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Solar Passive Techniques in the Vernacular Buildings of India – A Review

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Abstract

Due to Urbanization and elevating Environmental Issues and Challenges in the Building Sector, the professionals are implementing regional Architecture knowledge and Wisdom which are energy efficient and Sustainable. Vernacular buildings and climate responsiveness has become the focused topic today, but detailed review of previous studies is lacking currently in India therefore, this paper presents a comprehensive review of 24 qualitative and quantitative research articles written across the various climatic zones in India. The intent of the paper is to recognize solar passive features in vernacular buildings across the various climatic zones in India for adopting in contemporary buildings. The major climatic design strategies will be Form of the Building, Built Envelope, Orientation, Openings and Ventilation techniques, Materials and Construction techniques. The author used Systematic review and Bibliometric methods to write this paper and concluded the Solar passive features of Vernacular Buildings in each climatic zones in India. This review aims to establish an actual summary of this domain for more advancement of environmentally conscious architecture in Indian Context.

Keywords: *Sustainable Architecture, Vernacular Architecture, Solar Passive Architecture, Warm Humid climate, Hot dry Climate*

1. Introduction

Due to Urbanisation and Industrialisation Cities are becoming hot and leads to various issues like global warming, pollution and Energy consumption in buildings played a pivotal role in designing Sustainable buildings. Building Industry consumes more Energy due to development of Modern Living Standards adopted by the People in Worlds population and the scientist across the globe urged the planners, Architects and builders to incorporate the renewable and sustainable energy techniques and designing climate sensitive buildings by adopting solar passive principles are better options for reducing Energy in buildings. Energy savings could be achieved (40 -50%) if the buildings were thoughtfully designed by adopting the design strategies of Solar passive techniques. Vernacular buildings were evolved over a period of time across varied climatic zones across the globe. These typologies were designed and built with regionally available materials and methods and also based on their Culture and belief, Climate and Environment It is evident that variety of Vernacular buildings can be traced which is unique with respect to their climatic zones. The solar passive elements found in the buildings provides thermal comfort to the dwellings. Many researchers across the world have proved Vernacular dwellings provides solution for Energy and Environmental issues thereby making the cities sustainable. Many researchers have emphasized the importance of implementing the traditional knowledge system like design strategies, materials and construction techniques and the solar passive features in Modern buildings to achieve Energy Efficiency and comfort.

The traditional wisdom witnessed in the Vernacular dwellings has been paid attention by many researchers across the globe. However, a systematic review of solar passive techniques in vernacular buildings of India is still missing in this field, so the authors collected and structured the research articles focussing on climate sensitive traditional buildings across varied climatic zones to arrive at guidelines and strategies for building professionals. This review also identified various methods and arrive at research gap and conclusions for future research. The solar passive techniques

identified in vernacular buildings has been studied by many authors, across the globe to adopt the regional design ideas, material knowledge and spatial knowledge to design modern buildings to enhance the Energy Efficiency and sustainability. This paper recognises various Architectural style and Climatic design strategies employed in vernacular dwellings across varied climatic zones in India incorporating climatic design features, materials and construction techniques in Modern Buildings. The objective of the paper recognises the solar passive features in vernacular dwellings in terms of thermal comfort, energy efficiency for adopting in Modern Buildings. In this background a detailed Literature review of related research papers was identified from 1996 -2023 with focus on solar passive design strategies.

Research Methodology

The major literature database for this paper are Scopus and Web of Science. The keywords used for search from appropriate publications were "vernacular architecture" OR "traditional architecture" OR "regional architecture") AND ("thermal comfort" OR "visual comfort" OR "energy efficiency" OR "solar passive architecture" OR "climate responsive architecture")) AND "India").

Climatic Zone and its impact on Solar Passive Architecture

Indian is classified into varied major climatic Zones as per ECBC and NBC like (i) hot-dry; (ii)warm-humid; (iii) cold; (iv) temperate; and (v)composite (Figure- 2). Solar Passive Techniques in Vernacular Buildings are witnessed in all Climatic Zones and research has been done all over India globally by many researchers. However no comprehensive review has been done so far to understand the solar passive techniques of vernacular buildings in all climatic zones in Indian Context. Figure-3 represents the research studies done in Indian context on solar passive techniques in vernacular buildings across varied climatic Zone and from the chart it is evident that a greater number of studies is done in Warm Humid Climatic region of India. Many research studies were done in tropical climate than cold climate, since tropical climate are extremely hot and energy consumption plays a major role in building sector and the results proved that further studies to be done in other climatic zones of India. There exist a corelation between the Climate and Buildings in each climatic Zone. Figure-4 shows the number of research articles published in Scopus and Web of Science journals and the number of publications are increased over the Time line and the researchers also have published the research content in reputed journals (Figure- 5). In India diverse geographical regions have varied climate, and each context has unique traditional typology which was designed with respect to local climate and material availability. There are majorly five climatic Zones in India- Hot dry, Warm humid, composite, temperate and cold. The street layouts, spatial planning, Spatial organisation and design of varied spaces and usage of Local materials and techniques is unique in each climatic zone and the occupants modified their houses with respect to their culture, belief system and Energy Consumption and they lived in an Energy Efficient house with a sustainable Life style by adopting the bioclimatic design features for achieving thermal comfort

