Understanding the Sustainable Design Principles of Traditional Houses: The Case of Sawantwadi, Maharashtra, India

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Abstract

Traditional architecture is tested with time, follows the laws of Nature, is user friendly, and most importantly is contextual. It reflects identity, traditions and the culture of any place. Different aspects such as the context, geographic conditions, life -styles, socio-economic and political backgrounds of residents influence traditional architecture. Thus, traditional architecture follows the sustainable design principles in all respects.

Traditional building practices go very well with green building practices which involve green building considerations including site development, selection of materials and techniques, indoor air quality and the use of energy efficient techniques.

The aim of this paper is to explore and understand the concepts and the principles of sustainable design of traditional dwellings of Sawantwadi and their performance over a period of time. A sample is selected, from the Sawantwadi town, Maharashtra, India during the British era.

The research collected official records, descriptive and perspective writings of traditional dwellings and analyzed archival writings. It interviewed people employing a structured questionnaire, carried out photographic documentation, video recordings and documentations of traditional houses. It thus identified sustainable design principles in the traditional domestic architecture of Sawantwadi.

The study concludes that the identified sample house is highly responsive to the climatic conditions and adheres to the principles of sustainable design. It also concludes that the dwellings of Sawantwadi have evolved in response to the climatic conditions and traditional knowledge systems leading to sustainability.

Keywords: Traditional house, climate responsiveness, traditional architecture, sustainability, tradition and culture.

Introduction

India is one of the largest consumers of electricity in the world and is on the way to become a developed country. A tremendous growth in the population, rapid industrialization and a huge railway network need a lot of energy. The power crisis is increasing in India day by day.

Today, environmental degradation is on the increase leading to an energy crisis. As per the Fig.1, domestic energy consumption in India in 2021 is 26%.

The priority is to fulfill the demands of energy without disturbing the environment. In this context, sustainability can play a significant role in reducing the energy demand. Indeed, it is a benefit for both the consumers as well as the suppliers.

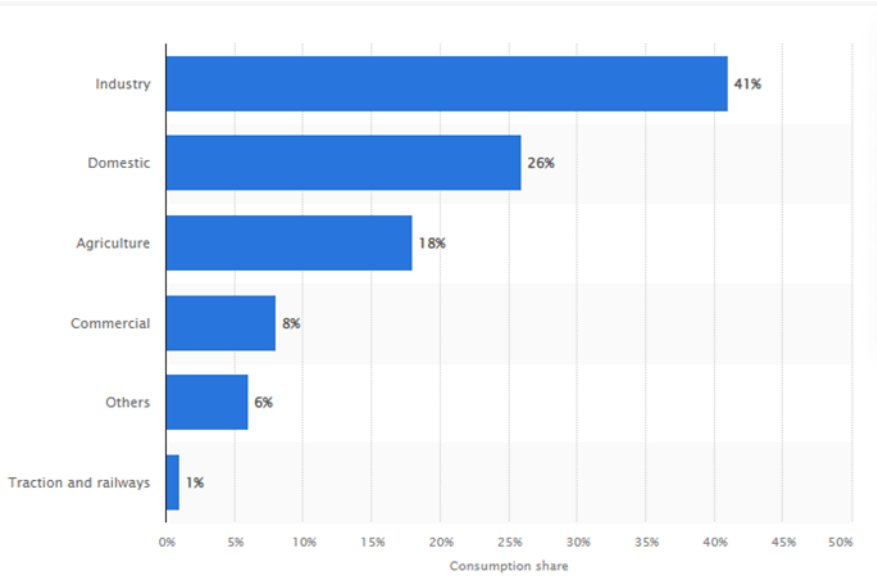

Fig. 1: Energy consumption in India: 2021
Source: India electricity consumption share by sector

In this context, it is necessary to understand traditional architecture, because traditional architecture is the root of sustainable knowledge, climate responsive principles of architectural design and energy efficient design aspects. This should not be studied as past traditions but should contribute towards new techniques & methods for future interventions in the construction industry. The utilization of passive solar techniques and methods learnt from traditional architecture to achieve thermal comforts in buildings allows the possibilities to decrease the dependence on fossil fuel based energy.

Table 1: Five major elements of green building design.
Source: Author

S.no.	Five major elements of green building design
1	Sustainable site development.
2	Use of materials, techniques and resources.
3	Indoor air and environmental quality.
4	Quality of water and its conservation.
5	Energy efficient design.

India has various traditional building practices due to the diverse geographical terrain. The traditional building practices go very well with green building practices which involve green building considerations including site development, selection of materials and techniques, indoor air quality and the use of energy efficient techniques.

The aim of this paper is to understand the concept of sustainability in the traditional houses in Sawantwadi during the British era.

Review of Literature

The pioneers of research into traditional architecture still work in search of the essence of traditional architecture. The book "Architecture without architects" published by Bernard Rudofsky explained some of the undiscovered architecture around the world surviving for thousands of years in a sustainable manner.

Many researchers have explored the sustainable design principles of traditional houses. Ganguly (2015), Gautam (2008) and Chadalavada (2017) have presented simple solutions that respond to sustainability such as passive solar techniques to provide for human comfort including orientation, form, materials and techniques achieved from the local resources.

Ozay (2005) and Singh (2010) have said that climate responsive building designs are essential rather than energy conservation. Indeed, sustainable solutions, environmental friendly designs and traditions are not supplementary to each other but pre-requisites. Philokyprou & Michael (2012) have investigated the bioclimatic design principles followed in traditional dwellings in the rural semi mountainous villages of Cyprus. According to them, different bioclimatic elements of traditional architecture are best understood by exploring the building features such as the central courtyard, the semi-open spaces, building orientation, lighting and ventilation, shading strategies, construction materials and the relationship between buildings to their surroundings.

