Appeal, Energy Efficiency Concerns, Heat Loss, Air Conditioning Costs, Privacy Concerns, Security Risks, Noise Pollution, Building Codes and Regulations, Insufficient Standards.

* 1. Field survey results on Thermal Comfort index

Data on thermal comfort was gathered during the field study by taking into account the opinions of the building's residents. The data collected from the survey is graphically represented as occupants’ comfort level in all the months within a year as shown in Fig. 6. The analysis based on field survey depicts the comfort level of occupants of the houses in Rajasthan which categorized the climatic condition as hot, cold and tolerable climate. The data is based on how the occupant is feeling inside the building in different months which shows the thermal comfort index for Rajasthan.

Fig. 6(a) shows the thermal comfort index for the traditional houses of Rajasthan. From the graph, it is clear that the thermal comfort in the majority of traditional houses remains tolerable throughout the year and the temperature inside the house remains very much cooler than outside temperature whereas in winters, the indoor temperature of the houses is much comfortable as compared to outside temperature.

Fig. 6(b) shows the thermal comfort index for the conventional houses of Rajasthan where it has been found that residents of the houses feels extreme heat in summers and extreme cold in winters. The comfort level of the residents are not much tolerable as compared to traditional houses. Therefore, it is clear that in the present construction, people of Rajasthan feels more heat and less comfort in their houses for the maximum number of months. Under these circumstances, it is very necessary to increase the thermal comfort of the occupants which can be attained by following the design guidelines and modern building techniques for Hot and dry climatic conditions.

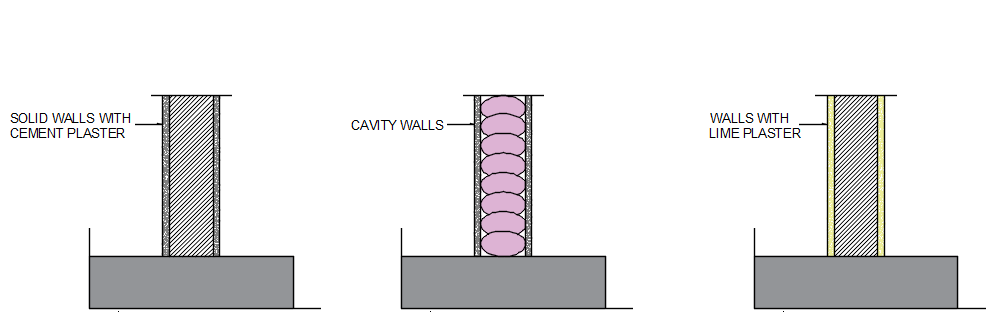
1. Traditional Houses

(b) Conventional Houses

**Fig. 6.** Thermal Comfort Index

**3. RETHINKING BUILDING DESIGN FOR THE FUTURE**

Climatic resilient buildings in Rajasthan are specifically designed to address the region's extreme temperatures and environmental challenges while promoting sustainability and comfort. Given the hot, arid climate, these structures often utilize materials with high thermal mass, such as compressed stabilized earth blocks (CSEB), AAC (Autoclave Aerated Concrete) Blocks, adobe, and locally sourced stone [2]. These materials help regulate indoor temperatures by absorbing heat during the day and releasing it at night, ensuring a more stable and comfortable indoor environment. Additionally, effective insulation in walls (solid walls, cavity walls and lime plastered walls) as shown in Fig. 7 minimizes heat transfer, further enhancing thermal comfort despite external fluctuations [5].



(a) Solid Wall (b) Cavity Wall (c) Lime Plastered Wall

**Fig. 7.** Typical section of walls

Incorporating passive solar design principles is crucial for climatic resilience. Buildings are strategically oriented and feature well-placed windows to maximize natural light and ventilation while minimizing unwanted heat gain. Architectural elements like deep overhangs and shading devices protect against direct sunlight, promoting a cooler indoor climate. Natural ventilation is also emphasized through techniques that allow for cross-ventilation, utilizing high ceilings and strategically located openings to facilitate airflow. Courtyards and balconies provide outdoor living spaces that enhance comfort during the sweltering summer months. Water management is another critical aspect of climatic resilience in Rajasthan. Many buildings integrate rainwater harvesting systems and greywater recycling to promote sustainable water use, addressing the region's water scarcity issues.

1. Conclusions

This study reveals the advantages as well as drawbacks of the vernacular and present construction in Rajasthan. Therefore, some techniques are introduced in order to make the building sustainable for living. Orientation and shape of building resist heat gain and decreases exposed surface area. Buildings should be oriented to maximize natural sunlight during winter and minimize solar heat gain during summer. The building should be placed on the building longer face should be on North South direction and building shorter face should be on East West direction, reducing the heat gain inside the building.

Recycled bricks, stone dust waste, timber, and metal are being incorporated into building designs to promote sustainability. Insulating materials, such as thermal insulation panels and reflective coatings should be applied which helps in maintaining comfortable indoor temperatures while reducing energy consumption. Insulation of building envelope increases the thermal resistance. Massive structure increases thermal capacity. Material like AAC blocks, adobe bricks, and CSEB blocks should be used in building as these materials are the best insulators and gives more utility.

Although shading of the whole building is beneficial, shading of the window is crucial as insulation of the building components and air exchange rate was evaluated. Passive ventilation systems, such as wind catchers and courtyard designs, promote natural airflow and reduce the need for mechanical cooling. Common ratio for courtyards should be between 1:2 and 1:3, means the width of the courtyard is about 1/2 to 1/3 of its length. This ratio often provides a good balance of space and functionality. Provision of windows and exhausts helps in ventilation of appliances, therefore, promote heat loss**.**

The use of eco-friendly and locally sourced materials, such as bamboo and rammed earth, not only reduces the carbon footprint of construction but also ensures that the structures are well-suited to withstand local climatic conditions. Additionally, features like green roofs and native landscaping contribute to improved insulation and biodiversity, creating microclimates that further enhance the ecological balance of the area. By embracing these strategies, Rajasthan can develop buildings that are not only resilient to its harsh climate but also enhance the quality of life for its residents while respecting the region's cultural heritage.

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