Bibliometric Analysis

The Literature data sets were further explored with Bibliometric analysis with mapping and visualisation data sets to analyse the knowledge existing and identify the research gap. The keywords were extracted from the Literature and analysed by the tool VOS viewer for scientific visualisations. Figure represents the Clustering of Keywords indicated by a size of the circle. The key words are represented by a circle and the correlation is based on circles distance. The major clusters are Thermal performance, Vernacular Architecture, solar passive techniques and the cluster diagram shows the strong relation between all the keywords. A group of clusters in yellow colour are poorly corelated. Figure shows the list of papers collected based on keywords forms a word cloud. The keywords highlighted are Vernacular Architecture and we can witness other keywords like thermal comfort, Energy Efficiency and sustainable development and from the word cloud we can witness Vernacular Architecture plays a key role in the research field based on huge number of Publications in this domain in Indian Context. Amongst the various research methods used Field

study and Simulation study played a major role in Assessing Vernacular typologies (Figure -6,7).

Solar Passive Features in Vernacular Buildings

Hot dry Climate

Tarun Gehlot et. al (2022) discussed the importance of Climatic design in Jodhpur which experiences strong desert winds and hot dry climate and the buildings need to be designed to achieve climatic comfort throughout the year by incorporating solar passive features like orientation of the buildings, shading devices, fenestrations and openings and building envelope (1). Vijayalaxmi K. Biradar et. al (2016) documented and analysed the Environmental, Socio cultural aspects of vernacular buildings in Kalaburagi, hot and dry region in Karnataka and appreciated the climatic design principles which can be integrated in today's context (2). Pooja Raval et. al (2016) has done a survey on Vernacular Buildings that are located in the Maniayri Village of chanasma region, gujarat to understand the Earth quake resistance features to resist seismic loads (3). The authors inferred the following design features such as row house with one wall shared, rectangular building plan with Light Weight regionally available materials like wood, brick, country tiles etc.

Warm humid

Dili et. al (2010) conducted a qualitative and quantitative analysis of vernacular buildings in kerala to understand the climate sensitive design features in Buildings. From the qualitative analysis the authors figured out various design strategies like Building orientation, spatial arrangement of rooms, openings and courtyards, local materials and construction methods were analysed for interior comfort. Field experiments were conducted in the vernacular houses for recording climatic parameters for achieving indoor thermal comfort and the results proved that passive system provided indoor comfort (4). The qualitative and Quantitative analysis was conducted in the vernacular buildings of Coastal region in Nagappattinam by continuously recording the climatic variables both in indoor and outdoor by AES and the results proved that the solar passive elements like Windcatchers, courtyards, Projection of roofs from Building outline and Envelope design played a major role in achieving Thermal Comfort in Buildings Shanthi Priya et al (2012) (5). The solar passive features were analysied in vernacular mud houses in Madurai. The key parameters were orientation, shape and form of building, sun exposure, surface volume ratio, building envelope and shading, openings, material and technology etc. and field study was conducted in the house and the simulation was carried out to understand the performance of mud houses during extreme summer and this house also provided insight for designing Energy Efficient house (6) (Madhumathi et al 2014). The vernacular and modern buildings found around the Temple Town, srirangam trichy was studied in terms of sustainability and comfort using questionnairre survey and simulation using ISV and the thermal comfort differences were addressed in both typology of houses was addressed. The Questionnairre survey was conducted amongst the occupants living in both traditional and Modern Architecture of Konearrajapuram Village, Nagappattinam to understand the perception of the occupants for achieving indoor environmental comfort in varied building typologies and the datas were analysed with varied tools and charts like olygay bioclimatic charts and mahoney tables. The authors concluded new residential development in Nagappattinam can be approached through traditional architectural approaches (7)(purushothaman et. al (2020).

