CHAPTER 1

INTRODUCTION

Increase in global population has lead to a rapid development of housing and commercial buildings. In the process of modernization, contemporary buildings constructed are designed without considering its form, orientation and other climatic variables. Most of the contemporary buildings depend on mechanically controlled building environments, in order to achieve the thermal comfort. Energy is primarily used for cooling, heating, ventilating and lighting. In the operation of the contemporary buildings, around 70% of the total energy is used for climate control system. This contributes to serious environmental problems because of excessive consumption of energy and other natural resources. It is a known fact that energy reserves are depleting at a rapid rate. So, there is urgent need to design energy efficient buildings to achieve thermal comfort with minimal use of external energy inputs.

Solar passive techniques adopted in traditional buildings provide thermal comfort with minimal or no use of mechanical devices because energy flow in these systems are due to natural conduction, convection and heat radiation. Thus, load on conventional system can be minimized by incorporating solar passive techniques in building designs.

Solar passive design is a way of designing buildings that takes advantage of prevailing climate and natural energy resources to achieve a comfortable indoor environment thereby minimizing energy need and reliance on mechanical system. Solar passive system provides thermal and visual comfort by using natural energy sources and sinks.

Every building should be climate responsive and site specific because each site has its own feature. Solar passive house is a comprehensive system as it emphasizes receptivity and retention capacity.

Hence architects, engineers and other building designers should focus on the ways and means to increase thermal comfort by incorporating solar passive techniques in contemporary buildings with an aim to achieve energy efficient and sustainable building design.
1.1 NECESSITY FOR THE PRESENT STUDY
One of the main objectives of designing a building is to provide a comfortable indoor condition for the inhabitants; however, at the same time minimizing the energy consumption also remains significant. Thermal comfort in a building is important for the general well-being, health and productivity of occupants. For achieving the required thermal comfort, contemporary buildings tend to be energy dependent to such a degree that without it, building could not be operated or inhabited. A review of traditional architecture revealed that solar passive technologies had been incorporated in buildings for several years for protection of people against harsh climatic conditions. Also, the increase in damage level to the environment has created a greater awareness worldwide which resulted in green energy building concepts in the infrastructural sector. So far, no attempt has been made in Thanjavur district, Tamilnadu, to construct and study the thermal performance of a modern residential building with solar passive design strategies. Hence, the focus of the present research work is to construct a modern style house with solar passive architecture in Thanjavur District.

1.2 AREA OF STUDY
The area for the present study - Thanjavur region, is geographically located at 10.75° N, 79.10° E in Tamilnadu, South India. The city has an elevation of 57 m above the Mean Sea Level (MSL) which is located in Cauvery delta region, about 320 km from the state capital, Chennai and 56 km from Tiruchirapalli. The location of Thanjavur is shown in Figure 1.1. The city falls under warm and humid climate zone as per the classification of National Building Code (NBC) of India and shown in Figure 1.2. The monthly mean climate data of Thanjavur obtained from the nearest weather station (Tiruchirapalli) is given in Table 1.1. The mean maximum temperature is 37 °C during May - July (summer) with maximum temperature at times exceeding 40 °C. Similarly the mean minimum temperature is 21 °C during November – January (winter).
Figure 1.1 Location of Thanjavur (Source: Google Images)

Figure 1.2 Thanjavur in Warm Humid Climatic Zone of India
Source: ECBC
Table 1.1 Climate Data for Thanjavur

<table>
<thead>
<tr>
<th>Month</th>
<th>Temperature ($^\circ$C)</th>
<th>Relative Humidity (%)</th>
<th>Wind Velocity (m/h)</th>
<th>Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>32.1</td>
<td>19.8</td>
<td>94</td>
<td>47</td>
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<tr>
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<tr>
<td>October</td>
<td>32.3</td>
<td>23.7</td>
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<tr>
<td>November</td>
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<td>22.8</td>
<td>96</td>
<td>62</td>
</tr>
<tr>
<td>December</td>
<td>28.8</td>
<td>20.4</td>
<td>96</td>
<td>54</td>
</tr>
</tbody>
</table>

Source: International Airport, Tiruchirappalli, India (nearest weather station)

1.3 SOLAR PASSIVE ARCHITECTURE

Solar passive design is a method of collecting, storing, distributing and controlling thermal energy flow by means of natural principles of heat transfer. Passive systems have no separate devices for collecting energy or storage units or mechanical means for transporting heat. Instead, it makes use of building components for energy exchange through natural processes and energy available in its immediate environment.

