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A study on sustainable design principles: A case study of a vernacular dwelling in Thanjavur region of Tamil Nadu, India

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Traditional architectural principles always respected nature, and was climate conscious, user-friendly, reflected the culture and tradition of the community at large and most important was contextual. Various parameters such as geographical location, climatic conditions, occupation, culture and tradition of the society/ community decide these principles in a specific set up and make the structures sustainable in all respect. So, a specific case study example was selected and explored to understand these principles adopted in the structures and their performances over a long period of time in an identified study area in Thanjavur region of Tamil Nadu, India and assessing their appropriateness in the present context. The selected sample was analysed based on its architectural qualities in terms of spatial design, scale and proportion of the building components, integration with nature and thermal performance study during hottest day and the coldest day of the year using ECOTECT software. This paper specifically aims at identifying and understanding the generic sustainable principles in traditional and vernacular architecture that could be imbibed and incorporated by designers and builders at large to create appropriate buildings suitable to that particular context.

Keywords: Generic sustainable principles, Appropriate buildings, Traditional architecture, Nature, Climate conscious, Culture and tradition

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Vernacular architecture is the source of essential knowledge for sustainable, energy efficient and climate responsive architectural design principles. It is significant and unique in terms of the concept of balance within everyday life. The direct relation to human needs and accommodation of economy, belief and cultural values yields a phenomenological sense of place that is therefore important value to the study of architectural design[1]. Understanding vernacular architecture should be not as the study of past traditions but as a contribution to new methods, solutions and achievements for the future built environment[2]. The need for the understanding through study and analysis of vernacular architecture is getting increased day by day as the present scenario of climate conditions and energy consumption of built forms is the major crisis and contributing to the environment degradation. It expresses a higher degree of design sensitivity through their modest structures. This has been more powerfully explored in domestic architecture. They address the local climate constraints and shows maximum adaptability and flexibility[3]. It is a direct response to context and resources including materials and techniques using available potentials such as the indigenous skills of the locale passed on from generations to generations. There is a close connection between energy use in buildings and the resulted environmental damage[4]. All the building materials used to construct the vernacular houses are available locally. This provides an edge on environmental front as less energy is involved in processing and transportation and henceforth minimal environmental degradation[5]. Building sector electricity consumption has increased from 14% to nearly 33% in 2004-2005 (BEE, 2010)[6]. If energy efficiency measures are incorporated in the buildings judiciously, then the potential for energy savings could be 40%- 50% in these buildings (BEE, 2010)[6]. Climate responsive buildings or solar passive buildings with advanced active systems seem to be most appropriate and efficient solutions to this problem[6]. The utilization of solar passive methods and techniques in modern buildings to achieve thermal comfort allows the possibility of decreasing the

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dependence on fossil energy as much as possible and realizes sustainability[4]. Bioclimatism integrates the micro climate and architecture to human thermal comfort conditions. Recent studies on vernacular architecture conclude that bioclimatism is an integral part of vernacular architecture and a deciding parameter towards achieving sustainability of modern architecture[3].

Research methodology

The research is aimed at exploring the generic sustainable principles in vernacular architecture of Thanjavur region of Tamil Nadu, India by selecting, documenting and analyzing a case study example in one of the traditional settlements in this region.

Documentation of the selected sample dwelling

Understanding contextual relevance and conditions

Thanjavur is a traditional town which dates back to 3rd century AD and located in South-East part of India at 10°46′56.99″N latitude and 79°7′52.51″E longitude with an elevation of 88m MSL. It is located in almost the geographical centre of Tamil Nadu and possesses rich culture and tradition. Due to its geographical location, the vernacular architecture of this region could be considered as a representative style whose influence is seen in all the vernacular traditions prevail in other parts of Tamil Nadu. So, the study was conducted in a selected sample in Vallam, one of the traditional settlements (Fig. 1) to identify and understand the appropriateness of the generic sustainable principles in the vernacular architecture of this region.

