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Traditional Kerala Courtyard Houses: An Insight into Indoor Thermal Comfort within a Tropical Context

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Abstract - The indoor thermal environment holds a critical position within the realm of sustainable building practices, especially in the context of Kerala's warm and humid tropical climate. It plays a pivotal role in ensuring the comfort and well-being of occupants, making it a key consideration from the very inception of building design. This early emphasis on environmental concerns is essential for seamlessly integrating sustainability into the fabric of the building environment.

The backdrop against which this emphasis on indoor thermal comfort occurs is the backdrop of global climate change, exemplified by the ongoing challenge of global warming. This phenomenon directly affects human comfort as a significant portion of our daily lives is spent indoors, engaged in various activities. As Kerala grapples with a growing urban population, the demand for additional housing, commercial spaces, offices, and amenities is on the rise. Modern-day occupants are increasingly cognizant of the pivotal role that sustainability plays in enhancing their overall quality of life.

Central to this quality of life is the attainment of a favourable indoor thermal environment. This is especially true in residential settings, where the well-being and safety of residents are paramount. Global warming, with its rising temperatures and escalating greenhouse gas emissions, has wide-ranging repercussions for outdoor environments. In response, residential developments undergo transformations that alter urban climate dynamics. These changes are manifest in shifts in building materials, structural elements, and energy consumption patterns, all of which are driven by the economic activities of the human population.

It is crucial to recognize that the indoor environment is intricately connected to external conditions. Therefore, understanding the factors that influence indoor thermal comfort is imperative when endeavouring to create a comfortable and health-promoting atmosphere within traditional Kerala courtyard houses. These factors encompass the microclimate of the site, including variables such as temperature, relative humidity, and wind patterns. These elements collectively contribute to the dynamic nature of the indoor thermal environment within these traditional tropical dwellings, underscoring the importance of considering them within the context of sustainability and comfort.

Key Words: Vernacular Architecture, Thermal Comfort, Traditional Courtyard Houses, Climate Adaptation, Heritage.

1.INTRODUCTION

Vernacular architecture, a product of the intricate interplay between human behaviour and the surrounding environment, is a manifestation of diverse building forms that respond uniquely to each specific context. Within this multifaceted realm, the lifestyle and customs of the occupants play a pivotal role in shaping architectural designs. Factors such as household size, communal living arrangements, culinary practices, patterns of social interaction both within and among families, and a myriad of cultural nuances intricately influence the configuration and dimensions of dwellings.

In the verdant state of Kerala, situated in the southern part of India, the tapestry of vernacular architecture weaves a particularly captivating story. Here, the fusion of human life with the natural world has resulted in the creation of traditional courtyard houses that epitomize the rich cultural heritage and climatic sensibilities of the region. These courtyard houses stand as testaments to the profound impact of lifestyle, climate, and culture on architectural design, exemplifying a harmonious coexistence between the built environment and the lives it shelters.

This research paper embarks on a journey to explore the nuanced relationship between Kerala's traditional courtyard houses and the cultural, climatic, and social dynamics that have molded their distinctive forms. By delving into the depths of this intricate architectural heritage, we aim to unravel the secrets of how vernacular architecture in Kerala has not only adapted to its surroundings but also contributed to the sustainable and culturally rich fabric of the region. Through this exploration, we seek to shed light on the enduring significance of these houses in contemporary times and the invaluable lesson (Rahat, 2015)s they offer in the realm of architectural design, cultural preservation, and environmental stewardship.

2.0 Balancing Ecology and Architecture: Sustainable Built Environments

Sustainability lies at the heart of preserving our planet for future generations without compromising the immediate needs of the present. This ethos extends to safeguarding both our human habitat and the natural environment. In the tropical warmth and humidity of Kerala, this balance between ecology and architecture takes on unique significance.

Within the domain of the built environment, the concept of sustainable development has gained increasing prominence. It has led to a heightened focus on the performance of buildings,

with the goal of certifying them as environmentally responsible structures. Such assessments serve a dual purpose: to create a healthy indoor living environment and to do so while conserving the precious natural resources of the region and minimizing adverse impacts on the environment.

