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Exploring the Passive Technique for Achieving Thermal Comfort in an Indigenous Architecture of Kerala

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***Abstract*: In a rapidly developing economy globalization, energy crisis, mass migration, climatic changes, etc. are leading to mass consumption of energy to achieve indoor thermal comfort. However traditional building with less dependence on technology has skillfully mastered the effective technique to neglect the harness sun rays and remain comfortable. Traditional architecture is the best example of evaluating how architecture evolved according to human requisite without distressing the ecological cycle. This paper deals with the study features of the traditional architecture of Kerala and its contribution to achieving thermal comfort using the passive technique.**

***Keywords*: Kerala, Passive Design, Thermal Comfort, Traditional Architecture.**

1. Introduction

The term sustainable architecture, means that the architecture that blends with the nature without harming the environment. The old vernacular building helps us to understand the architecture, planning, social feature and cultural aspect of the past. Vernacular architecture has a very strong tie with social and cultural traditions. And it also has a great concern about the ecology. The vernacular building is always sustainable.

The vernacular architecture is a climatic responsive building and it responds to the environmental condition throughout naturally evolving time. The vernacular buildings react to the time of the day and the seasons of the year. Thus for the majority of the time, the building relies on the natural means for day light and ventilation and relies less on the mechanical means. But now-a-days, the contemporary building doesn't implement the passive strategies to achieve indoor thermal comfort. Industrial revolution is the main reason for this change. Because of the introduction of the new materials in the building industries has implemented this change in the design of the building. These new materials new materials require new techniques to construct the building.

This study is mainly to analyze the passive strategies used in the vernacular building, which makes the building thermally comfortable. Kerala experiences Warm Humid climate because of its geographical position. Humidity in the atmosphere is the major concern because it creates thermal discomfort throughout the year. Heavy rain fall, high solar radiation and effects of high temperature are the other concerns.

Vernacular architecture depends upon various factors like social, cultural, economic, climate, topography etc. The principles of Kerala Vernacular architecture were based on several observations and experimentations. The use of natural and passive methods helps in achieving thermal comfort in the indoor environment.

An Ancient Vernacular Building was takes as the case study. To proceed the study to another level, field measurements were taken to check the thermal comfort. This paper analyses the natural passive strategies and materials used in an ancient museum building, which makes the building comfortable.

2. Case study: Napier Museum

A. Climate

India is a tropical country with diverse climatic condition. The classification of climate, based on the climatic factor is classified into different climatic zone. According to the Bureau of Indian standards, the country is classified into five climatic zones, namely hot and dry, warm and humid, cold, moderate, and composite. Fig 1 show the corresponding climatic zone classification map of India. Kerala lies in the subtropical belt comes under warm-humid climatic zone. Based on the altitude Kerala has three distinct zones high land (800-2700 m), mid land (300-700 m) and low land (sea level to 150 m). Kerala experience two predominant seasons — rainy season and non-rainy season. Winter and Summer come under non-rainy seasons. The site is located in Trivandrum on the west coast of India. This district extends over area of 214.86 sq. km. It is located in an altitude of 64 m above sea level. The geographical location extent from 8.18 °N to 12.48°N latitude and 74.85°E to 72.82°E longitude, and also lies on the South-West coast of India lying between the Arabian Sea on the west and the Western Ghats on the East. Summer in the month of March to June reaches a maximum of 40°C in month May (the hottest month during summer). Winter in the month of December to February. This region experience long and heavy monsoon seasons, south-west monsoon from June to August and north-west monsoon from October to November. The average rainfall of this region is 3000 mm. The temperature varies from 21 deg

C to 33 deg C. Humidity is very high throughout the year, ranges from 65% to 75 %.

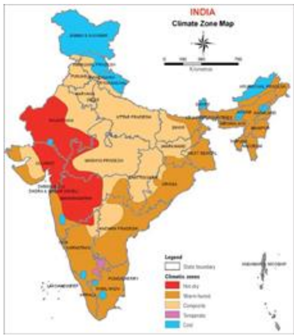


Fig. 1. Climatic zone classification map of India. Source: NBC, 2005.