Dhote (2012) and Chavan (2018) have studied the traditional settlements and have identified that the populations from these settlements still use the indigenous traditional styles (native natural building resources) to construct their houses. These respond to the local climatic conditions in a better way and provide human comfort.

Halicioglu (2012) and Chadalavada (2017) say that compact planning of houses and the use of small size windows and openings help to reduce heat loss from inside the houses in the winter. They also add that the use of locally available materials from the same climatic zones fit perfectly into the local environment. They have environmental advantages such as significant reduction in energy involved in material processing and transportation and low environmental impact in their production.

Other scholars have explored the links between traditional houses and sustainability. For example, Dhepe (2017) and Harimohan (2010) have concluded that the adoption of traditional design systems and details to modern houses link them to the past. They show ways to understand how modern houses could adopt to human and environment realities and can be designed and built to create post traditional built forms.

Nair (2006) says that sustainable development is to improve the life styles according to human needs and feelings of well-being on the one hand and preserving natural sources for future generations on other hand. Sustainable-affordable housing cannot be understood without environmental friendly technological innovations. Hence, it is necessary to understand the connections between sustainability and houses.

The Research Methodology

A sample of traditional houses is selected from Sawantwadi, Maharashtra, India during the British era (study period) to explore and analyze the relevance of the general principles of sustainability.

The study collected secondary data such as official records, descriptive and perspective writings of traditional dwellings and archival writings. It administered a structured questionnaire to the target group (house owners of buildings 100 or more years old). It also gathered photographic documentations, video recordings, and subsequently documented the traditional houses.

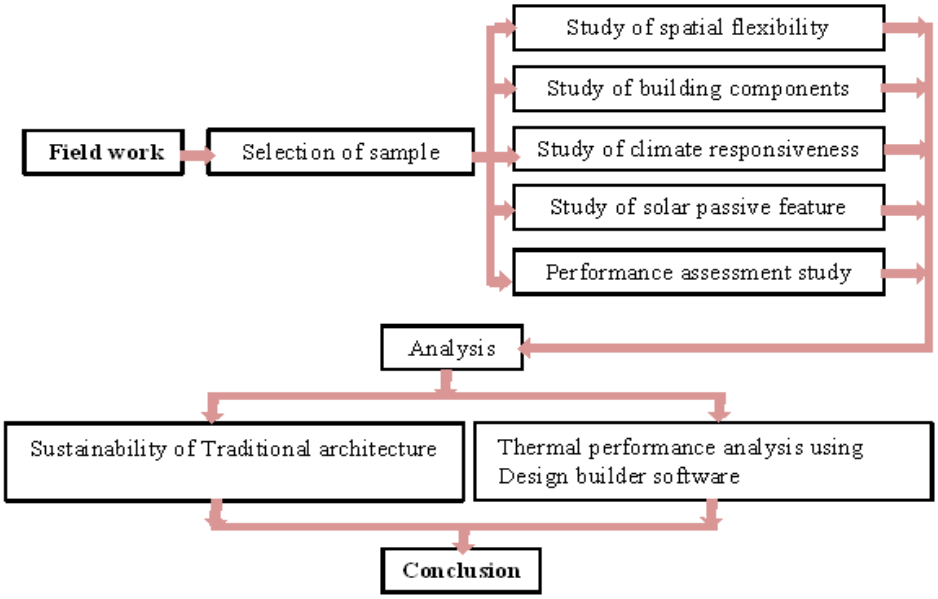

Fig.2: Flow chart of research methodology
Source: Author

Sample selection criteria
1. Sample more than 100 years old.
2. Sample with a single owner.
3. Sample with traditional architecture features.
4. Sample with a good condition and minimum modifications.

A total of 35 interviews were conducted in October 2021 applying a structured questionnaire. The interviews were analysed using different rubrics to produce graphs. Following is an outline of the questionnaire.

Table 2: The Structured Questionnaire
Source: Author

S.NO.		DETAILS	DESCRIPTIONS
1		**Details of Contact Persons (Interviewed person)**	
		Name of the contact person	
		Address	
2		**Property description**	
		Name of the owner & occupation (Since how long ownership)	
		Ownership type	i) Sale deed ii) Lease deed iii) Gift deed iv) Any other
		Address of the property	
		Location on the map	
	Q 2.1	Age of the property i) As per discussion. ii) As per property tax dept.	
	Q 2.2	Would you like to retain this house for future generation?	i) Yes ii) No
3		**Description of the Structure**	
	Q 3.1	Type of the structure	i) RCC with brick work ii) Mud & brick iii) Mud only iv Mud & stone v. Any other
	Q 3.2	Plot area	
	Q 3.3	Built up area	
	Q 3.4	Planning of the structure	i) Linear ii) Courtyard iii) Grid iv) Any other
	Q 3.5	Are you happy with the original house form?	i) Yes ii) No
4		**Construction technology & Materials**	
	Q 4.1	Are you happy with the materials used?	
	Q 4.2	Are you happy with the construction techniques used?	
5		**Environmental values of the house**	
	Q 5.1	How comfortable is this house during each season?	
	Q 5.2	What are the problems faced during each season?	
	Q 5.3	What type of maintenance do you need to do seasonally?	
	Q 5.4	What is the maintenance cost every year?	
6		**Transformations of the house**	
	Q 6.1	Have you done any modifications in the original house structure? What are they with reason?	
	Q 6.2	Are the modifications temporary or permanent?	
	Q 6.3	Are you happy with the transformations/ changes?	i) Yes ii) No

Introduction to the Case Study: Historic Town of Sawantwadi

A sample for the study is selected from the historic town of Sawantwadi formerly called Sundarwadi to display the expression of cultural identity. It is a 300 year old town with a unique character in terms of its setting in the landscape with a rich culture and traditions. It is a town in a scenic location surrounded by the beautiful *Sahyadri Mountain*[1] and a lake with clean water at the heart of the town. Earlier, the town was planned with a traditional water management system employing sustainable planning.

