INTRODUCTION
The main purpose of building is to provide shelter for privacy and thermal comfort. Building must also act as a barrier to transform the outdoor climatic condition suitable for indoor activities. Traditional construction was comparatively well adapted to climate passively. But in the process of modernization, the knowledge from traditional construction is often lost. In modern building construction, people tend to make use of the site economically with the modern materials available at reasonable cost without any consideration for energy efficiency. People install electromechanical cooling devices to improve thermal comfort in their dwellings. Perhaps for buildings not adapted to the climate, the amount of energy required to run the equipment and its cost will be high and also has a negative impact on environment. Hence, the designer’s role is vital as a creative enabler of latent solutions.
Typical design process is a satisfactory compromise between conflicting demands between passive strategies and active climate. Solar Passive Design (SPD) strategy varies according to climatic conditions. These designs help to achieve energy efficiency and thermal comfort by using natural energy sources and techniques. Such energy efficient designs provide comfortable and healthy indoor environment apart from reducing the environmental impact of buildings moving towards sustainable habitat.
Literature survey reveals that no attempt has been made so far in Thanjavur district, Tamilnadu, to construct a modern residential building with SPD strategies. So, a modern style house is designed and constructed incorporating solar passive architecture principles in Thanjavur. The main objective of the study is to evaluate the importance and outcome of incorporating SPD strategies to achieve thermal comfort.
5.1 SITE LOCATION
The site for constructing modern building with SPD strategy is located in a developing residential area called Rahman Nagar at a distance of 2 km from the Central Bus stand of Thanjavur. The location of the building planned for construction is shown in Figure 5.1.

Figure 5.1 Map showing the location of the site in Thanjavur (Source: Google)

5.2 ORIENTATION AND PLANNING
A rectangular plot of size 80’ x 40’ with a total area of 3200 sq. ft. was chosen for constructing a modern house with SPD strategy. The site is facing North with a slight tilt of 20˚ towards West. It has long been believed that buildings which maintain golden ratio (also called golden rectangle of ratio 1:1.61) in its design, produce aesthetic pleasing shapes in nature, and has been used in many works of architecture worldwide. So, the size of the building planned for construction is chosen as 55’x 33’, which maintains a ratio of 1:1.67 (close to the golden ratio), for a pleasing and balanced layout. Surrounding site features, sun path and prevailing wind directions with respect to the site chosen for construction is shown in Figure 5.2.
Based on sun path, prevailing wind direction (South East to North West) and the site limitations, the building proposed for construction is designed with main door openings on the central axis facing North and South directions. This can aid better air movement inside the building.

The building plan is inward looking as in traditional courtyard houses both for climatic reasons and privacy. Simplicity and minimalism in forms are planned in the design. Proper care is taken to locate buffer spaces, shading devices, shading trees and proper fenestrations in the plan. The plan, perspective view and site plan of the building proposed is shown from Figure 5.3 to 5.5.
Figure 5.3 Plan of the proposed building

Figure 5.4 Perspective sketch of the proposed building
Figure 5.5 Site plan of the proposed building
5.3 DESIGN OF THE PROPOSED BUILDING

For warm and humid climatic condition, the design approach for SPA incorporated house should have three major focuses:

1. Avoid heating of the building elements to reduce cooling demand.
2. Promote adequate ventilation / heat loss.
3. Maximize the usage of daylight to reduce artificial lighting demand.

With these considerations, the residence is planned with a living cum dining room of size 15’6” x 22’3” surrounded by study room of size 9’6” x 7’9” on north side, kitchen of size 15’6” x 8’ on east side, bedroom of size 15’3” x 11’9” on south side and another room of size 15’3” x 13’9” on west side as shown in Figure 5.3. The challenge of using 9” exterior wall, as used in the other modern buildings is taken up and solved effectively with buffer spaces incorporated in between habitable spaces to reduce the heat gain. To provide buffer spaces in the building, the location of toilet spaces, staircase, roof overhang, courtyard, high ceiling in hall, exterior landscaping and other shading devices are planned at appropriate places as seen in the plan and site plan. On the east side of the house, the courtyard acts as the buffer space protecting the living cum dining space from the heat gain. In the same way on the west side; toilet spaces, staircase, storage wardrobes of bedroom protects the living cum dining space and bedroom from heat gain. Roof overhang projections (17’ on North and 5’ on South) are made to protect the building from harsh summer on the south and north directions along with landscaping.