B. *History of the Site*

The Art museum is one of the earliest museum in India. It was established in 1855; during the reign of highness Uthram Thirunal Marthandavarma Maharaja of Travancore dynasty. In the period of 1872, the Madras Province Governor Lord Napier sent Architect Robert Fellowes Chislom, to the Government of Madras to Travancore; to redesign a new museum building with the influence of Ayilyam Tirunal Rama Varma. In 1874, the old building was pulled down, and a new building was constructed. The Napier museum started its functioning from 1880 after reconstruction. The 137 years old structure is an ideal landmark in the city with its unique ornamentation and architectural style.

C. *Description of the building*

The Napier Museum Stands as a Magnificent structure in the heart of the city Trivandrum. It is massive breath taking structure standing in between the public gardens spread over 55 acres. This massive building has its unique structure, style and color. It follows a specific geographic brickwork pattern and color combination.

Fig. 2. View of the Napier Museum

Fig. 3. Site map showing details

This magnificent structure in shades of red is ornamented with stained glass windows and four huge minarets. It is an Indo- Saracenic style building as it was built during the British period. Inside the museum there are 3 big halls connected by long corridors with walls creatively painted in light blue, yellow and red. The arches are colored in yellow along with red and white patterns. The museum has four towers which once gave the visitors a beautiful glimpse of Trivandrum. There is a narrow spiral stair way (now the visitors are not allowed here) to reach the top of the tower. The amazing fact about the museum is its natural air conditioning effect. The double wall with ventilation provide this effect. The sliding doors are another notable feature. Both the central hall and the side halls have balconies with carvings and decorations. The stained glass windows add beauty to the museum.

The 3 big halls are connected by long corridors, four towers, many gables, ornamental ceiling panels, wood works, colored panels and artistically painted walls both inside and outside constitutes the main scheme of the building. The double wall with ventilation provide a natural air conditioned effect inside the building. The museum offers an array of display of artistic cultural and antique objects.

D. *Micro Climate*

The museum is located within the zoo premise, where the area is fully covered with dense vegetation and few water bodies. This green and blue corridor help in creating cooling effect which has an adverse effect on the microclimate of the region. The spaces around the museum is fully covered with large trees, bushes and lawn which provide good shading effect and also helps in improving the quality of air. A little amount of area is allocated for stone pavement for circulation.

E. *Planning and Orientation of the building*

The building is in linear form. The longer axis is along the northeast and southwest direction. The orientation of the building is tilted so that it takes advantage of the climatic factors like wind, solar radiation, etc., with passive solar techniques. The corridor around the building layout help to prevent the harness of solar radiation from entering the building. The spatial planning and the organization of spaces affect the building to receive maximum ventilation and minimize the solar heat gain inside the building.

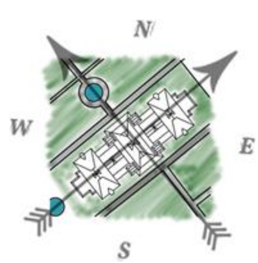


Fig. 4. Orientation of the building

F. *Design and Spatial organization*

The building is in linear form. The building has four entrances in which two entrances were closed and only two are in operation. The building has one main hall and three secondary halls connected with two secondary halls on either side. These halls are connected by corridors on either side. The main hall has four towers encouraging visitors to have a good view of the city through the spiral staircase. These spaces in the museum are flexible in nature. The raised platform on either side acts as a connecting element for the museum to the exterior spaces, this is the main source of social activities which enhances the social bonding among the visitors. The spatial organization is arranged in accordance with the climatic requirements. The semi-open spaces in the form of the corridor around the building layout reduced the direct exposure of internal spaces from solar radiation and the space more thermally comfortable.