The human environment, often shaped by human intervention, encompasses individual buildings, clusters of structures, various architectural forms, and their associated infrastructures [5]. The building industry, as one of the world's largest sectors, wields substantial influence over the living environment and ecosystems. This places environmental considerations at the forefront of sustainable building design. Given the intimate connection between climate characteristics and thermal comfort, the selection of climate modification strategies becomes a fundamental pillar of building design in Kerala's warm and humid climate.

In the context of Kerala's tropical climate, a sustainable building adheres to several key principles:

Resource Efficiency: Sustainable buildings strive to conserve energy, minimize resource consumption, promote material recycling, and reduce the emission of harmful substances throughout their entire lifecycle.

Cultural and Environmental Integration: They seamlessly blend with the local climate, traditions, culture, and immediate environment, respecting and honoring the rich heritage of Kerala.

Human Well-being and Ecosystem Preservation: Sustainable buildings aim to enhance the quality of human life while simultaneously preserving the delicate balance of both local and global ecosystems [6].

Choi and Yu have underscored the significance of Eastern cultural design, which is increasingly recognized for its ability to create healthy environments conducive to sustainability within the human habitat [7]. Traditional building design and construction practices have long been celebrated for their climate-responsive attributes, offering solutions to contemporary climatic challenges. In the pursuit of sustainable design, these traditional approaches, grounded in a combination of techniques and natural principles, are undergoing a revival and revaluation. This resurgence is driven by a shared goal: to elevate the quality of human life while respecting the delicate balance of our ecosystems.

In Kerala's warm and humid climate, balancing ecology and architecture is not merely an academic concept; it is an imperative born out of necessity. The state's unique environmental challenges demand innovative solutions that integrate cultural wisdom, sustainable practices, and modern architectural ingenuity to create a harmonious coexistence between humans and nature.

2.1 Architectural Responses to Tropical Climates

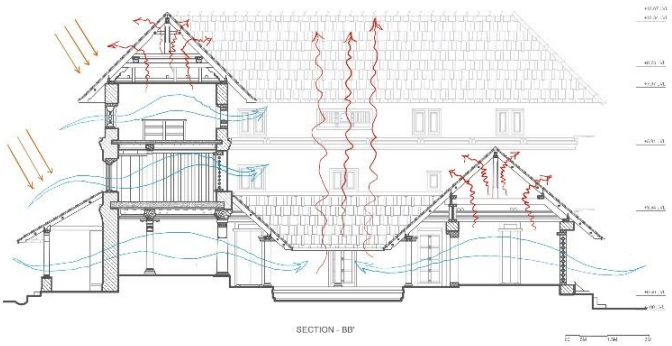

Figure 1 Air movement in Kerala courtyard houses (author)

The tropical region, spanning the Tropics of Cancer and Capricorn between latitudes 15°South and 15°North, presents a rich tapestry of geographical diversity. This vast expanse encompasses countries such as Malaysia, Singapore, Indonesia, the Philippines, India, northern Australia, parts of Africa, and Latin America. Yet, despite its diversity, the common thread that unites this region is its warm and humid climate, which poses distinctive challenges and opportunities for builders and architects alike [8,9].

Tropical climates are characterized by their high humidity, abundant rainfall, and copious solar radiation. For those engaged in the craft of building, this environment demands a nuanced understanding of climatic elements that intricately shape the local building context [8,9].

Among the most prominent climatic factors influencing building design in the tropics are temperature, relative humidity, solar radiation, rainfall, and prevailing wind patterns. These elements serve as both constraints and catalysts for innovative architectural solutions that cater to the unique needs of Kerala's tropical environment.

In the tropical context, the interplay of high temperatures and humidity levels significantly impacts the rate of moisture evaporation from the human skin. Achieving thermal comfort within this environment necessitates effective cooling and ventilation strategies. The abundant solar radiation and regular rainfall characteristic of tropical climates contribute to continuous moisture evaporation from the human body. While this natural cooling process is beneficial, it can also lead to discomfort within indoor building environments. To mitigate the adverse effects of excessive solar radiation, architects and designers must incorporate solar control measures into their building designs.