Towards the aim of achieving thermal comfort, various Solar Passive Architecture design features proposed in the design of the building are:

1. Courtyard design and stack effect
2. Nocturnal radiation effect
3. Atrium design / Solar chimney effect
4. Heat reflecting roof tiles
5. Roof level ventilators and high ceiling
6. Shading elements
7. Landscaping for microclimate
8. Light coloured building exterior
9. Day lighting
Based on the proposed plan, elevation and views of the building are developed to have a visualization of the architectural forms and proportions in line with the concept and is shown from Figure 5.6 to 5.11.

Figure 5.6 Bird’s eye view of the proposed building

Figure 5.7 Front elevation of the proposed building
Figure 5.8 North East side elevation of the proposed building

Figure 5.9 South West side elevation of the proposed building
Figure 5.10 North West side view of the proposed building

Figure 5.11 North East side view of the proposed building
5.4 CONSTRUCTION OF THE PROPOSED MODERN BUILDING WITH SPD

As planned and designed, the modern house is constructed with SPD features. During the construction process, shallow foundation is used according to the soil condition.

![Excavation pits for the shallow foundation](image1.jpg)

**Figure 5.12 Excavation pits for the shallow foundation**

A hard stratum was found at a depth of 3’ from the ground level during the soil test carried out at the site and the excavated pits are shown in Figure 5.12.

![Installation of shallow foundation](image2.jpg)

**Figure 5.13 Installation of shallow foundation**
Hence excavation pits were made up to that depth and foundation work was carried out to raise the columns for the structure as shown in Figures 5.13 and 5.14.

![Figure 5.14 Foundation beam laid along with reinforcement rods for column](image)

Earth sheltered thermal mass is created with 4500 cubic feet of soil filled below the building, up to plinth level of 3’ height (as shown in Figure 5.15 and 5.16), which has a capacity to retain the coolness inside the building during varied thermal conditions of outdoor. This can contribute coolness inside the building during harsh outdoor day time.

![Figure 5.15 Walls built from foundation level up to plinth level](image)
Figure 5.16 Soil filled up to 3’ height plinth level

Framed structure with columns, beams and concrete slabs are used in construction as shown from Figure 5.16 to 5.19. Brick masonry is used for the construction of walls. All the exterior walls are constructed with 9” thickness with adequate buffer spaces to avoid heat gain through solar radiation and the internal partition walls are constructed with 4.5” thickness.

Figure 5.17 Walls built up to lintel level during construction
Floor to roof height of 9’ is followed. Living room is raised to double floor height of 18’. A mid (mezzanine) floor at the height of 9’ introduced adjacent to living room, is diagonally connected with the dining space located in the ground floor as shown in Figure 5.19. This enables adequate stack effect and also provides buffer with high ceiling for the heat entering through roof.
Tinted glasses with timber frames are used for windows of size 4’ x 5’ or 4’ x 3’ as per the positions shown in the plan of the building (Figure 5.3 and 5.21).
5.5 RESULTS AND DISCUSSION

The Solar passive features incorporated in the building and their effects are as follows:

5.5.1 Courtyard and stack effect in the designed building

Courtyard is an unroofed area that is partially or completely enclosed by walls of building. A courtyard of size 3’ x 10’ is designed on the eastern part of the house as shown in Figure 5.22.

![Figure 5.22 View of buffer courtyard with dry garden in the designed house](image)

Courtyard is the main source of energy; providing better ventilation, lighting and thermal comfort as it acts as a buffer space avoiding heat gain on the wall exposed to solar radiations. This narrow courtyard allows view of sky making a perfect blend with nature allowing rain water inside. The rain water is drained through the sunken pebble bed. The hot air rises up through the narrow courtyard due to heat convection. When this stack effect takes place, a low pressure is created which helps to draw more cool air into the building through the openings (windows and doors).

5.5.2 Nocturnal radiation effect

The heat absorbed throughout the day is radiated out through the courtyard during the night. The courtyard acts like a thermostat which can control the temperature inside the

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house. The inward looking plan focusing towards the courtyard enables ventilation and light entering the house throughout the day. Nocturnal cooling takes place as displacement ventilation with the connectivity of atrium opening at the top of high ceiling towards the narrow courtyard at lower level.