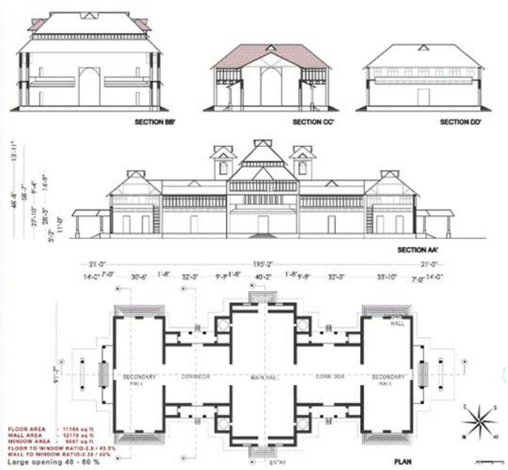


Fig. 5. Plan Section Elevation of the museum

G. Material specification

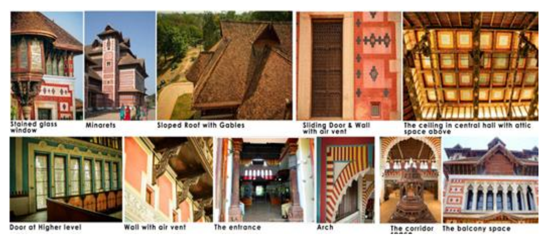
- *Wall:* Laterite stone is used for wall. Laterite, seen in shallow depth, is the most commonly used building material in Kerala, which can be easily cut, dressed and used as building blocks. It is strong and durable with exposure to atmospheric air. Laterite brick is porous which allows the wall to breath.
- *Plastering:* The wall is plastered by Shurka, a mixture of lime, jaggery, shell, egg white. The wall is painted in red, pinkish red, black and white giving a pattern with unique look.
- *Floor:* Unpolished granite is used for flooring inside the museum. It gives the appearance of a rustic look. It has rough finish. Granite is very strong and durable material used as the flooring. The cladding in the exterior wall adds the majestic look to the building.
- *Ceiling:* The ceiling in the main hall is painted with organic painting which enhances the rich look inside the building.
- *Window:* Stained glass is used in windows. It enhances look in the interior. Timber like wood is used for frames, beams and for trusses. Lots of rich wooden carvings could be seen. Granite with jallies could be seen in the windows. Teak wood is highly resistance to moisture.
- *Roof:* Fish tile which is traditional to Kerala is used in this building for roof. Fish tile is a good thermal insulation material.

Table 1
Properties of the Material

Material	Thermal Conductivity W/mK	U-Value (W/m^{2}K)
Granite	0.523	0.341
Laterite Brick	1.631	
Granite Stone	3.022	0.620
Teak Wood	0.265	0.841
Stained Glass	1.042	
Clay Fish Tile	1.631	

H. Natural light and Ventilation

The light gets into internal spaces through the large glass openings and gable roof. Attic is also provided. The light entering the building lit the common spaces and the circulation area. The openings provided are parallel and opposite to each other, thus it enhances the air flow inside the building by cross ventilation. The double wall with air cavity provide a natural air conditioned space for the internal spaces. The thickness of the wall is 50 cm with double layer of laterite masonry with a gap in between makes the external wall are highly insulated. This is a notable feature adopted in this building. Jaalis provided on the exterior walls, which cut down the solar radiation into inside space, at the same time it allows light and ventilation.



I. Passive design strategies

Thermal insulation - The thermal insulation in buildings is achieved by the effective use of materials and the techniques used in the construction of walls and roof. In order to achieve thermal insulation, wooden ceiling (tattu) is also provided beneath the roof. This provides a large air space at the attic which acts as an insulation layer against the conduction of external heat through the roof. Thermal insulation can have reverse effect, when for some reason the indoor temperature is even higher than outdoor and the buildings insulation obstructs a quick heat loss. In Kerala vernacular architecture, the above problem is overcome with the constant air exchange between outdoor and indoor with the help of openings provided on the external wall. The thermal insulation in this building is achieved by using cavity wall, attic roof. Stack Effect - The stack effect in this building is achieved by using windows provided at higher level. Gable vent is provided in the roof which performs as the stack effect.