The hands-on research was done in 10 native dwellings in kottar, Nagerkoil in kanyakumari district. The qualitative survey was done to understand the effect of planning, building envelope, openings and construction materials etc and the findings revealed the need thermal zone management, delay of heat transmission due to heavy thermal mass were identified as important factors in design and planning. S. Monika et. al (2023)(8). Leo et al(2017)(9) studied and assessed the Thermal comfort of Eight Vernacular buildings which was constructed latest construction materials like cement and steel was monitored in Hyderabad. The results showed that many passive cooling features thick walls to minimize fluctuation in temperature, heat transfer is reduced by the presence of air cavities in the structures had an immense impact in achieving thermal comfort. Madhavi Indraganti et al. (2010) studied and

documented Maraikal, a traditional community in a composite climate of Andhra Pradesh. The cluster of houses lies in harmony with the climate situation and Geological condition and the walls were painted in white colour, roof thickness was heavy with narrow streets for achieving climatic sensitivity and the residents were found to be adaptable and their activities were synchronised with respect to the Environmental Qualities of Space(10).

Dili et al(2011) has done experimental investigation in the traditional and modern buildings of Kerala to evaluate thermal comfort by continuously monitoring the buildings with data loggers for both summer and winter season and the results revealed that the traditional houses provide thermal comfort due to passive cooling strategies used in the building irrespective of outdoor climatic situations(11). Dili et al(2010) conducted a survey in the traditional and Modern Buildings during the different seasons of Kerala to recognize the impact of various factors which affects the Thermal Comfort indoors and the results obtained were collated and found that kerala traditional buildings provided comfortable indoor spaces(12). Dili et. al (2010) conducted a qualitative and quantitative analysis of vernacular dwellings in kerala to understand the climate sensitive design features in Buildings. From the qualitative analysis the authors figured out various design strategies like Building orientation, spatial arrangement of rooms, openings and courtyards, locally sourced materials and construction methods were analysed for indoor comfort. Field experiments were conducted in the vernacular houses for recording climatic parameters for achieving indoor thermal comfort and the results proved that passive system provided indoor comfort (13). The sustainable design principles of vernacular buildings in Thanjavur region were analysed and explored. A case study building was selected and thermal performance was analysed using Ecotect software and sustainable principles leading to thermal comfort was analysed. The authors discussed varied design parameters identified in the traditional buildings to be incorporated in modern buildings (jayasudha et. al (2014) (14). The vernacular and modern buildings found around the Temple Town, srirangam trichy was studied in terms of sustainability and comfort using questionnairre survey and simulation using ISV and the thermal comfort differences were addressed in both typology of houses was addressed Kesavaperumal, Thirumaran et. al (2019) (15). J Vijayalakshmi et. al (2022) assessed and evaluated the spatial qualities and Energy efficient features of the traditional weavers' settlement in Pillayarpalayam, Kanchipuram, Tamil Nadu by physical documentation and Interviews. The author identified the Climate responsive design features such as the Orientation of the Building, Materials and Construction techniques, openings for achieving Natural ventilation and stressed the need to protect the buildings since the buildings are undergoing lots of transformation which are not adaptable to climate (16). Abhishek Tripathi et. al (2023) collected the samples of Chettinadu lime Plaster and mortar which has high durable properties and smooth finish, was collected from two structures to explore the various composition and applications, since such local wisdom is lost in today's applications. The authors documented the method of traditional binder production and the composition differences in the chettinadu plaster and mortar used at various locations were decoded to restore the structures (17). Karthick chadalavada et. al (2017) studied, documented and analysed the climatic design principles such as proportion, form, construction materials spatial design aspects, in a traditional building in Pipparru village at Andra Pradesh. The quantitative analysis was carried out for analysing the thermal and visual performance through IES- VE. The analysis was done to understand the spatial transformation of the courtyard as per the needs of the occupants and the simulation results proved that 30% thermal performance has been improved after courtyard transformation (18).

Composite climate

The key parameters were identified by taking design clues from the vernacular building and incorporating in Contemporary building for designing energy efficient house in Lucknow. Research methods included Questionnaire survey and field study. Thermal Comfort Survey was done in the above said typology and the climatic parameters were analysed in 35 vernacular houses and the datas were validated from Nicol and

Humpreys equation (19). Madavi Indraganti (2010) documented and analysed the climate sensitive vernacular settlement and varied built typologies in Maraikkal located in Andra Pradesh in Composite region. The settlements were organically grown with dense cluster of compact houses, narrow streets and alleys which protected the walls from direct solar radiation and glare. Thick walls and roofs painted in white color and small openings and used regionally available materials for construction The transformation of Maraikkal settlement leads to irrelevant architecture with respect to context and climate so the Author urged the need for code of practice for balancing vernacular and Modernisation (10).

