Evaluating the Thermal Performance of Traditional and Modern Toda huts in Nilgiris Hills

R. Shanthi Priya, S. Radhakrishnan

Abstract: Architecture is a physical manifestation of the needs and aspirations of the society and is determined by the environmental, socio cultural and political climate of a place or a region. Good architecture may be defined as any built form which is sensitive to the climate and context of a place. However in spite of its effectiveness and sustainability, traditional Architecture and its methods and strategies are often undervalued and are not preferred in new constructions. The Vernacular architecture of Toda huts in Nilgiris has developed sustainable strategies in planning and construction from their long standing experience. The traditional Houses in the Hilly region and Modern Houses are examined qualitatively and quantitatively to understand the Thermal Performance of the house. The results thus obtained were compared with Olygay Bioclimatic chart and found that the Toda houses were thermally comfortable irrespective of their outdoor Climatic conditions than Modern Houses.

Keywords: Thermal Performance, Traditional Building, Sustainable architecture

I. INTRODUCTION

Sustainable development is one of the most crucial challenges we face in the Architecture profession. High Energy Consuming and environmentally damaging buildings can no longer be considered as sustainable [1-5]. Passive and low energy – climate responsive buildings can improve human comfort and in doing so improve the human condition in all parts of the world [6]. Design strategies for passive and cooling of buildings presented by simos yannas discusses the overview of various elements of design that are responsive to their climatic context. S.V Szokolay in his book on Building Envelope presents the technique for control of heat flow through the envelope through mathematical formulations that help, analyse and design the Envelope [7]. Traditionally builders used knowledge and techniques passed on from generation to generation to ensure that the buildings constructed could withstand the impact of hostile outdoor environment [8, 9] The earlier vernacular residences which were found in the hills were found all along the Niligiris of Tamil Nadu. In contrast to the modern buildings, the vernacular architecture in this Hilly region is more adoptable to environment in many ways. The vernacular dwellings of Ooty represent the principle of climate oriented architecture [18]. These are constructed with locally available materials and are in accordance with traditional lifestyles. This paper intends to find out qualitatively and quantitatively during summer to assess the behavior of these residences with respect to the thermal comfort.

II. CLIMATE OF OOTY:

The general climatic condition in this region is col. Although situated in the tropical zone, this region enjoys a sub-tropical to temperate climate by virtue of its altitude. The variation of temperature throughout the year exhibits a cold climatic condition in study area. Ooty enjoys a pleasant climate throughout the year. Due to the presence of high mountain ranges, southwest monsoon is not very strong but northeast monsoon causes heavy downpour during the months of October and November. The Outdoor Ambient temperature recorded during summer varies from 26°C to 32°C and during winter varies from 17°C to 24°C.

Table: 1

	J	F	M	A	M	J	J	A	S	O	N	D
Min. Temp (°C)	17	19	20	21	26	25	20	20	20	20	19	18
Max. Temp (°C)	24	29	31	32	30	26	25	25	26	26	26	26
RH	50	50	60	70	70	75	60	65	70	70	60	60
Wind Speed (km/	5	5	6	6	7	7	7	7	6	6	5	5

Revised Manuscript Received on July 06, 2019.

R.Shanthi Priya, Kalasalingam School of Architecture, Kalasalingam Academy of Research and Education, Srivilliputur, Tamil Nadu, India

S. Radhakrishnan, Prime Nest College of Architecture and Planning, Affiliated to Anna University, Chennai, Tamil Nadu, India

III. RESEARCH METHODOLOGY

STEP	Methods	Materials	Results Achieved
I	Climate Zoning	Ooty in Nilgiris Hills	Climatic Analysis
II	Documentation and collection and analysis of data's	Vernacular Toda House, Modern House	Arrived at Architectural Typology
III	Systematic Analysis	Investigation on Climate Responsive Design Strategies.	Qualitative Evaluation
IV	Systematic Analysis	Hobo Data Loggers	Quantitative Evaluation
V		Results and Discussions	Concluding Remarks