5.5.3 Atrium design / Solar chimney effect
A covered courtyard cum atrium space of size 3’ x 6’ is designed in the central part of the house as shown in Figures 5.23 and 5.24. It is elevated to 6’ and is covered with translucent roofing sheet with adequate space below for ventilation and day lighting. Since the atrium covered with translucent roofing sheet is at an elevated level, the air heated just below roofing sheet exhausts out through the ventilator gaps. It creates a stack effect pulling the air from room within and below. Air rushes through designed roof level ventilators.

Figure 5.23 View of the atrium cum solar chimney
5.5.4 Heat reflecting roof tiles

Light coloured roofs have Solar Reflectance Index (SRI) of 50% or more. Dark coloured weathering roof tiles have SRI in the range of 5 to 20%. Cool roofs with high emissivity can remain at a temperature 10-16°C lesser than other roofs during hot summer. Hence white roofing tiles with high reflectance are used in the present building instead of dark coloured weathering roof tiles and are shown in Figure 5.25. This reflects the heat radiation back thereby minimizing the heat gain into the building through roof.
5.5.5 Roof level ventilators and high ceiling

From the literature study it is inferred that a drop of $1^\circ$C can be obtained for each 20 cm increase in ceiling height. High ceilings also provide more volume of spaces in which stratification of air provides the occupants to use lower levels (human occupancy level) that are cooler. Roof level ventilator of size 2’ x 5’ as shown in Figure 5.26 and vented skylight are provided along with high ceiling. This acts as an opening for hot air to escape through buoyancy ventilation strategy. This augments the air flow through the openings provided just below the translucent roofing sheets by stack effect.

![Figure 5.26 Roof level ventilator](image)

5.5.6 Shading elements

![Figure 5.27 Side view of the constructed modern SPD building](image)
The building plan has a slight tilt, though it is facing north. On the North West direction and South East directions, roof overhangs completely shade the walls apart from shading devices for all other fenestrations. The side view of the designed building is shown in Figure 5.27, which shows roof projection at the front and other shading devices.

5.5.7 Microclimate through landscaping

![Figure 5.28 Landscaping used to shade South East walls](image)

![Figure 5.29 Landscaping used to shade North West walls](image)

In the designed building, trees and plants are used to shade South East walls and North West walls as shown in Figure 5.28 and 5.29.
Shrubs and creepers are used as ground cover in the front lawn as shown in Figure 5.30. This reduces heat generation from concrete surfaces and barren land. Thus, landscaping enhances the microclimate of the site condition.

5.5.8 Light coloured building exterior

The external finish of the building envelope determines the amount of heat gain. A smooth and light coloured surface finish reflects more light and heat as compared to any other coloured building.
So, the building exterior is coloured white due to its high emissivity and reflectivity. The building interior surfaces are also coloured white so as to provide good daylight inside the building. The front view of the constructed building is shown in Figure 5.31.

### 5.5.9 Day lighting

The building is designed in a way that daylight is ensured everywhere inside the residence in order to reduce artificial lighting. This can save power and reduce the exploring energy demand. Windows in all habitable rooms, courtyard and atrium satisfies the daylight requirement in the designed building. The depth of the building from the openings is kept as minimum (10’ to 12’) for adequate daylight to penetrate inside the building. Figure 5.32 shows adequate day lighting available inside the building.

![Day lighting inside the building](image)

**Figure 5.32 Day lighting inside the building**
5.6 SUMMARY
A modern residence has been constructed with solar passive design features such as courtyard, atrium, roof level ventilators, light coloured exterior, reflective white coloured roofing tiles, shading, buffer spaces and landscaping in Thanjavur. It should be noted that the techniques used are highly site specific and climate specific. Thus, coupling of techniques adopted in traditional buildings into the present day modern constructions with available modern materials will certainly be an example for bioclimatic Architecture towards achieving sustainable development. The results will certainly be an eye opener for Architects and Engineers to adopt solar passive design features in modern constructions and also to modify or retrofit in already executed modern buildings to make it climate responsive to achieve energy efficiency and the required thermal comfort.