The latitude and longitude of Sawantwadi is 15°54'18.95"N and 73°49'16.76"E respectively. The selected research area falls under the Western Ghats region, which is one of the UNESCO's listed World Heritage sites (Natural landscape). It is situated on the West coast of Maharashtra, India, and is 98km away from Goa, India.

The town is well known for its special Konkan architectural character. It has a different group of communities' like *Brahmins*[2], *Marathas*[3], *Bhandaris*[4], Muslims and others. Each community has a diverse culture and a socio-economic structure. Traditional houses of these communities evolved through the socio-cultural processes, daily activities, sustainable site developments, traditional knowledge systems and the climate.

The dwellings of the town were planned in harmony with the local weather conditions. The house promotes cultural conservation and traditional wisdom. The selected sample is a product of the socio-economic-political and cultural profile of the residents. It also has strong connections with the activity patterns of the inhabitants, the climate, the locally available materials and techniques, occupations, religions, position in the society, status of women and the family structure. Due to urbanization, the traditional house form is losing its identity and getting erased with time.

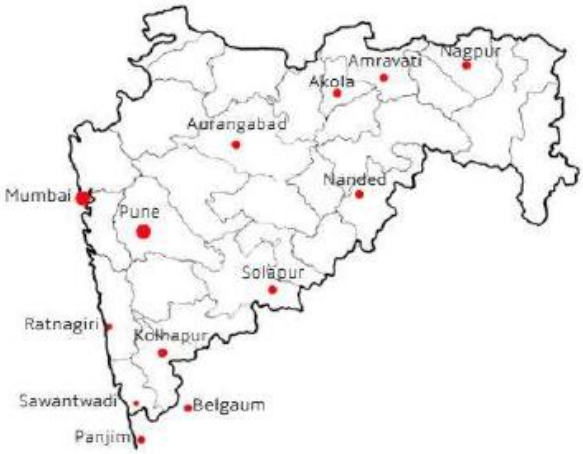

Fig. 3: The location of Sawantwadi Maharashtra state, India.
Source: (Shah, 2017)

Understanding the Contextual Relevance of the Sample

The sample belongs to a Brahmin family consisting of 8 members and is 137 years old. The house is oriented in the North-South direction with a front façade to the North. The plot area is half acre and the built up area is 340 sq.m. The structure is surrounded by open spaces from all sides helping to maintain an indoor-outdoor connection.

The house plan is rectangular, simple and functional (Fig. 6). It has a sloping roof structure covered with traditional mud tiles. The plinth of the dwelling is 0.6 meters above the

[1]The Western mountain range of India which covers the area of Maharashtra and Karnataka state is known as *Sahyadri Mountain* range.
[2]*Brahmin* is higher cast in Hindu in India.
[3]*Marathas* are the Marathi language speaking native person from Maharashtra state, India.
[4]*Bhandari* is a caste found in Konkan region Maharashtra, India and their main occupation is the Business.

natural ground level. The front is raised with a semi-covered veranda of the dwelling known as "*Loota*[5] " (Fig. 4). *Loota* acts as a semi - open space allowing natural ventilation & diffuse light to help lower down temperature of the air which will enter the house. It is the main space of social interaction. Entry to the guest bedroom and the staircase is provided through the *Loota.* The house consists of two living spaces traditionally termed as *Majghar/ walay* and is the main space of the house. The first *Majghar/walay* is for the males and the second is for the females. This space can be used for many activities, which represents the maximum adaptability and flexibility in planning. The staircase is provided through first *Majghar/walay* which leads to the *Mala* (attic). There is no rigidity with respect to activities in any space, as it provides flexibility for conducting various activities in various periods of time. The attic is provided over both the *Majghar/walay,* constructed with wood and mud ceiling in-between and acts as a double roof system. This helps to lower down the heat entering into the dwelling and to keep the interior cool.

Fig. 4: Front elevation of the selected sample
Source: Author

The house consists of a compact square courtyard called the *Chowpati*[6] at the rear side which is 1.8m X 1.8m. It is enclosed with an open veranda called the *Sopa*[7].This space was normally used by women and was surrounded by *Swayampakghar*[8], *Balantinichi-kholi*[9], *Adgalichikholi*[10], used as storage for grains. *Padvi*[11] is the space containing various equipment for different purposes like, *jata* for flour making, *ukkhan* for grounding *chillies, pata- varvanta* for grounding the spices, *chul*[12] etc, used by the ladies (Chavan, 2022).

An open space at the backyard of the dwelling is called the *paras*[13]. The *paras* are provided with *Gotha (cow shade), Maangar*[14] and a detached toilet. A small pit is also designed at *paras* where all the kitchen waste and dried leaves are decomposed to become organic manure.

[5] *Loota* is front semi-opened veranda.
[6]*Chowpati* is the courtyard provided at rear side of the house. This is open to sky space.
[7]*Sopa,* is a physical form of a covered veranda.
[8]*Swayampakghar* is a cooking space provided in every house.
[9]*Balantinichi-kholi* a dedicated room was provided for the new born babies and nurturing mother.
[10]*Adgalichikholi* is the store room.
[11]*Padavi* is the transitional space that connects Majghar/Walay and back courtyard.
[12]*Chul* is the traditional earthen stove.
[13] A *Paras* is the space at rear side of the house.
[14]*Maangar* is the covered space at the rear side of the house for storage of farming equipment, grass and wood.

Effective use of solar radiation keeps the indoor temperature warm during the winter and cold during the summer. The effectiveness with respect to sustainability can be explained in relation to planning of the house and its orientation, spatial arrangement, building components and its knowledge system.