IV. DESCRIPTION OF A TRADITIONAL TODA HOUSE

Toda hamlets have barrel shaped huts (Munds) scattered across the hilly terrain. Toda Village comprises of several Toda huts known as mund and these houses are rectangular in plan, 17 feet long and 8feet wide with a vaulted roof of height 10 feet which touches the ground. The approach to the hut is through eastern entrance, 3 feet height and they crawl to enter inside the house. The main reason for having a small entrance is to protect the people from weather. The spatial organization of a typical Toda house reflects the principle of binary opposites with a strong axis created by entrance door and subsequent openings. With orientation of the viewer facing towards the front of a dwelling, if the entrance is slightly to the left between two sitting platforms within the front porch, inside there will be an earthen sleeping platform , 45 – 60cm high to the right and a working area to the left and vice versa. Binary opposite of the gender roles in the community are seen with an mortar distinguishing the more public male spaces in the front part of the house, where males churn sacred milk with the aid of a churn pole next to the front wall and the private female spaces in the back, where there is a fireplace, a storage platform, and often several shelves above it for the storage of a wide assortment of vessels which a Toda family likes to display. The most auspicious space of the house, the puja room is located adjacent to the entry. The front façade of the Toda huts constructed with stone and decorated with symbols of sun, moon, floral motifs and buffalo horn forms. The houses are seated at a depth of 2 feet from ground level and it surrounded by a boundary wall of 3' height to define the territory of each hut and also it act as a wind shield to prevent **the vault from extreme wind at high altitude [Table -3].**

Figure: 1 Toda Hut   Figure: 2 Toda huts with boundary wall

IV. (a) BUILDING FORM AND ORIENTATION:

The houses are constructed in rectangular shape with vault like structures. All the houses are oriented towards eastern and western direction to receive the maximum radiation. The houses were protected with heavy compound walls and they are constructed in such a way that they do not fall in the path of prevailing winds.

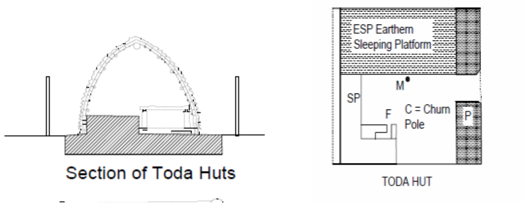

Figure 3(a): Layout of Toda huts (18, 19)

IV (b) WALLS AND ROOFS:

The walls were constructed with Light weight structures and the thickness of the Bamboo wall is around 0.3metres and stone wall is around 0.45metres. The Building envelope is constructed with Bamboo, cane and dried grass is stacked over this as thatch and it is closely constructed to minimize the infiltration. Dried grass acts as an excellent insulator and minimizes both heat gain or heat loss. The front and rear side walls of the house are constructed with stones and it is 0.45m thick. Thicker stone walls or walls with high thermal mass stores heat during the day and it is radiated in to the night. Toda huts are constructed with barrel Vault roofs and it absorbs more solar radiation during the day and dissipates the heat during night.

IV(C) SHADING AND OPENINGS: In Toda houses windows are not present and the size of the door is only 3' by 3'. The percentage of openings is only about 10% of the total floor area and the ratio of window to wall is about 0.10. No shading techniques were used and all the walls receive maximum solar radiation available.

4(d) SURFACE AREA TO VOLUME RATIO:

Shape	Surface Area	Volume	Ratio (S/V)
Rectangular Shape	76.2	45	1.6

The surface area to volume (S/V) ratio is an important factor determining heat loss and gain. In Toda Houses the Surface to Volume ratio is low to minimise heat loss.

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Table - 3

Building Form	**Compact**	**Very less open spaces**
Orientation	**Longer walls facing North – South – Shorter walls facing East – West**	**receives more solar heat during summer and winter months**
Shading Devices	**Not present**	**Building envelopes receive maximum radiation**
Openings	**No windows, Low doors Only door 3' x 3' facing east**	**Openings are minimum to prevent heat loss**
Walls	**Type – I Thick Stone wall front and rear side of the hut. Type – II Bamboo and cane walls with dried grass over layed.**	**Thick walls stores heat during the day and dissipate during night.**
Day Lighting	**Poor**	**Due to minimum openings**
Perimeter to wall ratio	**minimal**	**Ensures minimum heat loss**
Ground Character near the hut within the boundary wall	**Stone paving**	**Store more heat and reradiate it at later time. Increases absorptivity and reflectivity**