Description of the selected sample

The selected sample dwelling falls is 150 yrs old and belongs to an agricultural family consists of 6 members. The orientation of the house is North-South and it is facing southern direction. It is a small tile roofed structure has a typical plan (Fig. 2) of this region measuring 12m x 15m. It has a raised platform on either side of the main entrance to the house which is the transitional zone. The entire dwelling consists of a small courtyard almost a square at the centre measuring 1.6m x 1.5m. The living hall is located on one side of the courtyard and few private rooms on the other side. The house abuts the wide street at its front and an open yard at its rear side each dwelling has a backyard space where kitchen garden and outdoor washing area are located. A small pit in the backyard area is an essential feature of all the dwellings in this settlement where the kitchen waste

Fig. 1—Map of study area – *Vallam* settlement

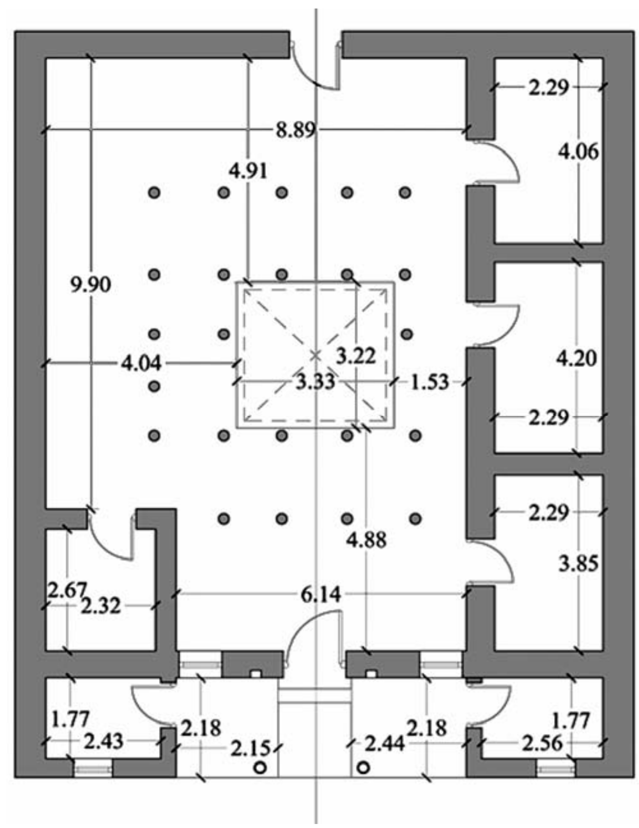

Fig. 2—Plan of the selected sample dwelling

and cow dung are stored, gets decomposed and becomes the compost - the organic manure.

Analysis of the dwelling

A solar passive house or structure is designed such that it makes effective use of solar radiation to warm up indoors in winter for heating and to block out this radiation in summer for cooling and provides better indoor illumination through natural lighting[6]. The solar passive building design techniques were practiced for thousands of years, by necessity before the advent of mechanical heating and cooling[6]. The scientific basis for passive solar building design has been developed from the combination of local climate, solar heat gain or loss and human thermal comfort. Most often the solar passive features in the vernacular buildings are very difficult to quantify scientifically. The effectiveness of the solar passive features is explained on basis of building planning and orientation, building components, spatial design and activities of the inhabitants[6].