An optimal building orientation, particularly facing east or north, is pivotal in minimizing direct solar heat gain [10]. Such orientations receive less direct solar radiation, making them ideal for incorporating larger windows that facilitate natural ventilation. Various natural ventilation strategies, including cross ventilation, single-sided ventilation, and stack ventilation, can induce air movement within the building, significantly enhancing thermal comfort [11]. Wind movement emerges as another critical factor for natural cooling in tropical regions. Stagnant air with high

temperatures and humidity levels can exacerbate thermal discomfort. While wind patterns can be unpredictable, aligning building orientations with prevailing local winds can promote effective natural ventilation for cooling purposes.
In the warm and humid climates of Kerala, building designs must prioritize openness and the ability to filter the climate effectively. This optimization of the relationship between site characteristics, climatic conditions, and project requirements is essential. Research conducted by Kondrat'ev and Volkov [12] emphasizes the value of open-design apartments, as they maximize space utilization, create a sense of openness, and enhance overall convenience.

Tropical climates are often characterized by heavy rainfall periods, interspersed with one or two dry seasons each year. These rainfall events, coupled with high temperatures, elevate relative humidity levels. Consequently, building designs in the tropics must address the challenge of preventing rainwater and strong winds from penetrating the structure. Furthermore, heavy and frequent urban rainfall can lead to flash floods and other environmental issues. Therefore, an efficient drainage system for roofs and paved surfaces becomes imperative to manage water runoff, thereby influencing traffic flow in urban areas. The incorporation of green spaces and microclimate strategies in urban planning can further enhance indoor thermal comfort conditions [13].

Embracing passive design strategies, which leverage local climate elements to modify building designs, holds significant promise for addressing these challenges in tropical regions [14]. By integrating these strategies, architects and builders can create structures that not only respond effectively to the unique characteristics of the local climate but also prioritize the well-being and comfort of occupants in traditional Kerala courtyard houses. This delicate balance between nature and architecture forms the cornerstone of sustainable and comfortable living in Kerala's tropical warmth and humidity.

2.2 The Courtyard-House in Kerala According to Manusyalaya Candrika

Manusyalaya Candrika, a traditional architectural manuscript dating back to the 17th century AD, is a valuable source of insights into Kerala's architectural heritage (Achyutyan and Prabhu, 1998; Thampuran, 2001). This ancient text provides a comprehensive guide to Kerala's traditional residential architecture, including the iconic courtyard house known as "nalukettu." In their commentary text, Achyutyan and Prabhu (1998) elucidated the principles outlined in Manusyalaya Candrika, offering valuable insights for analyzing these courtyard houses.

Central to the architectural guidance provided in Manusyalaya Candrika is the concept of an abstract gridiron known as a "mandala." This mandala serves as a guiding framework for the configuration of nalukettu. The mandala embodies a concentric order, with the highest-ranking deity placed at its center, where no physical structure is allowed. Overlaying this concentric order is a diagonal hierarchical orientation that slopes gradually from the northeast to the southwest corner. The arrangement of rooms within the nalukettu follows this hierarchical and diagonal orientation.
Building upon this mandala, conceptual lines and dots are drawn, following the principles of "sutram" and "marmam". "Sutram" refers to conceptual lines pulled perpendicularly and diagonally from the intersections of the gridlines, resulting in intersecting dots known as "marmam". These lines represent the flow of positive energy, and no objects or structures are permitted to obstruct this flow within the conceptual intersections. Therefore, the "marmam" or dotted areas are typically reserved for fenestrations and openings, ensuring the unobstructed flow of energy.
Visually, the mandala, sutram, and marmam collectively form the geometrical orientation principles that govern the layout of a nalukettu. Structurally, a nalukettu consists of four independent halls (salas) surrounding a central courtyard, each facing one of the four cardinal directions. A single proper hall (sala) comprises the main hall (vidik sala), distinguished by a ring beam or wall plate, an extended beam (diksala) to adjust the hall's length, and a connecting structure known as alindam. Together, these multi-layered principles, including the mandala, marmam-sutram, fourfold salas, and diksala-vidik sala, form the structural foundation of a nalukettu. These prescribed configurations collectively represent the axis mundi or the central, sacred core of the house, emphasizing the profound cultural and architectural significance of Kerala's courtyard houses.