V. DESCRIPTION OF A MODERN TODA HOUSE:

The Modern Toda House selected for the Experimental Investigation had a huge raised platform in the entrance, Living hall, Bedroom, Dining and Kitchen. The modern house for experimental Investigation was selected in the same Locality at a distance of 150 m from the traditional House. The walls and roof of the Traditional Toda house looks like a barrel vault constructed with a Ferro cement technique and plastered with cement mortar. It is a simple rectangular plan with interior walls dividing the rooms. The windows and doors are provided at the entrance. The height of the room is 4metres. The Longer walls are facing north – South and the shorter walls are facing East – West. The average room height of the building is 4m. The windows are **of** size 1.0m x1.2m and door 1.0m x2.5m facing in East and west direction. The projection of roofs acts as shading devices for doors and windows and it projects for about 45cm from the building outline for protection from sun and rain. The thickness of the wall is around 0.27metres .

Figure – 3(b) – Modern Toda House

VI. QUANTITATIVE STUDY

Experimentation setup

The Instruments used for investigation is called as Mini meteorological station and Hobo data loggers were fixed both outside and inside the traditional and Modern House and the comfort parameters like Air Temperature, Relative Humidity, wind speed were measured simultaneously with 30 minutes interval in the data logging system.

VII. RESULTS AND ANALYSIS FROM TRADITIONAL

BUILDING

From the Experimental Investigation, it was found that the Outdoor ambient air temperature has a diurnal variation of 14°C i.e from 16°C to 30°C (Figure:5,6). The indoor temperature has a diurnal variation of 6°C i.e from 22°C to 28°C. The temperature recorded in the room during the night is found to be 26°C to 28°C when the outside temperature is as low as 18°C(Figure:5,6) Figure :7 shows the variation in temperature and Relative Humidity corresponding to Outdoor and room. The Relative humidity Outdoor is fluctuating between 60% to 70% and it reaches its maximum 70% during day time when the outdoor ambient temperature reaches 30°C and its minimum 60% during Night time when the outdoor ambient temperature reaches 20°C. During day time the Relative Humidity outdoor reaches its maximum (60 to 70%)the relative humidity indoor is fluctuating between 50% to 60% only. The diurnal variation of Relative Humidity Outdoor (figure -6) is 10% and the diurnal variation of Relative Humidity indoor is only 10%. The air movement is recorded both outdoor and indoor at an interval of one hour for a period of 3 months (Figure:5,6) While the Outdoor wind velocity is highly fluctuating and reaches its maximum i.e more than 10 to 20 m/sec, the indoor wind velocity is maintained around 0 to 1m/sec. The room temperature and the Relative Humidity show a diurnal

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variation of 8°C and 10%. The room temperature shows a diurnal variation of 8°C due to thick stone and bamboo walls. The Relative Humidity indoor is controlled and maintained within the building and it ranges from 50% to 60 % when the outdoor humidity is 70% due to the presence of small door. There is a mild air movement recorded because the percentage of openings is only about 10% of the total floor area and the ratio of window to wall is about 0.10. The Time lag observed is 10 hrs. and the building envelope stores heat during the day (radiation observed by the walls and roofs) and dissipates heat inside the room during night and increases the room temperature when the outdoor is cool and minimizes heat loss in buildings. When the results are compared with Olygay Bioclimatic chart, it is found that the results lies within the comfort zone and hence proved that Toda hut is thermally comfortable.

