ISSN No:-2456-2165

Climatic Responsiveness of the Vernacular Houses towards Developing a Passive Design Sense for Architecture to Reduce Energy Dependency – Case Study

Deepak Joseph[1], Joseph V Thanikal[2], Elza Joseph[3]
[1]Deakin University, Geelong, Australia, [2]RICS School of Built Environment, Noida, India,
[3]Consulting Architect, India

Abstract:- Global climate change is demanding Architects to embrace regionalism and traditional architecture in their designs. The objective of this paper is to analyse design works of renowned Architects who made use of the vernacular architecture features at different region towards developing passive cooling. The study aims to inform an architectural style from the vernacular houses of Kerala which incorporates thermal comfort of users, passive solar features, site planning, spatial organization, and material and construction technique. The study is comprised of four stages. The first stage was to study the architectural style of Kerala and understanding its uniqueness and cultural dependency along with its climatic reliability. Secondly, a database of the research is established from secondary sources, by collecting works of architects from different geographical locations having similar climate zone, economic background and cultural ethnicity. In the third phase, works of the architects were compared for similarities, dissimilarities and limitations to understand the most effective methodology.

Keywords:- *Climate Change, Vernacular Architecture, Passive Cooling Climatic Reliability.*

I. INTRODUCTION

Humankind spends most of its life indoors either in their workplace or home. The energy consumed by the residential sector and commercial sector for its basic use and maintaining indoor thermal comfort is the biggest contributor to the global total energy use (Chunekar, Varshney and Dixit, 2016). In the residential and commercial sector, the energy used for space heating and cooling can be minimized if the building utilises passive design strategies from local vernacular architecture. As it is estimated that by 2050 electrical energy consumption from the residential section will rise more than eight times in India (Shukla, Rawal and Shnapp, 2015), it is highly important that energy demand is reduced by using passive design, climate responsive strategies.

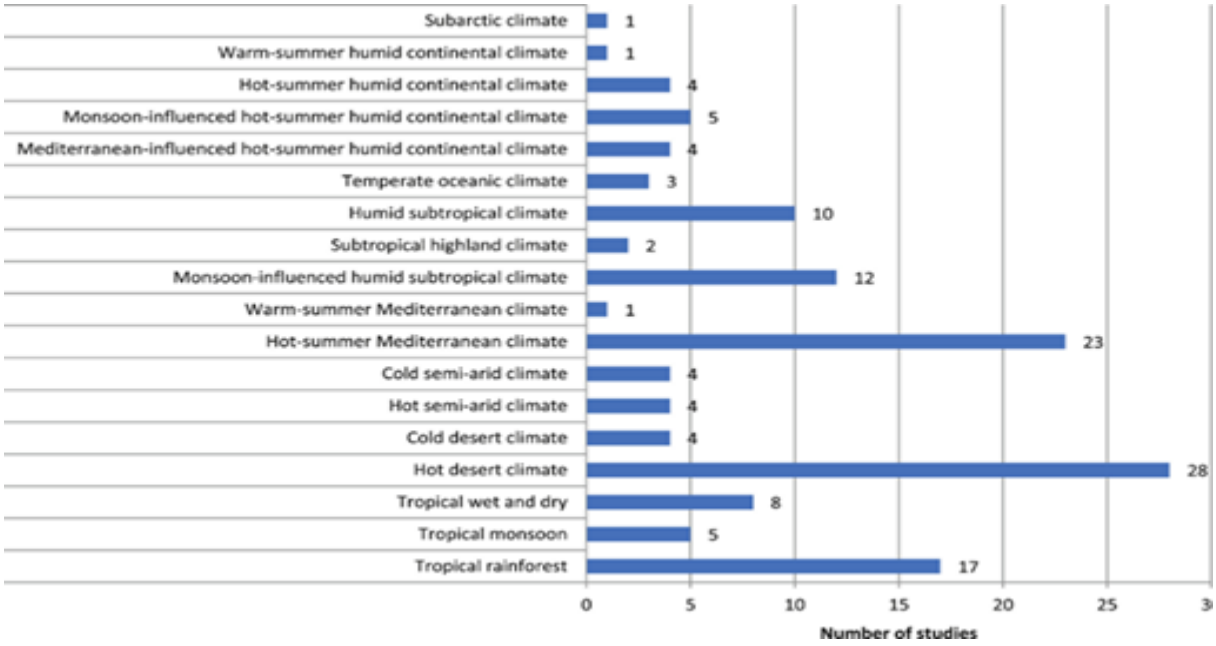
Vernacular architecture is largely the art of constructing shelter for safety and shelter. It is community based, environmentally oriented and is evolved over time with repetition and efforts of indigenous people's technologies and cultural values (Rudofsky, 1964). Vernacular buildings use a design approach that works towards reducing energy consumption with the use of natural resource for creating a sustainable living space which is comfortable and healthy, achieving the aims of climate responsive sustainable building design (Rudofsky, 1964). In contrast, modern houses are criticized for excess use of energy for maintaining indoor thermal comfort, and for lack of response to the local environment. With passage of time, traditional vernacular buildings are being replaced by modern contemporary houses with modern technologies and building materials. Hence to preserve our heritage and knowledge of past, architects need to adapt an approach which is an amalgamation of old and new.