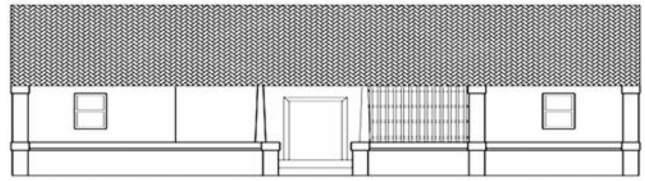

Fig. 3—Elevation of the selected sample

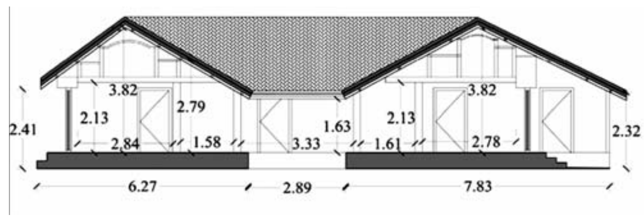

Fig. 4—Longitudinal section of the dwelling

Planning and orientation of the buildings

Climate of a region has a direct influence on the settlement and in its built form. Being in a warm humid climate where the temperature ranging from 27°C to 42°C in summer and 19°C to 30.5°C in winter with the RH ranging from 45% – 65%., the settlements in this region show a moderately dense, low rise development (Figs. 3 & 4) with courtyard type dwellings as its characteristics. The planning shows a regular grid iron pattern with each street in East-West orientation. In the lay out plan, the residences are set within a narrow plot abutting the street edge in its front forming a strict row housing pattern. But each house has a small lane on its side (Fig. 5a) which provides access to the backyard without entering the house. This makes the rigid street slightly porous which facilitates continuous air movement within the settlement. The exposure of building surfaces to direct solar heat is reduced to a maximum by planning the shorter side of the linear form facing the street. In addition, the eaves are projecting 0.7m beyond the front edge of the house so that the front wall is completely shaded from 10 AM onwards thus considerably reduces heat gain.

Fig. 5—Planning and spatial design of vernacular dwellings in *Vallam*: (a) Small lane in between the dwellings (b) Front *thinnai* – the socializing space for all age group

Design and spatial flexibility

The vernacular dwellings are adapted to specific social and cultural contexts. The built spaces are not arbitrary: They are the expressions of a reality slowly elaborated during centuries executed with local techniques and means, expressing precise functions and satisfying social, cultural and economic needs[12]. The local builders and residents always try to amalgamate the climatic constraints, culture, social, economic and religion while constructing these built environment with available resources and affordable technology. The strength of vernacular architecture is that it makes buildings that are in natural harmony with climate, built form and people. In traditional Indian architecture this harmony with nature was an important design element[7]. In addition to this, bringing natural elements inside the dwelling unit had been created effortlessly by the builders of the past. By their character, originality and the lack of pretention, the vernacular dwellings integrate themselves lithely and naturally in the surroundings[9]. Through the small courtyard, the inhabitants of the house could have their personalized sky, sun, moon and rain which make the dwelling as a micro-cosmos. This in turn facilitates designing of the micro climate, adaptation of passive energy techniques, etc.[7]. Vernacular architecture sets an example of harmony between dwellings, dwellers and the physical environment[8].

The spaces in this dwelling are minimum and flexible in nature. The raised platform on either side of the main entry is the connecting element for the house with its exterior. This is the main source of social activities which enhances societal bonding (Fig. 5b). The quality of spaces mainly depend upon its flexibility, the way in which they were organized and the quality of natural light inside these buildings. There are no rigid divisions or demarcation inside the house and spaces are flowing into the other. Because of this flexibility of spaces, different activities could be performed in the same space at different period of time. Table 1 summerises the flexibility of the important spaces in this dwelling.

There is a perfect balance between the human beings and the environment. Therefore, it is possible to live in harmony with nature without wasting the opportunities and giving harm to the nature unless its principles are taken into consideration[8]. These kinds of structure evolve over time to reflect the environmental, cultural and historical context in which they exist. It represents solutions which show maximum adaptability and flexibility and thus sets an example towards sustainability[10]. For sustainable solutions, environment and traditions are not supplementary to each other but are pre-requisites.