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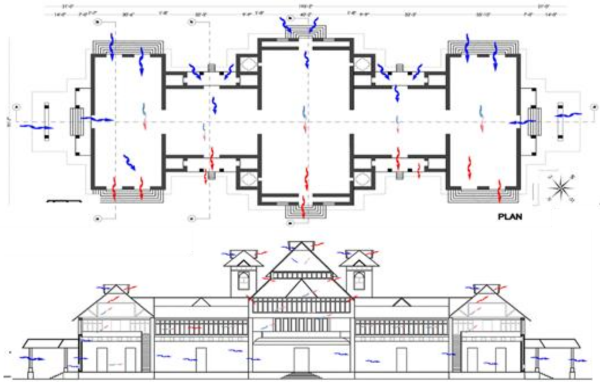


1) Double wall with air vent

Natural air conditioning inside the building is achieved by the double wall with air cavity which provide good ventilation effect. The thickness of the wall is 50 cm with double layer of laterite masonry with a gap in between makes the external wall highly insulated. This is a notable feature adopted in this building. These thick walls acts as a thermal barrier, which reduces the heat penetration inside the building.

Fig. 6. Double wall with cavity

2) Gable roof

The gables (mughappu) are provided at the ends of roof to enhance ventilation inside the building and allow the warm air to escape out of the building. The screening in cable are finely carved and ornamented with timber.

Fig. 7. Gable roof

3) Attic

Ventilators are provided for the ventilation of attic spaces that are formed by the wooden false ceiling (tattu) provided for the room spaces. This roof encloses a large insulated air space keeping the lower areas cooler. This acts as the thermal insulation.

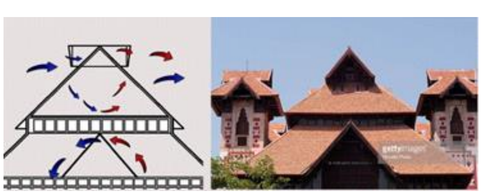


Fig. 8. Attic roof

4) Sloped Roof

The roofs have steep slopes up to almost 45. It gives protection from heavy rain as it drains the rain water easily. The extended sloping roof acts as the sun shade and gives protection the incident sun radiation. Fish tile and wooden rafter are used in the roof.

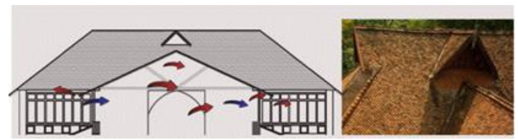


Fig. 9. Sloped roof

5) Layer wall

This two layer wall system reduces the intensity of the solar radiation into the building. Thus it maintains the thermal comfort inside the building.

Fig. 10. Layer wall

6) Fenestration

The exterior window are relatively larger and has high sill level to achieve well ventilated indoor spaces. There are double height spaces with clerestory windows enhances the venturi effect of the building where hot air rises up and passes out through upper level windows and gable. This will keeps interior cool. This helps in maintaining constant air circulation within the building and thus helps in coping up with the humid conditions and enhancing thermal comfort. This will help in reducing energy consumption, because we the use of electrical appliances such as fans is reduced. This kind of arrangement of openings helps to enhance the cross ventilation and keeps the interior cool by venture effect. In the plan, the openings provided are parallel or opposite to each other, thus it enhances the air flow inside the building.

Fig. 11. Natural lighting achieved inside the building

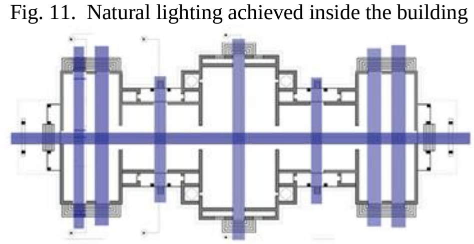


Fig. 12. Plan showing the cross ventilation

7) Jalli

Openings (jalli) permit maximum cross-ventilation. Jaalis are used in the exterior walls, which cut down the solar radiation into inside space, at the same time it allows diffused light and ventilation.