Solar passive techniques which are suitable for one place may not be suitable for another place due to the variation in climatic condition at different places. In a place with high solar radiation accompanied by high humidity, the building should be designed with sufficient shade to prevent solar radiation from entering the house and ventilate to take away the humidity. But, in a cold climatic region, it is necessary to keep the indoor warm. Thus, climate determines the design and construction of the building.
In order to achieve energy efficiency, architects need to study the macro and micro climate of the site conditions before applying solar passive principles to combat the extreme adverse conditions and making use of desirable conditions. Certain common design elements that directly or indirectly affect thermal comfort conditions and contributing towards energy consumption in a building are: orientation, plan form, building envelope and fenestration, landscaping, water bodies and building form.

1.3.1 Orientation

1.3.1.1 Building Orientation

Building orientation is an important parameter of design, mainly with regard to sun path, solar radiation and wind directions. Buildings should be oriented in such a way that it minimizes the solar gain and maximizes the benefits of wind. Optimization is required between the solar radiations and wind orientations with careful design on building and its elements as shown in Figure 1.3. Solar heat gain can be minimized by shading properly and deflecting heat away from the building; whereas wind can be diverted or directed into the building to the extent required.

![Figure 1.3 Optimization of building orientation](image)

1.3.1.2 Wind Orientation

Primary wind direction and secondary wind direction should be considered while designing the buildings. Elongating the settlement in a line across the prevailing wind direction gives low resistance to air movement and is therefore the ideal solution. Building should be oriented along the wind direction with longer axis intercepting the predominant wind directions as shown in Figure 1.4.
Cross-ventilation acts more effective in interior spaces by enlarging the openings of the internal partitions and by providing free passage, courtyards, verandah, etc. Design for good cross ventilation and excellent cross ventilation is shown in Figure 1.5 (a) and (b). Houses with raised platform facilitate better ventilation. Continuous circulation of air enhances the space with appropriate temperature and humidity.

**Figure 1.4 Building orientation along the wind direction**

1.3.2 Plan Form

Thermal performance of the building is also affected by the volume of space inside a building and the area of the envelope enclosing it. This parameter Surface to Volume ratio (S/V ratio) determines the magnitude of heat transfer and ventilation in buildings. Compact form with low S/V ratio reduces heat gain and losses. It is better to avoid more distance from the fenestration to reduce the requirements for artificial lighting.
1.3.3 Building Envelope and Fenestration

The building envelope and components decide the amount of heat gain / heat loss and the wind that enters the building. The basic elements that contribute towards the performance of the buildings are:

- Wall
- Roof
- Fenestration and Shading
- External finishes

1.3.3.1 Wall

Walls constitute major part of the building envelope and receive more solar radiations. It is also estimated that more than 25% of heat gain in a building occurs through wall conduction in the warmer regions of India. Hence it can be controlled by different wall thickness, thermal insulation, air cavities and buffer spaces. Such air cavities and buffer spaces created within walls or in the roof ceiling combination reduces the solar heat gain factor, thereby reducing space – conditioning loads.

1.3.3.2 Roof

Roof receives significant amount of solar radiation and plays a vital role in deciding heat loss / gain, day lighting and ventilation. In warmer regions, the roof should have proper treatment. Reflective roofing tiles or roof painted in light colour reflects more solar radiations.

1.3.3.3 Fenestration and Shading

Fenestrations are used for lighting and ventilation. According to the prevailing wind direction, openings can be located. Openings at higher levels would naturally aid in venting hot air out due to the tendency of hot air rising up. The size, position, shape and orientation of openings moderate air velocity inside the building. Sufficient air circulation is required in hot humid and warm humid climates. In such areas, fans are also essential to provide comfortable air motion. Fenestrations having 15-20% of floor area are adequate for both ventilation and day lighting in hot dry and hot humid regions. Shading devices block the solar radiations incident on the windows, other glazed areas and exposed surfaces of a building, consequently reducing heat gain as shown in Figure1.6.
The openings should be large enough and fully operable, equipped with flexible louvers (protection from driving rain) allowing appropriate regulation of ventilation.

![Types of shading devices](image)

**Figure 1.6 Types of shading devices**

### 1.3.3.4 External Finishes

The external finish of a surface determines the amount of heat absorbed or rejected by it. A smooth and light coloured surface reflects more light and heat than a rough, dark coloured surface. Light colour surfaces have higher emissivity and should be used for warm climate. High textured wall surfaces also help to reduce heat gain by mutual shading.