Building components

The structures are having varying wall thickness and construction techniques. The outer walls (65 cm thickness) are composite construction (Fig. 6a) having core constructed with flat bricks (8.5cm x 11cm x 4cm) in mud mortar lined externally with dressed laterite stone (10cm x 55cm x 30cm) . This provides excellent thermal insulation properties for the structure. The inner walls are constructed with an exclusive indigenous technique adopted in this region. The laterite soil, lime, sugarcane molasses, papers and *Nutmeg* (*kadukkai* - a herbal plant) juice are mixed well and ground manually and the mixture is used for constructing the wall. The roof is made of country wood or bamboo rafters and battens covered with two to three layers of pan tiles (Fig.6b). The sloping roof is one of the major climate responsive elements in vernacular setting. It plays a significant role in reducing the incident heat on the surface due its angle of slope (30°-35°) and in reflecting the maximum amount of heat back. The roof height near ridges is 5m (Fig. 6b) which acts as a major insulation space and facilitate a good air flow inside. Doors and windows are the only openings in the vernacular dwellings and they are minimum in numbers. The sizes of these openings are small (0.9m x 1.8m for doors and 0.45m x 0.75m for windows) which regulate the air flow and controls the amount of light entering the buildings. Front and back door alignment with courtyard eases the wind flow from exterior to interior (Fig. 6c). The side walls of the structure are provided with no windows to maintain the privacy, temperature and required lighting level. The courtyard has a greater impact on the thermal performance of the dwelling. It is an excellent thermal regulator in many ways. The heat gain from the sun will be more in the upper part of courtyard. This makes the air in the upper part of courtyard warmer and lighter, causing the air to move upwards (Fig. 7). Thus a low pressure develops in the courtyard and induces air movement from outside, through the surrounding spaces. After sunset also the phenomenon continues till the air in the courtyard cools fully by convective flow[11]. Though the size of the courtyard is very small, it helps in providing natural diffused day light to the entire house which reduces the energy consumption to a greater extent. The passage around the courtyard with proper light, temperature and air flow acts as the space for household activities. It acts as a buffer space to filter the light to living area. Courtyard is also used for ablution and washing purposes. Most of the time as it remains wet it also keep the surrounding spaces cool. The habitable spaces are arranged around the courtyard in such a way as to permit adequate air movement in all seasons.

Thermal performance study through ECOTECT analysis

The study of thermal comfort is very important because it is correlated not only with occupants comfort,

Table 1—Activity analysis to show the flexibility of spaces

Type of space	Nature of space	Time	Activity	Users	Condition	Sustainable Vernacular technique
Streets (*Theru*)	Public	Morning up to 8 AM	Socializing /	Men/ Women/ Elders Children	• Provides a pleasant and healthy morning sunlight • Enhances community interaction	• Orientation of street is East west and this allows houses to face north south and thus reduce heat in the front and back yard • Massing is such that the blocks are mutually shaded
		Evening from 4.30 PM to 7.30 PM	Socializing / Playing			
Raised Platform (*Thinnai*)	Semi private	Morning up to 8 AM	Socializing with neigh hours	Men/aged people	• Provides • Fully shaded and Well lit space • Visual contact with almost the entire street	• Deep recessed space allows filtered light. • Projected eaves (0.7m) provides complete shading of the *thinnai* throughout the day. • Connects the exterior and interior thus enhances interaction at family level and community level.
		Noon from 11AM-3PM	House hold activities	Women / Elders		
		Night 7PM-onwards	Socializing, sleeping	Strangers, Visitors, elders/ Aged people		
Courtyard (*Mutram*)	Private	Morning up to 8 AM	Brushing, bathing and other morning activities	Children and men	• Aligned along the axis and provides good air movement. • Allows direct sunlight inside the house meant for drying activities	• The focal point of the dwelling and acts as an activity generator. • Seasons and moods of the outside world could be conveyed to the inmates through courtyards by bringing nature inside.
		Noon from 11AM-3PM	Washing and drying vessels, drying grains, etc,	Women		
		Evening 4PM–6PM	Washing and cleaning	Men and adults		
		Night 7PM-onwards	Washing vessels House hold activities / sleeping (during summer)	Women		
Living Hall (*Koodam*)	Private	Morning up to 8 AM	Preparatory activities	Whole family	• Provides diffused light to the entire space around the court to facilitate work environment.	• Location of the living area adjacent to the court enables the space to get maximum benefit out of the court. • High ceiling provides a good amount of air flow. • Flexibility of spaces enabled the hall to accommodate variety of activities thus facilitates the interaction at family level to a greater extent.
		Noon from 11AM-3PM	Family household activities	Women		
		Evening 4PM – 6PM	Studying and related activities	Students and adults		
		Night 7PM-onwards	Relaxation, dining and sleeping	Whole family		