2.3 Types of Courtyard Configurations in Nalukettu

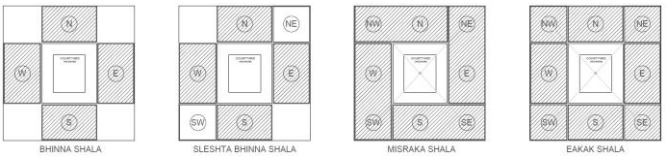

Figure 2 Types of Chatursha la and Courtyards (author)

Courtyards within Nalukettu homes, known as "anakanam," exhibit various styles across different communities, while certain common characteristics persist:
Courtyard Size: Courtyards in nalukettu homes typically have small dimensions, usually ranging from 1.8 meters to 5 meters in span.
Open Courtyard Design: Most courtyard houses have outer walls, and at least one hall opens into the courtyard, fostering a sense of connectivity with the outdoors.
Universal Significance: Regardless of religion or community, the kitchen, well, and orientation toward a nearby river hold significant importance in most Nalukettu houses.
Walled Wooden Hall: Many courtyard houses feature a walled wooden hall situated within the courtyard. This hall serves various purposes, including housing a raised granary in the middle (ara), providing a semi-basement storage pedestal (nilavara) for storing utensils and farming tools, and containing one or two supporting rooms (kalavara) adjacent to the ara.
These common elements contribute to the unique charm and functionality of Nalukettu courtyards, reflecting the cultural and practical aspects of Kerala's traditional architectural heritage.

2.4 Optimizing Indoor Comfort: A Residential Thermal Environment Study

Ensuring a comfortable indoor environment in residential buildings is a multifaceted undertaking, influenced by various critical factors. These factors encompass the prevailing microclimate conditions within the space, including humidity levels, radiant temperature, air temperatures, and air movement. Equally important are the physiological attributes of the occupants, such as their metabolic rate, activity levels, and clothing choices. Achieving an optimal indoor thermal condition is paramount as it contributes to the creation of a comfortable and healthy living space that safeguards the well-being of its occupants. Indeed, thermal comfort is among the foundational physiological and biological needs of humans. Regardless of external environmental conditions, the human body strives to maintain a constant core temperature of approximately 37°C, with an allowable range of ±5°C.

Maintaining indoor thermal conditions within acceptable parameters holds great significance in maximizing human productivity and performance. The indoor thermal environment is profoundly influenced by the local climate, and efficient air circulation within buildings becomes imperative to alleviate discomfort resulting from overheating, a prevalent issue in tropical climates [15].

The indoor thermal environment is markedly shaped by various environmental factors, including air temperature, air movement, humidity levels, and radiant heat. In regions characterized by warm and humid climates, external air movement assumes a crucial role in regulating the indoor environment [16]. It is worth noting that in contemporary times, occupants frequently turn to the use of air conditioning systems to achieve comfortable indoor conditions in tropical climates. However, this reliance on mechanical systems for health and comfort has led to a notable surge in energy consumption within residential buildings [17]. The building sector is acknowledged as a significant energy consumer, particularly during the utilization phase, primarily for heating and cooling purposes [18]. Consequently, there is a pressing need to prioritize energy efficiency in the initial stages of building design to reduce energy consumption throughout the building's lifecycle.

Research conducted by Yoshino et al. (2006) underscores the effectiveness of strategies such as thermal insulation and airtightness in conserving energy for space heating within the residential sector [19]. Additionally, findings by Jamaludin et al. (2013) reveal that the linear layout of building structures can restrict the utilization of natural daylighting and ventilation, ultimately affecting the indoor comfort levels of occupants [20]. Hence, optimizing building designs to respond effectively to the local climate can significantly enhance the indoor thermal environment while concurrently reducing energy consumption.

The design phase of buildings plays a pivotal role in mitigating solar heat gain, with factors like the orientation of the structure being of paramount importance in managing energy costs [18]. Achieving a balanced ratio of external window area to external wall area can effectively control the penetration of solar radiation into the building, contributing to a more energy-efficient design.

In summary, creating an indoor thermal environment conducive to comfort and well-being in residential buildings within Kerala's tropical context necessitates a holistic approach that integrates climatic responsiveness, energy conservation, and occupant satisfaction. Such an approach is essential to address the escalating energy demands and enhance the sustainability of residential building designs in tropical regions.

3.0 Results and Discussion

The architectural character of residential homes often mirrors a region's climate, the availability of building materials, economic circumstances, and the rich cultural heritage of its residents [Hutchison, 2002]. Within this context, the traditional Malay house serves as a captivating example of vernacular architecture deeply rooted in historical environmental sustainability [21]. The construction and design of traditional Malay architecture were underpinned by sustainability principles encompassing energy efficiency, the creation of a superior indoor environment, sustainable site planning and management, and the utilization of locally sourced materials and resources [22].