Planning of the Dwellings and their Orientation

The climate of Sawantwadi is tropical with a temperature varying between 27 °C and 34 °C. The relative humidity rises from 56% to 93%. Natural thermal insulation is achieved by the orientation of dwellings, the position of the windows/doors, compactness, the provision of the attic, the courtyard, the proper spatial organization and the materials. The house is placed in such a way that the shorter sides are exposed to direct solar beam radiation whereas the longer side is exposed to the diffused solar radiation. Vegetation is provided at the boundaries of each dwelling for safety and also acts as the air and dust purifier. It reduces the additional heat gain. The courtyard is one of the main characteristics of the house that helps to improve natural light and ventilation. Maximum openings are provided in axis to achieve good light and ventilation.

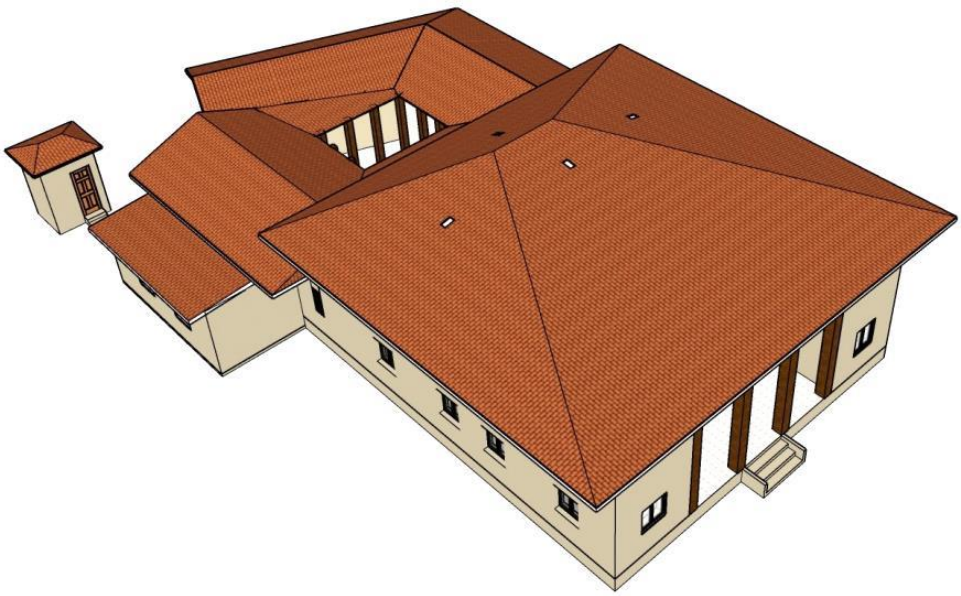

Fig. 5: View shows the roof pattern of the house
Source: Author

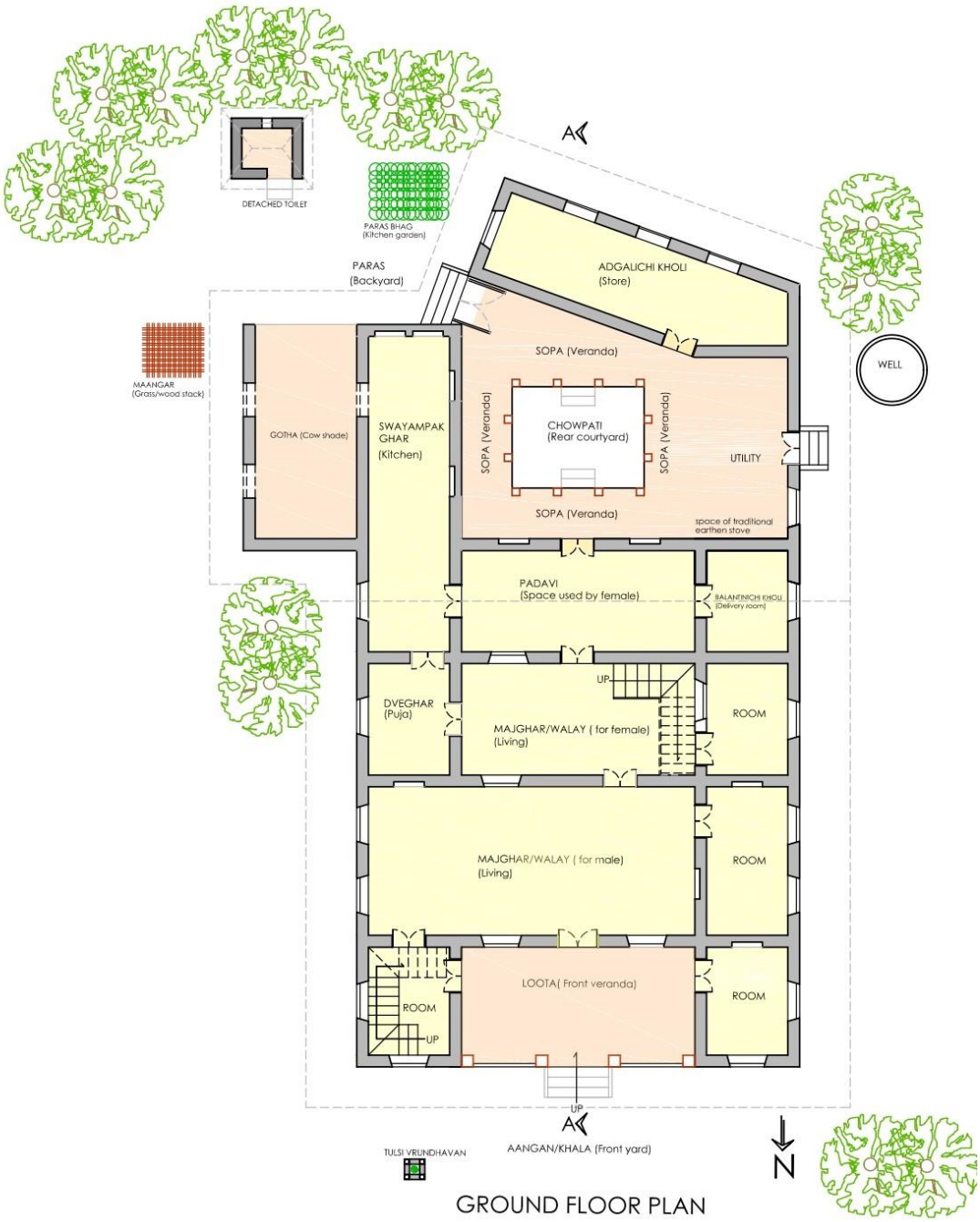

Fig.6: Ground floor plan of the selected sample
Source: Author

Building Components

The selected sample has a composite structure with stone, mud, wooden columns and a sloped roof with mud tiles.