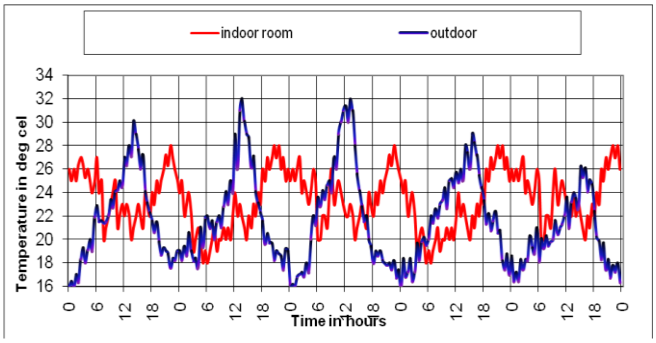

Figure 5: Air Temperature vs Time

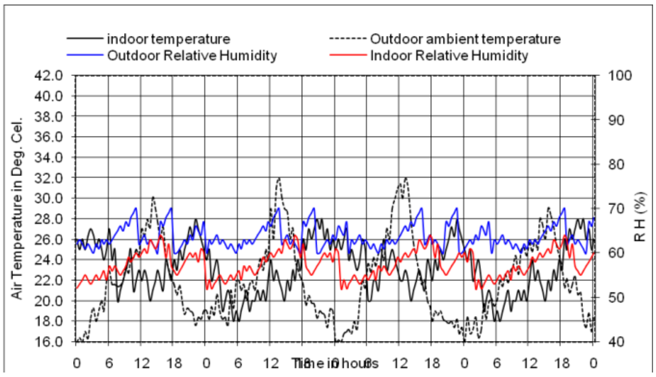

Figure: 6 Air Temperature vs Relative Humidity vs Time

VIII. RESULTS AND ANALYSIS FROM MODERN TODA HOUSE

From the Experimental Investigation, it was found that the Outdoor ambient air temperature has a diurnal variation of 13°C i.e from 17°C to 30°C (Figure:7,8). The indoor temperature has a diurnal variation of 10°C i.e from 15°C to 25°C. The temperature recorded in the room during the night is found to be 15°C to 20°C when the outside temperature is as low as 16°C(Figure:7,8) Figure :7 shows the variation in temperature and Relative Humidity corresponding to Outdoor and room. The Relative humidity Outdoor is fluctuating between 65% to 75% and it reaches its maximum 75% during day time when the outdoor ambient temperature reaches 30°C and its minimum 65% during Night time when the outdoor ambient temperature reaches 17°C. During day time the Relative Humidity outdoor reaches its maximum (70 to 75%) the relative humidity indoor is fluctuating between 65% to 70% only. The diurnal variation of Relative Humidity Outdoor (figure -8) is 10% and the diurnal variation of Relative Humidity indoor is only 5%. The air movement is recorded both outdoor and indoor at an interval of one hour for a period of 3 months (Figure:8) While the Outdoor wind velocity is highly fluctuating and reaches its maximum i.e more than 10 to 20 m/sec, the indoor wind velocity is maintained around 0 to 2m/sec. The room temperature and the Relative Humidity show a diurnal variation of 8°C and 10%. The room temperature shows a diurnal variation of 5°C due to thin walls constructed with ferrocement of 0,27metre thickness. The Relative Humidity indoor is controlled and maintained within the building and it ranges from 65% to 70 % when the outdoor humidity is 70% due to the presence of door and windows. There is a mild air movement recorded because the percentage of openings is about 20% of the total floor area and the ratio of window to wall is about 0.25. the Building Envelope of the Modern Building absorbs heat during the day due to increase in outdoor temperature and radiation. The heat is transmitted through the building envelope and the delay in transmitting the heat is known as time lag. The Time lag observed is 3 hrs. and the building envelopes stores heat during the day (radiation observed by the walls and roofs) and dissipates heat inside the room during day itself and increases the room temperature when the outdoor is hot and during Night Modern Toda house is cool and the temperature is 15°C due to maximum heat loss in buildings due to ferrocement building envelope and due to the presence of openings. When the results are compared with Olygay Bioclimatic chart (figure-10), it is found that the results does not lies within the comfort zone and hence proved that modern Toda hut is thermally uncomfortable.