Fig. 13. Jalli wall

8) Height of the building

The height inside the building varies in 3 halls. The main central hall has the height of 63 feet, the corridor is 38 feet high, the secondary hall is 42 feet height and the tower is 62 feet tall. The height ceiling increases the comfort level inside the building. This extreme height difference helps in enhancing the thermal comfort of the building as the hot air raises up and only cool air circulation on the occupant level.

Fig. 14. Roof Height

J. Thermal performance of the building through qualitative Analysis

To proceed the study to another level, field measurements were taken to check the thermal comfort. Instruments such as, Laser gun, Hydrometer, Lux meter, Aerometer were used to measure the surface temperature, temperature, humidity, light and wind speed. The readings were taken for 7 days on the month of September. Surveys were also taken from the 100 people who came to visit the museum.

1) Surface Temperature

It is observed that the outdoor surface wall temperature has the variation from 26°C to 38°C, while the indoor surface wall temperature was varying from 23°C to 26°C from 10:00 am till 05:00 pm. Even though there is a high variation in the external wall, there is a drastic change in the indoor wall temperature. This is due to thermal insulation achieved inside the building.

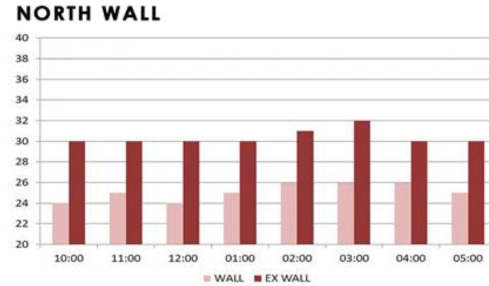


Fig. 15. Surface Temperature difference between outer and inner wall of the northern side

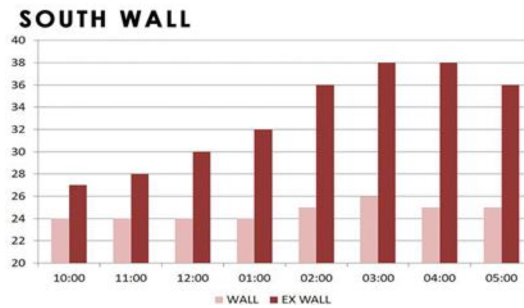


Fig. 16. Surface Temperature difference between outer and inner wall of the southern side

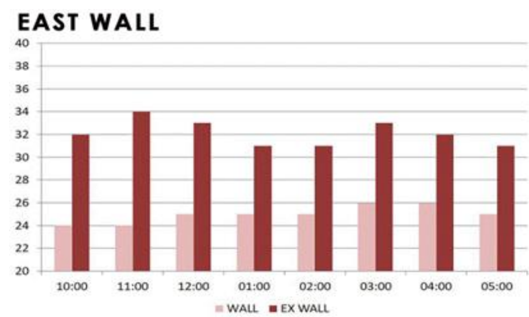


Fig. 17. Surface Temperature difference between outer and inner wall of the eastern side

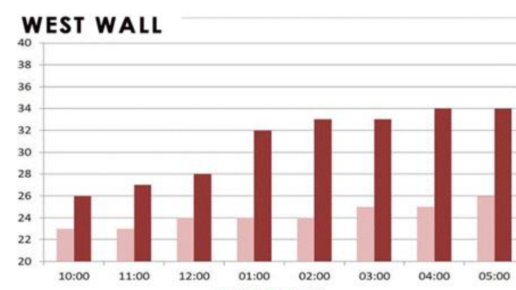


Fig. 18. Surface Temperature difference between outer and inner wall of the western side

2) Temperature outside to inside comparison

It is observed that the outdoor temperature has the variation from 32°C to 36°C. While the indoor temperature was varying from 30.5°C to 34°C from 10:00 am till 05:00 pm.