Walls

The dwelling is constructed with locally available mud, stone, timber and clay tiles. 350 mm thick internal and external mud walls act as thermal masses. It is strengthened with the help of a thick wooden column. Two columns are tied with the help of wooden logs which acts as a

load bearing structure and is earthquake resistant. The walls are constructed with an exclusive traditional technique and are regularly plastered by locally available mud or cow dung with lime which keeps the space cool. The interior of the house is kept cool in the summer and warm in the winter with the help of heavy walls.

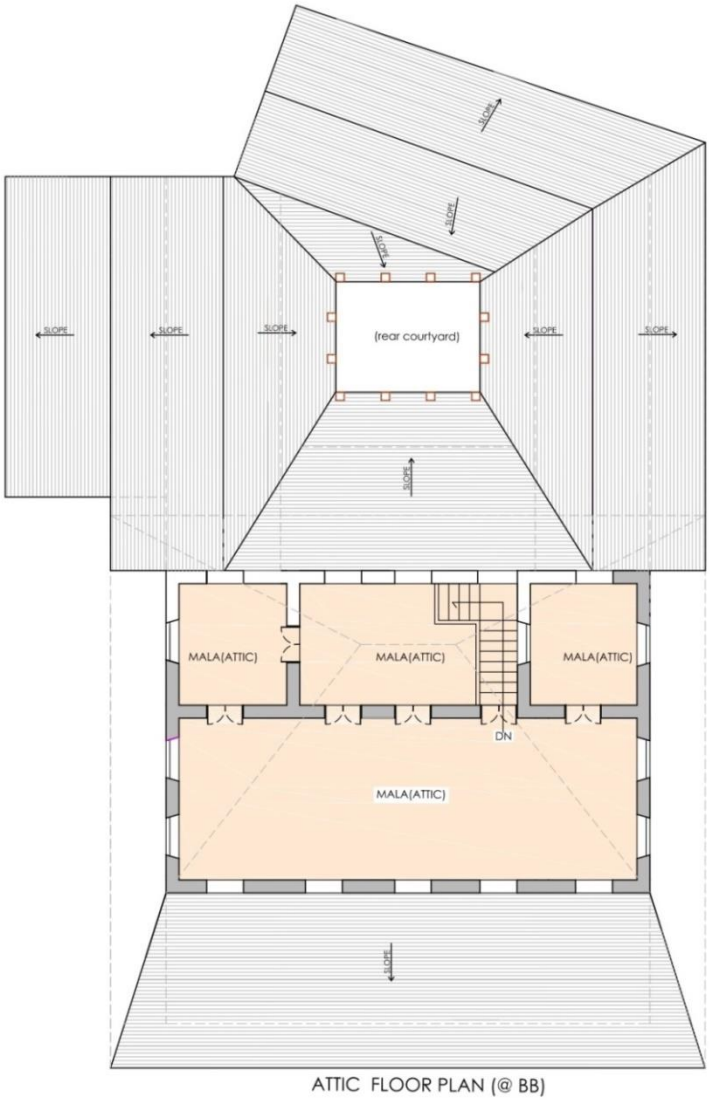

Fig.7: The attic floor plan of the house
Source: Author

Windows

The common features of the dwelling are the low level small windows with wooden frames, M.S. grills and wooden shutters. They provide good natural ventilation and are earthquake resistant. Low level small openings cut off the heat gain and prevent entry of dry hot winds in summer, where at the entry level, air gets compressed and then gets expanded due to the shape of the openings. This creates comfort in the interior of the house and results in the minimum or no use of external energy.

The proportion of wall to opening is 30% and all openings including doors, windows and ventilators amount to only 50% of the floor area. This case study has a total 41 windows/ventilators and 25 windows/ventilators are placed on windward directions and covered with roof hanging. 75% of windows allow diffused sun light and ensures cross ventilation. Almost all the windows were placed opposite to each other. The external wall of the dwelling has minimum openings to maintain the lighting level and the temperature.

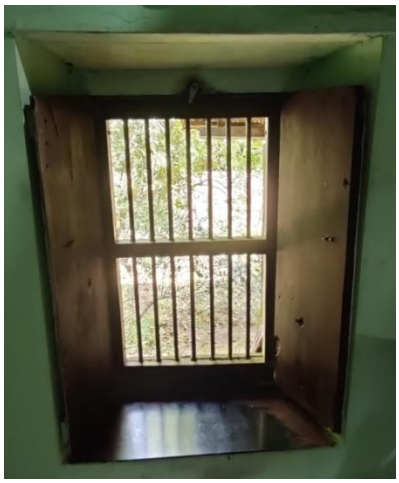

Fig. 8: Wooden window with a M. S. grill
Source: Author

Fig. 9: Rain water drain from the courtyard to the well.
Source: Author

The Courtyard

Courtyards are excellent thermal regulators and play an important role in thermal performance of the sample. The upper part of the courtyard has more heat gain from the sun, making the air warmer and lighter. Thus, due to the low pressure in the courtyard, air from the outside is induced inside from the surroundings. After the sunset, a convective flow of the air continues, keeping the courtyard cool.