The climatic design of traditional Malay houses exhibited a profound connection to the microclimates of their surroundings, using readily available materials to cultivate a cooler indoor environment conducive to occupants' thermal comfort. Elevated on stilts, these houses facilitated ventilation at the occupant's body level, a feature that naturally promoted cooling [23]. Crafted from locally sourced sustainable materials, including bamboo, softwood, hardwoods, tree barks, and Nipah palm leaves (Nypa fruticans) commonly found in tropical forests, these homes epitomized an eco-conscious ethos [23]. The successful integration of environmental factors into traditional house designs underscored the Malay people's historical grasp of climate-responsive architectural principles [24]. Traditional Malay houses fostered a dynamic integration of local societal, cultural, and environmental needs, nurturing a sense of community and harmony [25]. Characterized by numerous windows and a design that maximized wall-to-floor height, these dwellings prioritized cross-ventilation, thereby ensuring excellent indoor air quality and temperature control [26]. The strategic placement of openings facilitated the inflow of fresh air, the expulsion of indoor pollutants, and the circulation of used air [26].

Traditional Malay architecture esteemed the local climate, with outdoor elements designed to respond to the exposure of building surfaces, considering the aesthetic impacts of sunlight and sky conditions. This reverence for climatic nuances underscores the enduring importance of climate-responsive design in contemporary architectural solutions [27]. Through comprehensive interdisciplinary research encompassing fields like mathematics, engineering, materials science, sociology, and anthropology, the potential inherent in this evolved traditional Malay house becomes evident, offering valuable insights for modern housing planning [28].

Significantly, within tropical climates, the thermal performance of building envelopes is profoundly influenced

by the amount of solar radiation absorbed and admitted through openings [29]. Hence, the design of building envelopes warrants meticulous consideration in evaluating energy efficiency during the design phase. These sustainable design principles, deeply embedded in traditional Malay courtyard houses, continue to inspire contemporary architectural solutions that prioritize indoor thermal comfort within tropical contexts.

Therefore, it is crucial to sustain the fundamental understanding of climatic responsiveness in contemporary building design [27]. Through exhaustive and detailed research involving various knowledge disciplines such as mathematics, engineering, materials science, sociology, and anthropology, the potential offered by this evolved traditional Malay house can make a significant contribution to modern housing planning [28]. The thermal performance of building envelopes in a tropical climate is profoundly influenced by the amount of solar radiation absorbed and transmitted through openings [29]. Consequently, building envelope designs must be thoughtfully considered to assess energy efficiency during the design process.

4.0 Conclusions

Within the realm of sustainable building design, the paramount consideration is the well-being and comfort of its occupants. The indoor thermal environment stands out as a pivotal element, playing a profound role in sustaining peak human productivity and performance. Especially in warm and humid climates, the optimization of indoor thermal performance relies on effectively reducing excess heat from solar radiation whenever feasible. The local climatic conditions of a region wield substantial influence in delivering a thermally comfortable indoor environment. These climatic attributes exert a profound impact on various aspects of building performance, notably energy efficiency, the quality of the indoor thermal environment, and their ramifications on the surrounding environment.

Fundamental climatic characteristics, including temperature, humidity, air quality, potential sources of pollution, solar intensity, wind patterns, soil conditions, and site drainage, collectively contribute to shaping the sustainable design of buildings. A holistic approach to sustainable building design not only influences human productivity but also affects the operational efficiency of buildings and the judicious use of natural resources. The integration of critical elements such as building site location, orientation, and geometry, building envelope, layout arrangement, and an understanding of local climatic characteristics forms an indispensable framework that distinctly impacts both the occupant's environment and the overall efficiency of the building.

Essentially, the pursuit of sustainable building practices in tropical contexts, as exemplified by Traditional Kerala Courtyard Houses, underscores the need to harmonize the built environment with the natural surroundings. This harmony, facilitated by a profound understanding of local climate conditions and adherence to climate-responsive design principles, holds the key to achieving indoor thermal comfort while concurrently preserving environmental integrity. As we advance into an era where sustainable living is paramount, these insights from traditional architectural wisdom continue to guide us towards the creation of buildings that are not only functional and efficient but also conducive to the well-being of their occupants and the broader ecosystem..

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