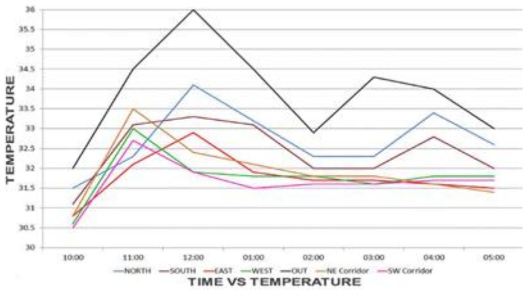


Fig. 19. Temperature - outside to inside comparison

3) Humidity outside to inside comparison

The humidity inside the building is higher when compared to the outdoor humidity level.

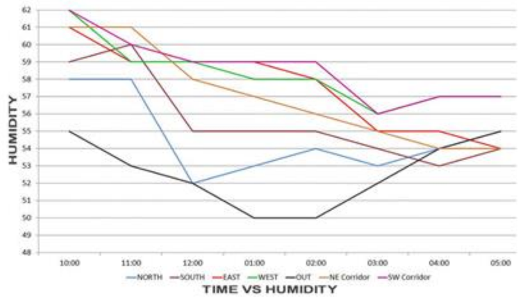


Fig. 20. Humidity - outside to inside comparison

4) Lux measurement

The light gets into the interior through the glass openings and gable roof. The natural light comes into the building through the wide stained glass windows which are arranged at the higher level in the building. The light even comes into the building through the gable roof provided.

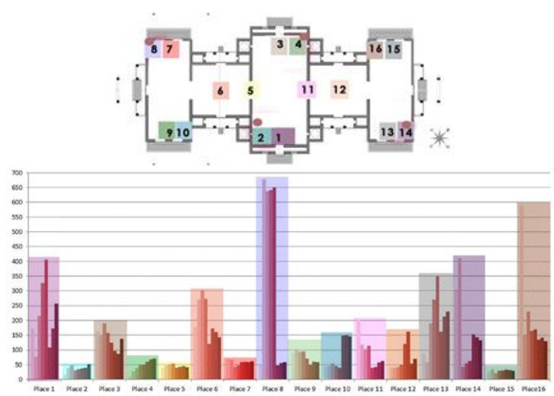
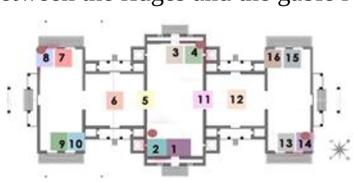


Fig. 21. Lux measurement with key map showing the places where the measurement is taken

5) Wind Speed

The wind gets into the building through the openings, wall with vent, gap between the ridges and the gable roof.



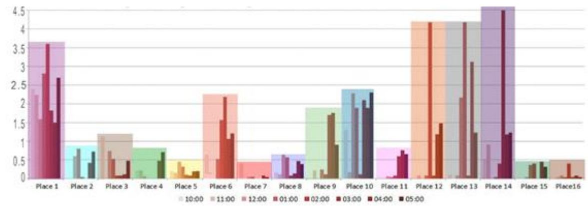


Fig. 22. Wind speed measurement with key map showing the places where the measurement is taken

6) User comfort

A questionnaire is given to the 100 visitors to answer about the thermal comfort and the lighting they get inside. 98% of the users felt very good thermal comfort inside the building.

Fig. 23. User analysis

3. Conclusion

Vernacular Architecture not only plays a vital role in displaying the local culture, social and economic life of the region but also helps us to understand the connection of nature with the built environment. Efficient usage of natural elements like sun, wind, light, topography, etc. help in providing good thermal and visual comfort inside the building. This help in providing more energy-efficient and sustainable building. This particular traditional building helps in maintaining the indoor environmental quality and also helps in enhancing the human comfort condition. Appropriate usage of material, high thermal mass, building height, window opening, sloping roof, and other passive strategies make the building more sustainable and energy-efficient over these years. Now a day's region to the global level, sustainability plays a major role and has become the basic fundamental tool. Therefore, instead of finding new technologies to achieve thermal comfort, it is better to look back at our traditional building and understand its design strategies which connect nature to the built environment and its approach in designing the building with good thermal comfort with low usage of modern technologies.

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