Fig. 10: Section of the house.
Source: Author
1. Aagan/Khala (front yard) 2. Loota (front veranda) 3 & 4.Majghar/walay (Living for males & females) 5. Padavi 6.Sopa 7. Chowpati 8. Adgalichikholi 9.Mala 10. Tulsivrundhavan

Although the courtyard is small, it helps in providing natural diffused day light to the entire house which reduces energy consumptions to a great extent. The *sopa* (veranda) surrounding the courtyard acts as a buffer to avoid direct light for the other rooms located around the courtyard. This courtyard is used by the females for day to day activities like washing and drying cloths, and utensils making the space wet which keeps the surrounding cool. To collect rain water during the rainy season, an arrangement of the stone gutter is made through the courtyard which is connected to the well at the rear side of the house. This refills the well as a rain water harvesting technique.

Roofing

Sawantwadi receives heavy rain; hence the steep sloped roof is a very good solution to drain off the rain water from the house. The pitch hip roof inclined at an angle of 35^0 reduces the solar beam radiations. The extended roof acts as an overhang to protect the wall from the heavy rainfall and the hot sun. In traditional dwellings, sloping roof is one of the climate responsive design features. The roof is made up of locally available wood from teak and jack fruit trees and the semi-circular mud tiles have been placed in two layers called *'nalichikoule'*[15]. The two layers increase the thickness of the roof which reduces the heat gain from the roof. A double roof system is adopted i.e. attic traditionally named as '*mala*' is created as an outlet for hot air as well as for the storage. It also helps in reducing the temperature of the dwelling. An interesting skyline is created with the timber pitched roof with country tiles. A large overhang of the roof protects the wall against the heavy rain and shades the building from the harsh sun.

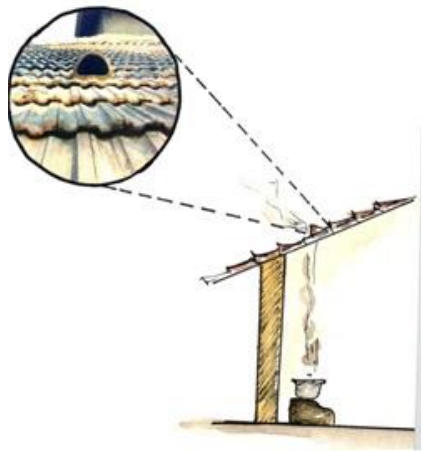

Fig. 11: Special roofing tiles fixed for ventilation
Source: Author

Fig. 12: The roofing system
Source: Author

Flooring

Flooring is generally made with mud and regularly plastered with cow dung which helps to regulate the indoor temperature. It has medicinal benefits as well.

[15] *nalichikoule* semicircular mud roofing tile.

Table 3: Structural elements and building materials of the house.
Source: Author

S.n	Structural elements	Building materials	Impact
1	Plinth	High level local stone plinth	Protect the structure from heavy rain.
2	Walls	350mm thick wall constructed with processed mud. Mud processing is done by adding lime, sometime jaggry and plastered with mud & lime.	Act as a thermal mass.
3	Plaster	The walls are regularly plastered by locally available mud or cow dung	Helps to regulate the indoor temperature and acts as a binding agent.
4	Wooden column beam frame	Wooden column with a stone pedestal. Its size depends upon the span of the room and the availability of wood size. Two columns are tied with the help of wooden logs.	Act as an earthquake resistant.
5	Window, Door	Low level small chamfered window with a wooden frame, M.S. grill with wooden shutters are the common features of the dwelling. Door with a wooden frame and wooden panel shutters.	A low level small opening cut off the heat gain and prevents entry of dry hot winds in the summer, where at the entry level air gets compressed and then gets expanded due to the champher shape of openings. This creates comfort in the interior of the house and results in minimum or no use of external energy. The frame acts as earthquake resistant.
6	Roofing	Steep sloped roof with mud tiles.	Reduces the solar beam radiations. Large overhang of the roof protects the wall against the heavy rain and shades the building from the harsh sun.
7	Flooring	Flooring is generally made with cow dung	Cow dung and mud floor regulates the indoor temperature and has medicinal benefits.

Thermal Performance Analysis of the House using Design Builder Software

Thermal performance study is important in relation to not only the user's comfort zone but also to understand the mechanical energy consumption. Indoor comfort of the dwelling determines the energy consumption and it plays a major role in sustainability.

Indoor environment of the traditional house is designed by passive techniques with consideration of human health and ease along with the maximum use of sustainable parameters. The practice of adapting sustainable principles in the contemporary structure will reduce the dependence on fossil energy.

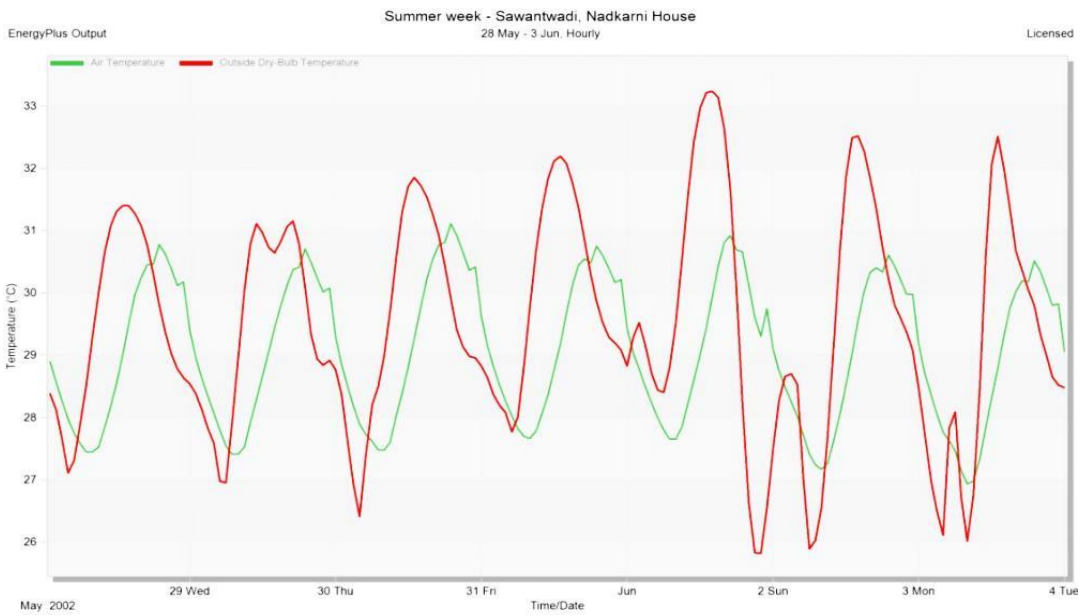

Fig. 13: Analysis of the thermal performance of the house for the hottest week i.e. 28th May 2021 to 3rd June 2021, calculated using Design builder software.
Source: Author