In recent years, researchers have considered the conservation of vernacular architecture around the world. There have been various attempts to understand the climate responsiveness of vernacular buildings in Kerala via experiments and analysing data through different seasons (Dili, Naseer and Varghese, 2010). Studies have focused on understanding the behaviour of courtyards in the traditional buildings of Kerala for climate responsiveness (A. S., M. A. and Varghese T., 2010). Books have discussed the sustainability of vernacular architecture in different geographical locations, such as Hungary, Portugal, Iran, Malaysia, etc., towards the development of modern translation (Ṣā'igh, 2019). The research by I.G.R.M.S. Bhopal about the vernacular architecture of India showed the diversity of vernacular residential building due to the vast geographical expanse and climatic range of India. India is full of cultural diversity and various vernacular architecture styles that have developed and survived in the wide and vivid Indian peninsula. Kerala is woven into the banks of rivers and has a rich history of settlers providing diversity of vernacular houses. The houses are also caste dependent on their materiality and grandeur. The major typologies of vernacular houses in Kerala *Veedu* are: *Ettukettu*, *Nalukettu*, *Eksala* and *Cheri*, depending on size and inhabitants. Local craftsmanship, use of ingenious

ISSN No:-2456-2165

material, passive design strategies for thermal comfort and spatial planning (Widiastuti, 2013) demonstrate climate responsiveness and energy efficiency. But modern houses in Kerala are leaving this knowledge behind and are based on modern housing principals that do not acknowledge the values of past. Therefore, there is a need to establish a link between vernacular architecture and modern architecture through echoing the passive design strategies with modern material detailing. The paper aims to suggest how traditional thermal comfort strategies might be adapted to modern construction techniques for Kerala.

The study uses data collected through literature review on vernacular architecture from database of indexed journals, books and other resources. Case studies were obtained from architects who have worked on the concept of vernacular translation to modern architecture. Primarily, through their articles and details of work. Archival research methods are used widely in architecture research, especially in works comparing the historical data with modern times (Marc J. Ventresca and John W. Mohr, 2001). Archival work is used here to explore the traditional climate responsive designs of houses in Kerala. The following chart indicates how many studies have been completed up to 2018 by climate studies ((Anh Tuan Nguyen, et al., 2019).



In the first stage, the data about the vernacular houses of Kerala is sourced through literature review, articles published online, research papers, journals and books such as ‘wooden architecture of Kerala’ and ‘the Bungalow in twentieth century India’ by Miki Desai. Vernacular houses built in Kerala is considered for vernacular architecture studies used for passive cooling. For the second phase, Architects work are considered to understand, how their designs were translated vernacular architecture to the modern house construction. The works of the architects were based in the Hot, Humid and Dry climate zone. In the third phase, data collected from four architects work were compared and critically analysed. The work is categorized in similar and different approach adopted by the architects. Using the findings from comparative analysis, principles are prepared to translate the essence of vernacular architecture to modern domestic architecture. In the fourth phase, the principles from phase 3 is applied to the documented vernacular architecture of Kerala from phase 1. These principles helped to translate passive design strategies from vernacular architecture of Kerala to modern house design with indoor thermal comfort using informed construction details.