Fig. 6—Building components and construction techniques: (a) Flat brick wall with laterite block covering (b) Naturally processed wooden roof trusses (c) Courtyard at the centre aligned along the axis

but also with energy consumption[12]. Thermal comfort of the interior determines the energy consumption by the environmental systems of a building and they play a vital role in building sustainability. Thermal comfort has been defined as the condition of mind expresses satisfaction with the thermal environment" [ASHRAE 55-74 standard (1)]. Hence, the indoor environment has to be designed and controlled in a passive manner so that occupants comfort and health can be assured with least amount of external energy[11]. There is a close connection between energy use in buildings and the resulted environmental damage. The utilization of solar passive methods and techniques in modern buildings to achieve thermal comfort allows the possibility of decreasing the dependence on fossil energy as much as possible and realizes sustainability[4]. Thermal performance study is one of the critical aspects of vernacular houses. Though these structures are evolved through generations, addressing the climate constraints and needs of residents, but still in depth study of thermal behavior is a necessity[5]. The thermal performance study is carried out for the hottest day of the year (April 30th, 2013) and the coldest day of the year (January 13th, 2013) using ECOTECT software for the selected house. It is evident from the results (Fig. 8) that, the difference in temperature between indoor and outdoor ambient temperature ranging with a minimum of 0.2°C and a maximum of 5.9°C. There is a drop in wind speed during this period in summer which is due to the external environmental conditions and the minimal vegetation. But the air circulation inside the dwelling due to the stack effect of the courtyard enhances comfort conditions. As there is a gradual increase in the thermal conditions of the entire environment, the internal temperature lies above the

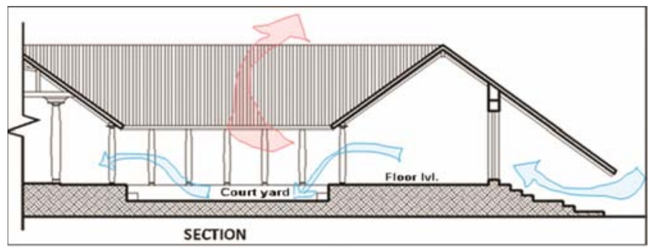

Fig. 7—Courtyard, minimum openings and projected eaves reduce the solar heat gain and regulate the air flow through the building.

comfort zone prescribed as per ASHRAE standards throughout the day in summer and during peak hours (11 AM to2 PM) in winter. However, the comfort conditions are achieved with the minimum help of mechanical devices.

Fig. 9 indicates that the difference between indoor and outdoor ambient temperature ranging with a minimum of 0.1^0 C (at 5.00 PM) and a maximum of 4.7^0 C (at 12.00 noon). The wind speed is slightly less during this period between 11AM to 4 PM in winter. During this time, there is no need for extra electrical instruments as the internal temperature lies well within the comfort zone. The completely shaded external walls on the eastern side, low wall height, presence of courtyard and the lane on its side reduces heat gain thus provide comfortable thermal conditions inside.

It is observed from (Fig. 10), that in the hottest day, the outdoor has a diurnal variation of 11.8°C, i.e. from 19.2°C to 31°C and the simultaneous indoor temperature was varying from 20°C to 30.1°C with a diurnal variation of 10.1°C (in living space around the court yard). Similarly in the coldest day, the outdoor has a diurnal variation of 12°C, i.e. from 29.8°C to

