APPLICATION POTENTIAL OF VERNACULAR RESIDENTIAL BUILDINGS OF KERALA

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF ARCHITECTURE

by

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CANDIDATE'S DECLARATION

I hereby certify that the work, which is being presented in the dissertation, entitled **"APPLICATION POTENTIAL OF VERNACULAR RESIDENTIAL BUILDINGS OF KERALA"** in partial fulfilment of the requirement for the award of the degree of **Master of Architecture,** submitted to the Department of Architecture and Planning, Indian Institute of Technology Roorkee, is an authentic record of my own work carried out during the period from June 2009 to June 2010 under the supervision of **Prof. Rita Ahuja and Prof. R.Shankar**, Department of Architecture and Planning, Indian Institute of Technology Roorkee.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

Place: Roorkee
Date: 29·06·2010

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CERTIFICATE

This is to certify that the above statement made by the candidate **Ms. Dibini Bulhar** is correct to the best of my knowledge.

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The acknowledgement will not be complete till I express my sincere thanks to my family for their prayers, support and encouragement right from the beginning of this dissertation.

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ABSTRACT

Vernacular buildings evolve over a long period of time and suite themselves to that particular region and its climate. On the other hand, most of the modern buildings are not that sensitive to the micro climate and usually the designs and the techniques used are not particular for that region. Because of this the comfort inside the building has to be mechanically balanced and this leads to higher energy consumption compared to the vernacular buildings of that area. So it is important to study the vernacular architecture of that area and understand the underlying concepts in order to attain thermal comfort in a natural way.

This dissertation aims in identifying the potential of vernacular residential buildings with respect to climate responsiveness and apply them in the present urban housing context; particularly in Kerala. To achieve this, first an understanding of the climate of Kerala and its characteristics is developed. The methodology is framed after the literature review and focuses on achieving the architectural means to attain the thermal comfort objectives inside the building through study and analysis of appropriate case studies.

Study of literature helped in understanding the principles of design and construction in a region neighbouring to Kerala, having same type of climate.

Further, a study area of Kerala vernacular residences is selected. Warm humid zones of Kerala, in particular were chosen for this study and they lie in the midlands and lowlands. Amongst these only the Central part of Kerala was selected, the vernacular buildings of that region were studied in detail, which is typical for the hot humid zones of Kerala. Three courtyard houses from Thrissur district and three row house communities from Palakkad district were selected for the study. Detailed surveys were done for each building on various aspects. Questionnaire surveys were conducted in the row houses to know the users' response. The data collected after each survey was analysed in detail on the basis of thermal comfort and inferences were arrived upon. From the study it was found that between vernacular buildings and contemporary ones, vernacular residences are more climate responsive. Further on comparing courtyard houses and row houses, the latter were found to be responding better to the climate. Following many such inferences

from the different studies, guidelines were framed for site planning and design of low rise (up to 4 storeys) and medium density (Net dwelling density of 120-180 dwelling units/hectare or gross dwelling density of 75-120 dwelling units/hectare) row houses in the present modern urban housing scenario, and the application of it is done at the site planning level.

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GLOSSARY OF VERNACULAR TERMS

A-B

Adukkala/Adukkalai : A kitchen

Agraharam : Rows houses of South India, where Brahmins reside as a community

Anganam : A courtyard in vernacular residence of Kerala

Ara : A grain store

C

Catusala : See *nalukettu*

D

Dwisala : A vernacular residence of Kerala with two *salas* or halls, in 'L' shape

E-J

Ekasala : A vernacular residence of Kerala with one *sala* or hall

Ettukettu : A vernacular residence in Kerala with two quadrangles or mansions with eight *salas* around two courtyards.