II. BACKGROUND AND HISTORY OF KERALA

➢ *Climate Analysis:*

Kerala is situated on the 8º18’N to 12º48‘N latitude and 74º52E to 72 º22’E longitude falls under the warm and humid climate zone of India according to the National Building Code. Kerala experiences seasonal changes in solar radiation and wind direction due to its location on the south west coast between the Western Ghats on east and Arabian Sea in the west. South- west to north-east is the predominant wind direction. The temperature fluctuates between 21 º C to 33 º C, with relative humidity 65 % to 70%. Kerala experiences three distinct seasons i.e. summer, winter and the rainy season. The rainy season last for about six months. The ambient temperature and relative humidity of the state fall above the comfortable limits; hence ventilation is the most important strategy to achieve indoor thermal comfort. The vernacular architecture of Kerala thus helps enhance air movement and cross ventilation. The vernacular architecture of Kerala is an amalgamation of the Indic and Southeast Asian style. The use of earthen material for construction and *Vedic* planning from the *Vaastu* are main characteristics of the Indic style. Kerala vernacular architecture for domestic residential unit or Veedu is of five types: (a) ordinary or

tribal people, *adivasis* wretched humble homes known as *cheri, chala, kudi, variyam or pumatham;* (b) Farmer or middle class non farmer's house which is I-shaped single rectangular hall house is known as *Ekasala;* (c) landlords dwelling which is a courtyard house known as Nalukettu; (d) rich landlords or kings people or higher official homes are known as an *Ettuketu or Patinjarukettu* which are huge structures or great mansions; and (e) Common houses which are spread across the state and have no original documentation, they have a respect to vernacular style and construction techniques. (Widiastuti, 2013).

- *Case studies*

Hassan Fathy is an Egyptian architect who worked to re-establish traditional building method and materials. His sensitivity towards form and space made the built environment visible to the world. His creative approach is a blend of his approach to regionalism and vernacularism culture and history of the place. He adopted new local material as clay during World War 2 due to absence of steel and concrete. Hassan Fathy presented a world view that focused on core of humanity and perpetual renewal rather than destruction and abstraction. He trained local inhabitants to build their own buildings using local materials (Ali, 2015). His work showed his awareness to issues like climate conditions, public health consideration and vernacular architecture.

Planning followed traditional Egyptian culture with open garden, cupolas, windows, and pergolas were used. The concept of Courtyard, which traps cool air and make the interior space comfortable and warmer during winter as less exposed to cold air, was very effectively used. He oriented the buildings to receive solar lighting and technics to control humidity and prevent wind borne particles entering inside. Traditional Mashrabiya, Wooden and stone*Jaali* allowed ventilation and light, natural stone sourced locally for wall and flooring.

One of his work, a residential building of two-storey house was studied for passive cooling. This house was lighted, naturally ventilated and passively cooled. The routine used rooms were placed on the south east side for benefit of solar radiation. Bedrooms were next to a buffer zone for cross ventilation on the north side. Small openings, vaults and wall openings provide natural light. On the south courtyards side, three open arched walls gave panoramic view of the green fields. Shaded courtyard on west side with domes catches the breeze for cooling. The fountain mixed water and air before entering the house for evaporative cooling. (Abdulrahman, 2013). The building of yellow *Hayum* limestone sealed with a coating of boiled *Helba* plant (Serageldin, 2007); the thickness providing thermal mass. The natural materials used are stone, brick, and wood. The materiality gives climate comfort to inhabitants. The house has divine lighting throughout via use of wooden latticework windows called '*Mashrabiyya*'. The house has achieved aesthetic with minimal costing. The spirituality of space is achieved through square shaped courtyard like *ka'bah*, use of water and trees for microclimate and using mosque architecture for planning of different levels. (Saqer Mustafa Sqour, 2018)

Laurie" Baker was a British-born Indian architect, renowned for his initiatives in cost-effective energy-efficient architecture and designs that maximized space, ventilation and light and maintained an uncluttered yet striking aesthetic sensibility. His philosophy of energy saving along with use of local materials resulted in cost effective and eco-friendly architecture for the common man (Deulgaonkar, 2014). He adopted indigenous architecture and used local craftsmanship, traditional techniques and local material combined with modern design principles. The prudent use of modern architecture with local materials kept the cost of building low and were popular among lower-middle to lower class people. His buildings have virtuosic masonry construction, instilling privacy and evoking history with brick *Jaali* walls - a perforated brick screen which invites a natural air flow to cool the building's interior. Use of traditional sloping roof for the climate of Kerala, with terracotta Mangalore tiles shingling with gables and vents for the rising hot air to escape. (Deulgaonkar, 2014)

His emphasis was not to impact natural environment, life cycle of material, use of recycled materials and worked towards sustainable architecture. His plans remained as ideology and developed at site as per environmental condition to suite the nature. He used cross ventilation as principal objective in warm and humid places. Openings of a relatively littler size was put on the windward side, while the comparing openings on the leeward side possibly greater for encouraging a plume impact for regular ventilation. He realized that vernacular architecture of Kerala is built based on *"Vastusastra".* (Bhatia, 1991). He had his own architectural principles using local materials, construction methods and employing trained local craftsman. His building theory was based on "Affordable for everyone". He always complemented form and site topography to create passive indoor comfort and reduce energy use.