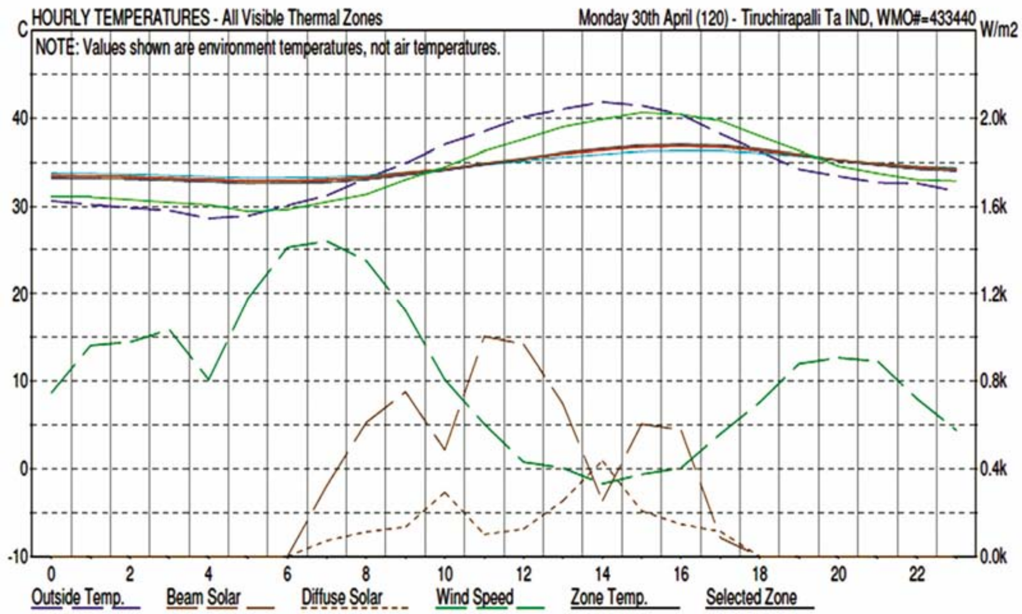

Fig. 8—Thermal performance analysis of the dwelling during the hottest day (April 30th, 2013) calculated through ECOTECT Analysis

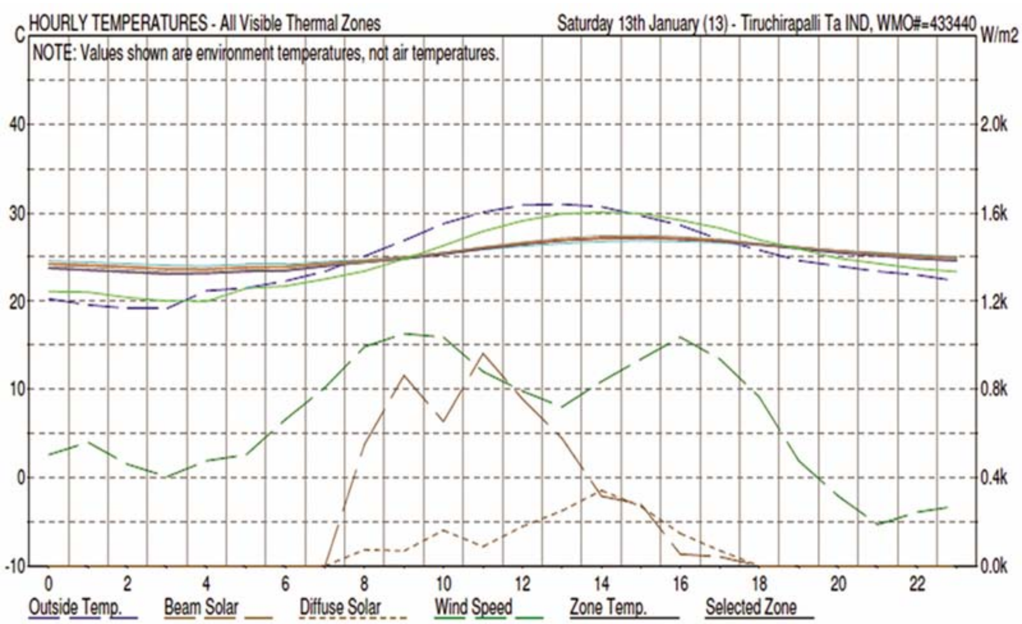

Fig. 9—Thermal performance analysis of the dwelling during the coldest day (January13th, 2013) calculated through ECOTECT Analysis.