### 1.3.4 Open Spaces and Built Forms

Open spaces and built forms are responsible for different air flow patterns in and around the building, together modifying the micro climate by affecting heat gain and heat loss. Courtyards can be designed as heat sinks. Such open spaces can create stack effect for
good ventilation. Narrow courtyards can cause mutual shading, reduce heat gain, facilitate proper ventilation and promote heat loss through building fabric. If vegetation cover or water is used in courtyard, it creates a cooling effect.

1.3.5 Landscaping

Landscaping is an important element in altering the micro climate of a place. Plants, trees and shrubs can provide a cool environment and shade for the building, as they absorb radiation. It can reduce the heat gain and reflect radiations if properly planted as shown in Figure 1.7. Evergreen trees will be suitable for hot climate. The pavement which is not shaded absorbs heat quickly and increases the temperature, whereas vegetal cover increases the micro climate keeping the outdoor comparatively low.

![Image of shading of trees in summer and winter](image)

**Figure 1.7 Shading of trees in summer and winter**

1.3.6 Nocturnal Radiation Cooling

In most humid climates, the night air is significantly cooler than the daytime. This cool night air can be used to flush out the heat from a building’s mass. The pre-cooled mass
can then act as a heat sink during the following day by absorbing heat. The ventilation removes the heat from the mass of the building at night which is called nocturnal radiation cooling. Accumulated heat in the building, during the day is lost by radiation to the cool outdoor, during nights thereby cooling the building envelope. The envelope thus acts as cold storage during the day, drawing the heat away from the living space. Regions with large diurnal temperature variations will have higher nocturnal radiation cooling. The thermal link between the emitting surface and the living space has to be good for effective radiant cooling.

1.3.7 Courtyard Effect

Due to incident solar radiation in a courtyard, the air gets warmer and rises. Cool air from the ground level flows through the openings of rooms surrounding a courtyard, by producing air flow. During night time, the cool air sinks into the court and enters the living space, gets warmed up and leaves the room through higher level openings as shown in Figure 1.8. However, care should be taken that the courtyard does not receive intense solar radiations, which may increase the heat gain into the building by conduction and radiation. More solar radiations in the courtyard also produces immense glare.

**Figure 1.8 Cooling of the building through ventilation**

The draft causes hot air to rise and escape to the ambient, drawing in cool air from openings near ground by the action of natural convection. A solar chimney can create continuous air circulation by combining Bernoulli effect (increased velocity because pressure at roof ridge will be lower than windows) and Venturi effect (more air velocity with less static pressure).
1.3.8 Wind Tower
In a wind tower, the hot air enters the tower through the top openings, gets cooled, becomes heavier and sinks down. The inlet and outlet of rooms induce cool air movement. The difference in density creates a draft, pulling air either upwards or downwards through the tower during evening hours. The walls of the tower absorb heat during the day and release it at night, warming cool night air in the tower. Warm air moves up creating upward draft. The pressure difference thus created pulls the cool night air through openings into the building. In the absence of wind, the tower acts as a chimney.

1.3.9 Insulation and Buffer Spaces
Heat loss or gain from various building components can be reduced by insulation and buffer spaces. Even air cavity in the external building fabric can provide good insulation. Cavity walls and buffer spaces inhibits the inward transmission of heat. Such cavity walls or spaces can be varied by selecting a ventilated or unventilated air cavity.

1.3.10 Daylight in Architecture
Natural light acts as a medium of understanding the space by relishing over its interpretation of form, texture and color in architecture. Natural light gives an immortal identity to architecture. The extent of its availability influences the overall planning and design. To obtain a reasonable lighting, consideration over the climate, the use of the space and visual work are taken into account. Daylight has two distinctive sources of light:

- Sunlight - Fraction of parallel rays of solar radiation reaching the earth’s surface after certain diminution by the atmosphere (direct component)
- Skylight - Fraction of solar radiation reaching the earth’s surface as a result of dispersion in the atmosphere. (diffused component)

On a practical note, daylight has the ability to satisfy biological and human need by means of its proper utilization. In general, lighting consumes about 25-40% of electricity in any building. Use of daylight can save or reduce it to half of its total energy consumption. It can also reduce the heating and cooling energy consumption when compared to electrical lighting.
Windows can provide an illumination to a depth of about 1.5 times the distance between the floor and the top of the window with the help of natural light. Use of elements such as light shelves or other reflector systems can increase the distance to two or more times than the standard depth.

1.3.10.1 Fenestrations and Glazing Ratio

In architecture, fenestration refers to the arrangement, proportion, design of window, skylight and door system within a building which acts as a means of admitting solar radiation for natural lighting, referred to as day lighting.