Cold climate

Sarkar, A (2013) has done a descriptive study to understand the climatic response in the traditional Architecture of Khyah Village in Hamirpur district of Himachal Pradesh. The entire settlement was documented and analysed in terms of Bio climatic feature at settlement and Building Level. The author also highlighted the interaction of various activities of the Occupants in their physical environment as a response to Local Weather conditions (20).

S.S. Chandel et. al (2016) has done a comprehensive review to recognize various sustainable features in vernacular buildings for achieving Thermal Comfort for adopting in Modern Buildings. He has done a case study of vernacular dwellings in Himalayan region to identify an unique style for incorporating the Passive solar features and construction methods for improving the climatic comfort in Contemporary buildings (21). Manoj Kumar Singh et. al (2011) analysed the solar passive elements in vernacular building typologies -Cold climatic zone of North East India and identified the following design strategies – the typologies were built to let in solar radiation and built in southern slope with thick stone walls and small openings to prevent the heat loss and the dwellings were constructed with locally sourced materials like bamboo, wood, stone chips, rock slabs and better thermal behaviour was witnessed inside the houses and provided comfortable built environment(22). Jitendra Bothara et. al (2022) evaluated the earthquake resilient construction techniques in vernacular buildings along the Himalayan arc qualitatively, since these buildings seismic performance was found to be better during the past earthquake. The authors concluded that the earthquake resilient buildings are found to be feasible when regionally available materials such as timber, mud, stone and techniques were practiced by the builders (23). Rahul Bhaumik et. al (2023) proposed a Smart Vernacular Architecture Framework and applied it to the vernacular Toda huts in Nilgiris, Tamilnadu. Field study and experimental investigation on climatic parameters was carried out by the author in the vernacular houses of hilly regions and the results showed that toda huts provided a warmer Environment during colder days due to the Eco-friendly building materials like local soil, straw, bamboo, wood and construction methods ensuring thermal comfort indoors (24).

The research aims at understanding passive-cooling techniques used in Wada, a vernacular-traditional building, in the moderate climate zone of Western Maharashtra. The research comprises a extensive literature review, with definition, field work and a selection of case studies. A survey is conducted by recording on-site observations, following an instrumentation setup and measurement procedure. The paper documents the principles that are used in vernacular-traditional buildings that are sustainable and are expected to be of relevance to architects and built form designers (25). Mihir N. Vakharia et al. (2023) discussed the climate Sensitive architecture of Wada settlements in Pune, India and identified various climate sensitive design strategies like Shading and Natural Ventilation, layout and orientation of the building, envelope design, etc