41.8°C and the simultaneous indoor temperature was varying from 29.6°C to 39.8°C with a diurnal variation of 10°C (in living space around the courtyard). It is clearly understood that there is a temperature difference of around 10°C exist between the maximum outdoor ambient temperatures and minimum outdoor ambient temperatures in both the hottest day and the coldest day (Fig. 10). This kind of thermal comfort is achieved mainly due to the thermally insulative building components and the effect of internal courtyard provided within the living space. So it can be concluded that the traditional buildings continuously respond to the external climatic conditions irrespective of the seasonal variations.

Results and discussion

The study reveals that the identified dwelling is highly responsive to the climatic conditions and cultural and societal needs. It is mainly due to the sustainable principles adopted in the dwelling which are explored in terms of spatial design and flexibility, and energy efficient principles in this paper. It is very much necessary to check the relevance and applicability of these principles in present conditions to create appropriate buildings to the context. It is observed from the study and analysis, that:

The buffer spaces such as *Thinnai* and *Thazhvaram (*passage around the court) allow a gradual and smooth transition of movement from exterior to interior. In addition, it encourages and facilitates interaction with people leads to strengthening of societal bonding.

The spaces are minimum and accommodate multiple activities at various time periods. No space is left unused for more than one hour in a day. Flowing of flexible spaces encourages family interaction at a higher degree.

Courtyard is the vital space in vernacular dwellings. It is the focal point of the dwelling and acts as an activity generator. It is the source of lighting and ventilation and makes the house climatically responsive. It plays a major role in the behavioural aspects of inmates by bringing nature to the interior.

It is clear from the analysis that, the bond between the materials and the nature and the way they react or respond to the nature will never change. It is only the link between the people and the materials and the way they look at the materials and using them is getting changed in time which has impact on its architecture. It is very much essential to respect and learn valuable lessons from the past as the present scenario forces people to get away from the box in box life style due to globalization, modernization and urbanization at least for a short duration.

Flexibility, appropriateness and the energy efficiency of spaces in vernacular dwellings are the main concepts to be explored not only for the present but also for the future. A clear understanding of various design principles, methods and techniques of construction employed and materials used in traditional architecture would be useful in contemporary architecture by judiciously adopting them even while using suitable modern materials and modern technology[4].

Conclusion

The study and analysis of the vernacular architectural principles is not just to copy them in the present context but to have a better understanding of the environment, life style, tradition and culture of the society and their influence on the built forms. So it is concluded that the architectural built forms of the vernacular settlements have evolved in response to the climate, life style and availability of the materials and techniques specific to that region which ultimately lead to sustainability. The vernacular dwellings strongly express that, more than quantity of spaces such as variety and size it is the quality of spaces with most efficient use that matters. Spatial flexibility and the climate conscious design approach have been adopted in these structures which enhances the qualitative aspects of each and individual space. The desirable thermal comfort conditions are achieved in these houses with no or minimum use of mechanical devices. The thermal performance analysis clearly indicate that the thermal comfort conditions of individual spaces inside the dwelling always lie well within the comfort zone. It is all achieved mainly due to its planning aspects in terms of its plan, elevation, section, form and other architectural details of the structure. The materials used and the techniques adopted may be expensive and time consuming in present condition but the context and relevance of these aspects in satisfying the users need is highly appreciable and the essence of these need to be explored in modern context.

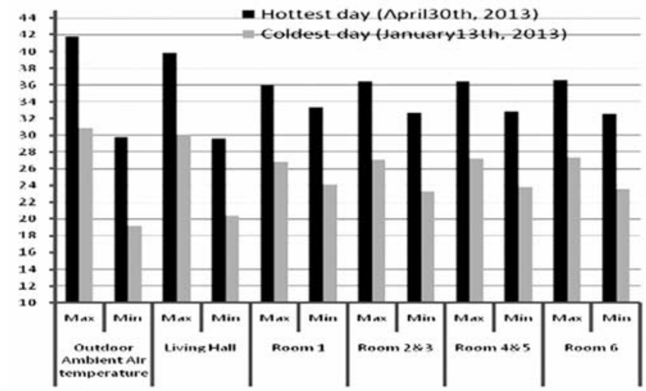

Fig. 10—Comparison of Air temperature during hottest day (April 30th, 2013) and the coldest day (January13th, 2013)

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