Filler slabs to reduce 20-35% materials, reducing the cost and is aesthetically pleasing. Rat trap bond is used as cost reduction technique by 25% less material usage than conventional English bond (Nair, 2015). Masonry arches are used for spanning the semi open space like Verandah and corridor surrounding courtyard. (Sreekanth, 2011). Brick *Jaali*provided cross ventilation and day lighting into the space it is often referred to as 'poetry in Bricks'.

Fisher man's village was one of his significant project where, all the architects refused to take up this work. The planning was based on the traditional ideas of providing safety in cyclone situation. The village has a total of 650 houses. The challenges were severity of environment, limitation of resources, dealing with insular groups with traditional ides and dealing with cyclones. Each unit was 25 Sq. m. area. (Bhatia, 1991). The units were grouped with a courtyard place in between. The long conventional housing is replaced by a staggering, so that the fronting courts get a view of sea and catches breeze. Since a good part of fisherman's life was spend outdoors, the house and court

ISSN No:-2456-2165

function admirably providing sleeping lofts within the adequate space outside for meandering nets and cleaning the drying fish. Lower height of the building also helped to reduce the cyclone effect.

III. DISCUSSION

In the works of architects, the common factors are use of passive thermal control system, local manpower and indigenous materials incorporated. Baker's concept and work is different, blending the eco system of Kerala and its people. He was conscious about cost and reused the joineries and wooden material from demolished buildings. His buildings had a distinctly local or regional identity, recognizing the forces that give them shape. Concrete is used very sparingly, often in a folded-slab design with broken and discarded tiles used as fillers, thereby making the roof light and inexpensive. Innovative bonding techniques for brick allow him to build walls of only a half-brick thickness. In many cases they are stepped and curved for added stiffness. To make the structure light, he used filler slabs for roof. Use of *Jaali*and cross ventilation provided helped control humidity inside the house.

Fathy's design was suited to the desert climate with passive cooling via water fountains through which the outside air passes. He used thicker walls for thermal insulation and wood screens for passage of wind through windows shielded against solar radiation. Fathy used courtyards and verandahs, with windows positioned for cross ventilation.

- *Spatial Planning*

While space is planned it is important to identify moisture and heat generating area, to separately ventilated. Houses with more than one floor, central courtyard can help to draw the hot air out. The courtyard act as climate regulator and retains cool air. Due to pressure difference induced through courtyard cool air travels in the house exhaling hot air out.

- *Material:*

Materials played an important role in Kerala architecture to align with the climate. Mud, clay, laterite, and bamboo is very commonly available Mud was used sometimes for plastering the walls. Flooring with clay tiles always made the room cool. Pitched roof with Mangalore tiles was used for the roofing. Clerestory arches were used for getting natural sunlight also promotes passive cooling. Gables had punctures through which hot air rises from the house and go out through the gable on top. Jaali are used for boosting ventilation in the house. Mud mortar is used for wall construction. Red oxide is used for interior flooring while rough granite is used for outside flooring. (Thirumaran and Reshmi, 2017)

- *Building envelop:*

The external walls are thick made with laterite stone bricks, the roughness of brick provides self-shading of the wall, which reduces the radiation falling on the wall. The wall thickness is made of double layer of laterite wall and sand infill inside the gap which provides insulation in the interior space with thermal mass. Maintaining indoor temperature to comparative low from outside. The whitewash also helps keep building cool by minimizing the heat absorption. (Thirumaran and Reshmi, 2017)

- *Roof:*

In the pitched roof, lower opening for inlet wind and an opening at the roof level for the wind to draw. This facilitate the hot air exit at the upper level openings providing cross ventilation. Larger opening on one side of the wall, that facilitate to draw more air into the room through smaller inlet opening, thus increasing air circulation area within the room. Use of natural sunlight decrease the heat inside the room due to the warmth of artificial lighting.High pitched roof and overhangs create pressure difference increasing the air flow. The attic space created due pitch roof acts as an insulating layer from the heat absorbed though roof. The attic space also has an opening gable detail which helps in removing hot air. The second roof of the upper floor and ground floor remains cooler than the pitched roof. The overhangs, steep roof and eaves helps rainwater drain quickly during heavy rains (Thirumaran and Reshmi, 2017).