Fenestrations can be broadly classified into two main types:

- Side lighting [windows]
- Top lighting [skylight]

Glazing affords surplus amount of natural light, provided it doesn’t allow unwanted summer solar gains and winter heat losses. An approximation of about 25% of glazing of the external wall is recommended for proper lighting. This percentage may vary in accordance to various factors such as orientation, location, obstructions [view of sky] and activity/user requirements.

1.4 RESEARCH HYPOTHESIS

The hypothesis of this research remains, by the use of solar passive techniques in designing modern buildings, it is possible to eliminate or reduce the use of mechanical devices like air-conditioner, air-cooler, fan and light, providing adequate indoor thermal comfort thereby reducing the energy demand as well as emissions of carbon-dioxide.

1.5 DEFINITION OF THE PROBLEM

In a developing country like India, where huge housing need exists for the growing population, there is a need to design energy efficient buildings for achieving thermal comfort using solar passive architectural principles. The use of solar passive architecture techniques to design modern buildings is found to be an eco-friendly, economical and practical approach. Hence, in the present study, an attempt has been made to design, construct and analyze solar passive architecture incorporated modern residential building for thermal comfort suiting warm humid climate.
1.6 SCOPE OF THE RESEARCH WORK
The scope of the present research work focuses on:

- the construction of energy efficient and economical modern residential buildings suitable for warm humid climate with innovative design by incorporating solar passive architectural techniques.
- the performance evaluation of designed modern building in attaining thermal comfort even during extreme summer and winter seasons.
- the comparison of thermal performance of the designed modern building with other modern buildings and traditional buildings to substantiate that the designed solar passive building is thermally comfortable.

1.7 OBJECTIVES OF THE RESEARCH WORK
The main objective of the research can be achieved by carrying out the following tasks:

- Determining the effect of various thermal comfort parameters like temperature, humidity and air movement among the occupants of traditional and modern buildings in Thanjavur region by questionnaire survey.
- Designing and constructing a modern residential building in warm and humid climate of Thanjavur with solar passive architecture concepts that can make the building thermally comfortable like traditional buildings.
- Investigating the thermal comfort in the newly constructed solar passive residential building by determining the following parameters - indoor and outdoor temperature, indoor and outdoor relative humidity, solar insolation, air flow inside the building and globe temperature (t_g).
- Assessing the thermal comfort zone of the designed building using bio-climatic chart analysis tool and determining Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) of the designed building using CBE Berkeley Thermal comfort tool.
- Comparing the performance of the newly designed solar passive modern building with other modern and traditional buildings of the region to resolve thermal efficiency of the building.
• Performing statistical analysis and determining regression equation for indoor temperature.
• Arriving design recommendations suitable for Thanjavur region.

1.8 RESEARCH QUESTIONS

This research work will seek answers to the following questions in the context of the study.

• What is the present status of thermal comfort in traditional and modern buildings in warm humid climate?
• Does the design of solar passive architecture incorporated modern building contribute for thermal comfort as achieved in traditional buildings?
• How far the performance of the solar passive architecture incorporated modern building is better when compared to modern buildings without solar passive design?

1.9 LIMITATIONS OF THE STUDY

• The study area is confined to warm and humid climate region of Thanjavur, Tamilnadu, India.
• Questionnaire survey is confined to 120 residents of traditional houses and 124 residents of modern houses in habitable condition with people living in it.
• Comparative analysis of the designed building is carried with three traditional houses and two modern houses of this region.
• Comparison of the performance of the identified traditional and modern houses with the designed solar passive building is carried out during peak summer and winter months.
• Thermal comfort parameters are measured keeping electromechanical devices such as fan, light, air conditioner and air cooler inside the building in off mode.
• The study area is confined to living rooms during the comparative analysis.
1.10 RESEARCH METHODOLOGY

![Flowchart showing the methodology adopted for research](image)

**Introduction**
- Research Need
- Research Area
- Aim & Objectives

**Literature Review**
- Climatic Design Recommendations for Thanjavur region
- Questionnaire survey on Traditional and Modern buildings

**Qualitative Analysis of Traditional and Modern buildings**

**Thermal performance Analysis of the SPA incorporated house**
- Comparative performance analysis of the SPA incorporated house with modern building
- Comparative performance analysis of the SPA incorporated house with Traditional building
- Analysis of the results

**Conclusion and Scope for future study**

Figure 1.9 Flowchart showing the methodology adopted for research