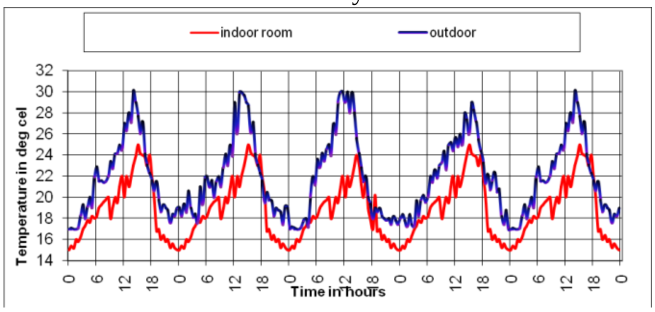

Figure – 7 Air Temperature Vs Time in modern House

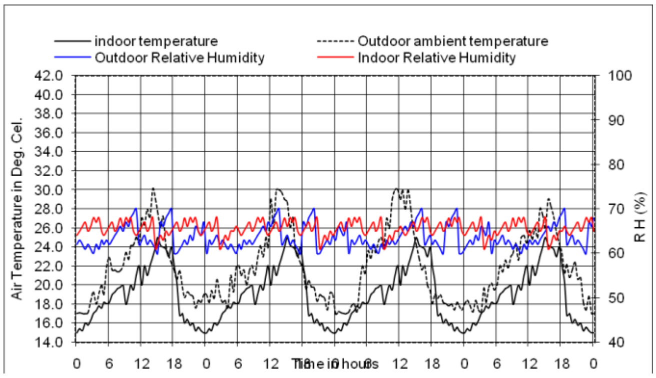

Figure – 8 Air Temperature vs Humidity vs Time in Modern Building

IX. COMPARISON OF RESULTS

The results of Modern and Traditional Buildings were compared and observed that, when the minimum temperature recorded in both the buildings are not same and it was found that minimum temperature of traditional buildings is higher by 5°C. From the figures it was found that the diurnal variation of traditional (6°C) and Modern House (10°C) also varies and it is evident that there exist a difference in the Thermal Comfort levels of Traditional and Modern House. (Figure-9)

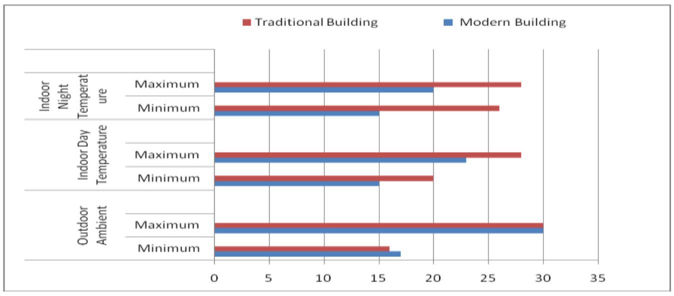

Figure – 9 Comparison of Traditional and Modern House

X . DISCUSSION OF RESULTS

The Time lag is an important factor in determining the Thermal Comfort. The Time lag observed in Traditional House is 10 hours and in modern house it is 3 hours. The Modern House lies in harmony with the Outdoor ambient temperature and during Night the Modern house is found to be cool than the Traditional House. In traditional House the walls are constructed with stones, Bamboo post and dried grass and it has a high thermal capacity due to additional layers of Bamboo, Cane and grass stacked one above other increases the thermal time delay for about 10 hours. The thermal time delay is mainly influenced by the thermo physical of the material and their relative location.The Envelope absorbs the radiation stores in the envelope and radiates heat inside the building during Night when the Outdoor temperature is less i.e 15°C, the indoor temperature varies from 26°C to 28°C and the traditional Toda hut.

XI. CONCLUSIONS

The Vernacular Toda huts were greatly influenced by **the** prevailing climatic conditions and the houses are designed for maximising solar heat gain and minimizing heat loss. These houses are designed with locally available materials. From the quantitative study the thermal performance of the houses lies within the adaptive Model of Olygay Bioclimatic chart. Vernacular Buildings in Hilly regions make good models for sustainable design lessons and often serve as laboratories for architects as these are comprehensive due to their often simple planning techniques, forms and resourceful use of materials and technology. The design clues from these typologies can be used in the future for designing a sustainable habitat.

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AUTHORS PROFILE

She has completed her Ph.D under Faculty of Architecture and Planning, Anna University, Chennai specialized in the area of Building Science. She has completed two Major Research Projects form UGC and published around 20 papers in reputed National and International journals.

Graduated from NIT- Bhopal and PHD from Anna University, Chennai He is backed with three decades of Professional, Academic and Research Experience in India especially teaching at various reputed Architectural colleges across North and South India. He is specialized in the area of Thermal Comfort studies and Sustainable Architecture.

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