The thermal performance study of the selected sample is considered for the hottest week in the year i.e. 28th May 2021 to 3rd June 2021 and the coldest week of the year i.e.19th February 2021 to 25th February 2021 using Design builder software. It is a testament from the result (Fig.13). The weekly temperature data says that the construction techniques and materials used to construct this house includes mud-lime walls, the roofing system, the doors, the windows, the flooring and the spatial arrangement which helps to maintain the indoor temperature between 27 °C to 30°C along with natural ventilation during the hottest week of the year.

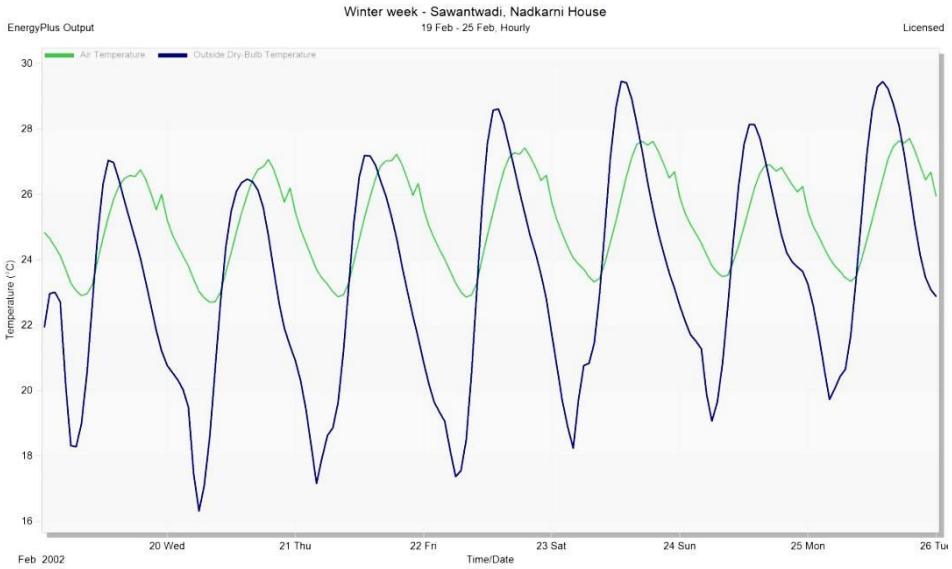

Fig. 14: Analysis of thermal performance for the house for the coolest week i.e. 19th February 2021 to 24th February 2021, calculated using Design builder software.
Source: Author

Table 2: Parameters consideration for analysis of thermal performance.
Source: Author

S.no.	Building components	Size	U-Value
1	External and internal wall	350mm thick	1.56 W/sq.m
2	Sloped roof with mud tiles (double layered)	600mm effective thickness	1.26 W/sq.m
3	Wooden windows	900mmX 1200mm	NA
4	Wooden doors	900mmX 2100mm	NA

Thus the house keeps the indoor cooler compared to the outdoors and maintains comfort conditions. In the summer, due to the outdoor conditions, the wind speed is less but the stack effect of the courtyard maintains the comfort of the interior. During the winter, it helps to maintain the temperature between 23°C to 27°C along with natural ventilation and maintains the comfort conditions inside the house (Fig.14). Hence, there is no need for mechanical devices for producing environmental comfort.

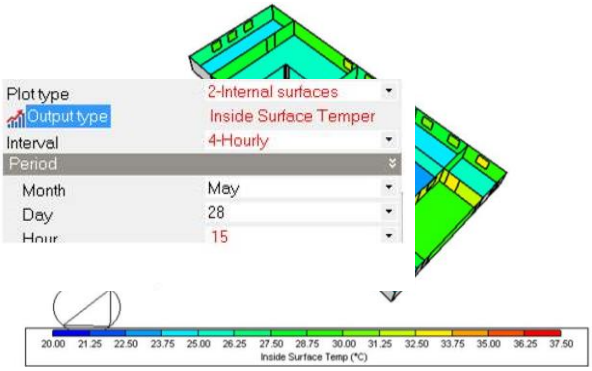

Fig. 15: Inside surface temperature of the house at the hottest day (28th May)
Source: Author

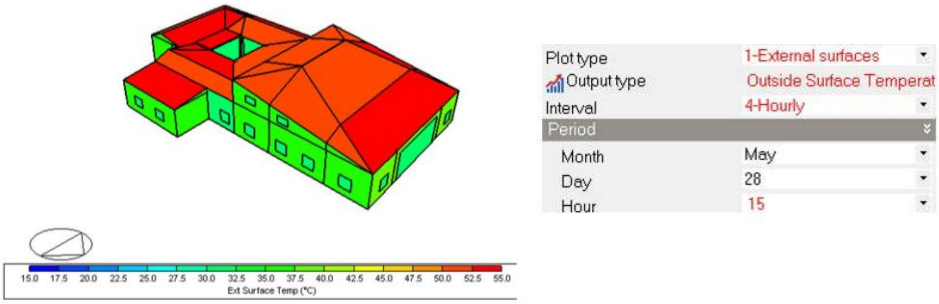

Fig. 16: External surface temperature of the house at the hottest day (28th May)
Source: Author

The spatial planning and the use of traditional materials and the techniques encourage the thermal comfort of the interior of the building. The pitch hip roof inclined at an angle of 35^0 reduces the solar beam radiations (Fig.16). The roof is one of the climate responsive design features. In this case, the roof surface temperature is 50°C to 55°C (Fig.16), whereas the internal surface temperature is from 22°C to 33°C (Fig.15).