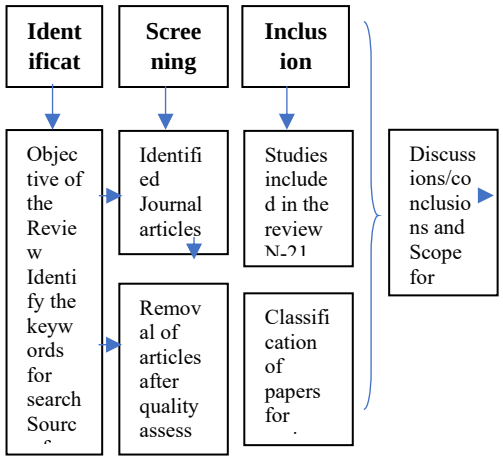

Figure 1. The Literature review methodology

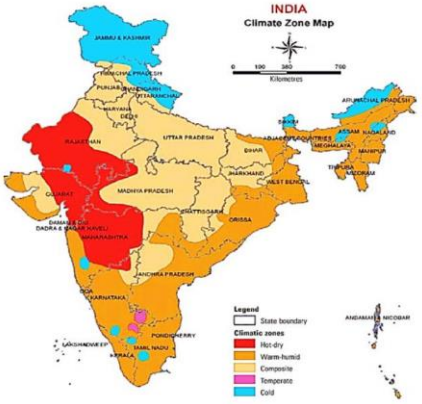

Figure-2 Indian Climatic Zones

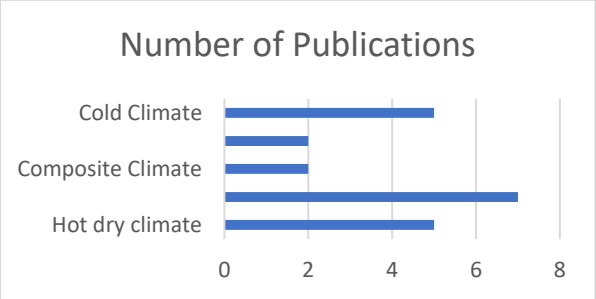

Figure-3 Number of Publications – varied climatic zones

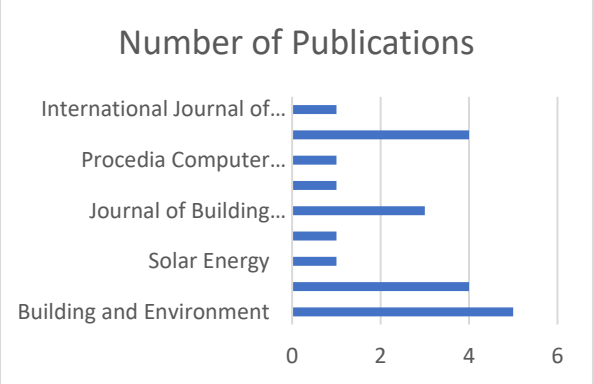

Figure-4 Number of articles published in varied Journals

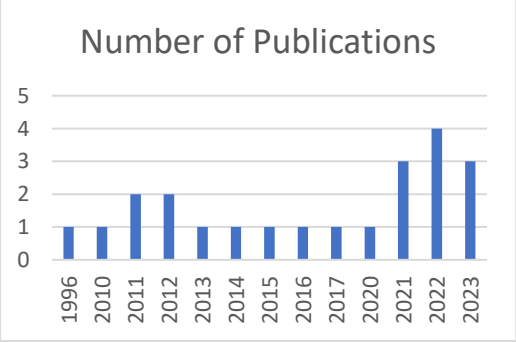

Figure-5 Number of articles published – Time Line

Classification of research objectives	Count
Identify solar passive features in Vernacular Architecture	7
Qualitative and Quantitative Assessment of Vernacular Architecture	6
Energy and Environment Performance of Vernacular Architecture	5
Eco friendly building Materials in Vernacular Architecture	4

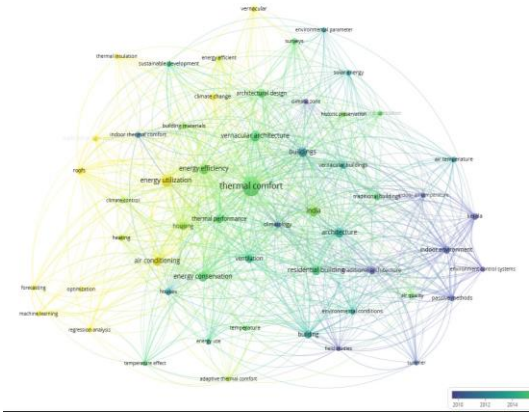

Figure-6 Cluster diagram

Figure-7 Word Cloud

Conclusion

This paper presents a review of 24 studies since 1995 about the solar passive techniques in Vernacular Buildings across varied climatic zones and primarily focussed on varied Climatic Zones in India. The authors witnessed qualitative and quantitative methods were used for the evaluation of solar passive architecture in Vernacular Buildings. The most keywords which occurred in the papers were Solar Passive Techniques, Building Performance, Thermal comfort, Energy

consumption was the mostly used keywords. The findings from the study were unique to the context and not similar, since the vernacular buildings evolved over a period of time in response to the local environment and context. The design strategies varied from hot climate to cold climate, so the common conclusions cannot be derived from the study. This study brought the knowledge system of regional builders with respect to Thermal domain in terms of selection of regional Building Materials and constructions, spatial planning, orientation, form, designing openings and solved climatic challenges. From the above discussed Literature few studies were descriptive in nature and focussed on cultural factors, symbolism, decoration, spatial and bioclimatic factors and mostly concluded on the Architectural Language of the buildings with respect to the context. Few studies were experimentative with field study carried out with Instruments and assessed through simulations for analysing the Thermal comfort, Energy Consumption, Indoor Air quality etc and most of the results proved that the vernacular buildings are climate responsive due solar passive techniques used in the vernacular typology. Though the scientific community has proved that vernacular buildings are sustainable but there are still issues and challenges to preserve the buildings, retrofitting and incorporating the designs in contemporary buildings due to norms and guidelines. The papers reviewed showed that lots of studies were done in Hot climates than cold climates. So there exists s research gap that the vernacular buildings in other climatic zones like cold climate, moderate and composite climate in India need to be further explored. The results shows that lack of studies on vernacular building materials with respect to all climatic zones and also research gap on norms and guidelines to incorporate vernacular techniques in varied climatic zones. Further research needed for vernacular buildings retrofitting measures for improving Thermal Comfort.

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