- *Fenestration:*

Walls have opening on both sides providing air circulation. Wooden *Jaali's* are used in the house cutting the glare and providing diffused light. The perforations increase air velocity and provides mild breeze into the house and deeper penetration essential for thermal comfort in warm humid climate. Northern side has more widows and fenestration for bringing in glare free light. Shading devices on windows and roof cuts the solar heat. (Thirumaran and Reshmi, 2017) The louvered umbrella type roof is used to have solar filter and for the wind movement. Mornings and late afternoon the louvers permit light penetration.

Another study, comparing a modern building built near a traditional building, in the same orientation, in the traditional building, the temperature variation at outdoor was from 28 ◦C to 41◦C, where the indoor temperature variation was from 31 ◦C to 35◦C. The lower part of the courtyard was found cooler by 8 ◦C from the maximum outdoor temperature during the day, while the upper part of the courtyard has a temperature 3 ◦C lower than the maximum outdoor temperature. The maximum air temperature in semi open space was slightly more and lower at the bedroom. The variation of relative humidity outside was 32% to 95%, the bedroom relative humidity was varying from 50% to 80%, while the courtyard had larger fluctuations.

IV. CONCLUSION

Studies were conducted to understand passive design strategies appropriate for the vernacular architecture of Kerala and how translation of vernacular architecture to modern architecture can be achieved. Based on the analysis, modern construction details are developed based on principles derived from the comparative analysis of vernacular and modern architecture. It is suggested that, vernacular detailing to be included in the modern design relating to, site, climate and culture. The resulting design will have passive strategy for heating and cooling and will minimize the energy usage of the household resulting in reducing residential energy usage for Kerala. The design will have indoor thermal comfort and continuous air flow created by a courtyard.

India is a nation of diversity with variety in culture resulting in different vernacular architecture patterns across the country. If the vernacular passive design is translated for every climate zone, it will contribute to solving the energy crisis of the country. Vernacular inspired design reflects local climate and develop climate comfort without any active measure. This form of residential will also create a more sustainable socio-economic balance.

REFERENCES

[1]. Ali, A., 2015. Sustainability in vernacular architecture: Laurie baker and Hassan fathy's approach. Anthropological Bulletin, 5(2).
[2]. Archival Research Methods Marc J. Ventresca and John W. Mohr To Appear in: *Companion to Organizations*. Edited by Joel A. C. Baum (2001), Blackwell Publishers.
[3]. Ar. Thomas George, Shanta Pragyan Dash, International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-9 Issue-2, December 2019
[4]. Chunekar, A., Varshney, S. and Dixit, S., 2016. Residential consumption in India: what do we know? *prayas energy group*,
[5]. Dili, A., Naseer, M. and Varghese, T., 2010. Passive control methods of Kerala traditional architecture for a comfortable indoor environment: A comparative investigation during winter and summer. *Building and Environment*, 45(5), pp.1134-1143.
[6]. Dili, A., Naseer, M. and Zacharia Varghese, T., 2010. Passive control methods of Kerala traditional architecture for a comfortable indoor environment: Comparative investigation during various periods of rainy season. *Building and Environment*, 45(10), pp.2218-2230.
[7]. K.Thirumaran, R.Reshmi, Analyzing Green Building Technologies in Indian Vernacular Architecture: A Case Study of Kerala, International Journal of Innovative Research in Science, Engineering and Technology, IJIRSET, Vol. 6, Issue 5, May 2017
[8]. Laurie Baker, Houses; How to reduce building cost, Costford
[9]. Laurie Baker, A manual of cost cuts for strong acceptable housing, Costford
[10]. Rudofsky, B., 1964. *Architecture without Architects*. New York: Doubleday
[11]. Ṣā'igh, '., 2019. *Sustainable Vernacular Architecture*.
[12]. Saqer Mustafa Sqour, 2018. Attaining Human Aspects to Avoid Alienation in Architecture. *Journal of Civil Engineering and Architecture*, 12(2).
[13]. Shukla, Y., Rawal, R. and Shnapp, S., 2015. *Residential Buildings in India: Energy Use Projections and Savings Potentials*. Policies and programmes towards a zero-energy building stock. european council for energy efficient economy
[14]. Thirumaran, D. and Reshmi, R., 2017. Analyzing Green Building Technologies in Indian Vernacular Architecture: A Case Study of Kerala. *International Journal of Innovative Research in Science, Engineering and Technology*, 6(5).