Day Lighting Analysis of the House using Revit software

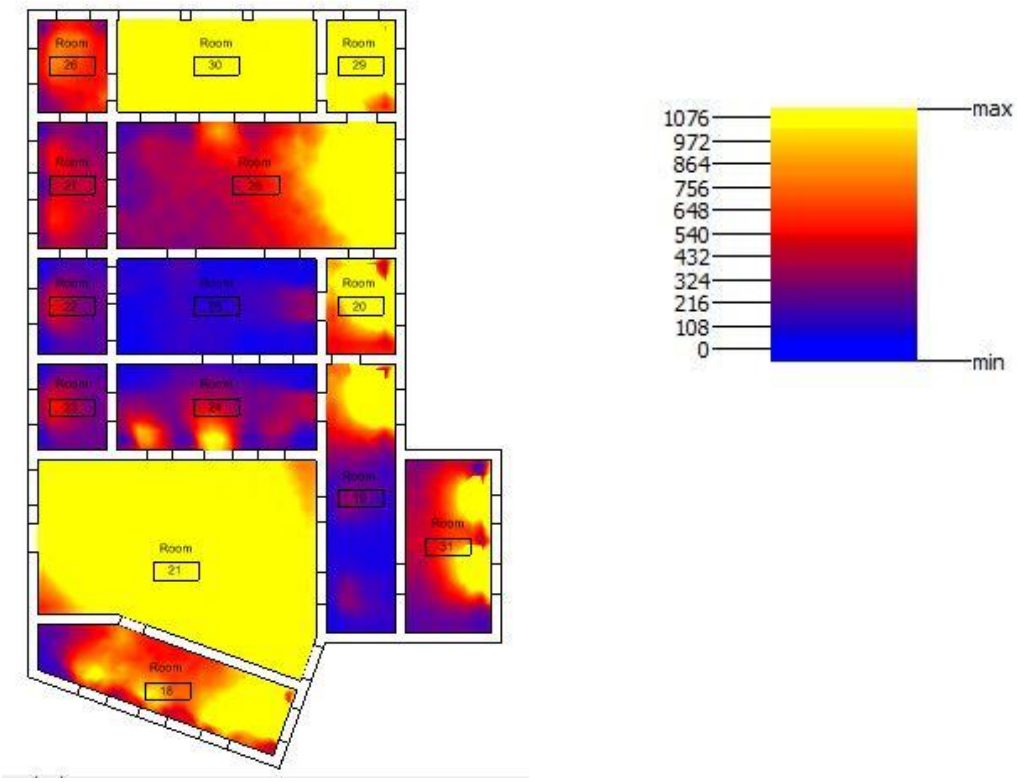

Fig. 17: Daylight factor of the house at the coldest day (21st February 2021)
Source: Author

Day light analysis for indoor lighting level and Revit radiance lighting simulation has been performed. The daylight simulation has been carried out on the coldest day of the year i.e. 21st February. Lighting simulation, external daylight levels have been determined as 8700 Lux (Energy conservation building code 2007, India). Enclosed space of the house has been considered to analyze day light factor (Fig.17). All openings include windows, doors, skylights and courtyard has been introduced as per existing conditions. According to the observations, 75% of indoor floor space received natural lighting.

Conclusions

The sample is highly responsive to the climatic conditions. Natural thermal insulation is achieved by orientation, organization of spaces, positions of windows/doors, compactness, provision of attic, and the selection of materials and techniques.

Space provided at *Loota*, *Majghar/walay* and space around *chowpati* having being used for various different activities represent flexibility in planning. Mud-lime wall with the thickness of 350mm plastered with mud, lime and cow dung act as thermal masses. Cow dung and mud floor regulates the indoor temperature. *Loota* and *sopa* are the semi open spaces which permit natural ventilation and help to lower down the temperature of the air which will enter into the house. The *Mala* (attic), the small wooden windows, the wooden doors, the skylights and *chowpati* provide a stack effect and maintain the indoor environmental quality of the house.

Local construction techniques are less expensive compared to others and are easy to construct. Wooden framed structure of the doors and windows and also the wooden columns with tie of wooden logs produces an earthquake resistance structure.

The study of traditional architectural principles is an important lesson to understand the environment and its effects on the built form. The selected traditional house has evolved in response to the climatic conditions and traditional knowledge system that lead to sustainability. The thermal comfort conditions in this house are the result of the minimalistic use of external energy.

The study of thermal performance shows that all the spaces within the dwelling lie between the standard comfort zone conditions, mainly due to planning and orientation of the built form, climate responsive architectural details of the structure, traditional knowledge systems and the user-friendly spaces.

It is observed that the sample responds to energy efficiency, flexibility and the appropriateness of space design. The buffer spaces such as the double roofing system above *Majghar/walay* (living), *Loota*; the semi opened raised veranda/platform at the entrance, *Chowpati* (rear courtyard) and semi opened *Sopa* (veranda) around the courtyard allow steady and smooth passage of air movement from the exterior to the interior spaces. It also facilitates and encourages social linkages. The space accommodates multiple activities which prove flexibility in planning.

Chowpati (Courtyard) is the important space in the sample. It is a focal element and creates a harmony between Nature and the interior. It provides natural light and ventilation and helps in making the dwelling climatically responsive. The use of local materials and techniques and their effectiveness towards sustainability is also one of the lessons learnt. It is essential to respect and learn valuable lessons from traditions, as learnt from this study.

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