K-L

Kinar : A well

Kizhakkini : Eastern part or hall of *nalukettu* or any other vernacular courtyard house of Kerala

Koodam : A hall in an *agraharam* where everyone gathers

Kottil : A work area next to kitchen in an *agraharam*

M

Machu : An attic space below the sloping roof of traditional Kerala homes

Machukkul : A strong room with thick wall masonry in an *agraharam* house

Meladukkala : An ante room of kitchen

Mittam : Open space or courtyard with in *agraharam* house

N

Nadumittam : A courtyard in the centre of the house

Nalukettu : A vernacular residence of Kerala with four *salas* around a courtyard

Nezhi : An ante room

Nilavara : A storage space or grain store in vernacular courtyard house which is mainly made of wood

Nilavarakkundu : A semi basement storage room below *nilavara*

O

Onaamkettu : First block of an *agraharam* house

Ovumuri : Urinal space in vernacular residence of Kerala

P-Q

Padinjattini : Western part or hall of *nalukettu* or any other vernacular courtyard house of Kerala

Pandrandukettu : A vernacular residence in Kerala with three quadrangles or mansions with twelve *salas* around three courtyards

Pathinarukettu : A vernacular residence in Kerala with four quadrangles or mansions with sixteen *salas* around four courtyards

Poomukham : A sit out or portico of vernacular residence of Kerala

R

Randaamkettu : Second block of an *agraharam* house

S

Sala : A square or rectangular living room or hall with verandah on one or more sides

T-U

Thattu : Wooden ceiling over a space

Thazhvaram : A passage which gives connection to all the rooms in an *agraharam*

Thekkini : Southern part or hall of *nalukettu* or any other vernacular courtyard house of Kerala

Thinna/Thinnai : A sit-out, mainly on a raised plinth

Thodi : A land property behind *agraharam* house

Thozhuthu : A cow shed in vernacular residential building of Kerala

Trisala : A vernacular residence of Kerala with three *salas* or halls, in 'C' shape

V-Z

Vadakkini : Northern part or hall of *nalukettu* or any other vernacular courtyard house of Kerala

CHAPTER 1
INTRODUCTION

1.1 INTRODUCTION

Since the early existence of man, climate was one of the defining factors for his shelter to protect himself from nature's elements like rain, wind, sun, snow, etc. and other forms of danger. Slowly he moved from caves to shelter built by his own hands. The primary concern of shelter then shifted from climate to comfort, while still not compromising on the climatic aspects.

Each part of the world developed its own techniques and design for its buildings that are best suited to that particular region and its climate. This is the vernacular architecture of a particular region or "forms which grow out of the practical needs of the inhabitants of a place and the constraints of the site and climate (Oktay)."

In the vernacular architecture style practised in Kerala, the climatic aspect was well reflected. The designs elements were evolved out of experience and their relationship with the climate. The major elements employed were raised plinths, internal and external verandahs, sloping roofs with steep pitches, projecting eaves, double roofs, gable windows, courtyards etc.

1.2 IDENTIFICATION OF THE PROBLEM

In the vernacular architecture of the warm humid part of Kerala, in low lands and mid lands, the buildings were designed predominantly for maximising ventilation, minimising heat gain, daylight penetration and precipitation.

In the contemporary context, advancement in building technology and materials lead to increased building activity. But the buildings erected are not usually climatic responsive as compared to traditional buildings and consume more energy. Hence, there is a need to study and analyse the vernacular design concepts and apply those in the contemporary buildings, to make it climate responsive.

1.3 AIM AND OBJECTIVES

Aim

To formulate guidelines for the planning and design of residential buildings based on the study of vernacular architecture of Kerala and apply those guidelines at site planning level in the modern context.

Objectives

- To understand the major issues affecting thermal comfort in buildings, particularly residential, of warm humid climate.
- To study the examples of vernacular residential architecture of warm humid regions of Kerala.
- To analyse the planning, design and functions of architectural elements of vernacular residential buildings and draw useful inferences.
- To formulate site planning and design guidelines for climate responsive residential buildings in modern context.
- Apply the derived guidelines in the modern context of low rise[1] and medium density[2] urban housing at site planning level.

1.4 SCOPE AND LIMITATIONS

Scope

- Since the vernacular residential buildings are resource-conserving and 'green', the inferences from the case studies, and hence, the planning and design guidelines formulated for application in modern context, will, when applied, result in resource-conserving and 'green' architecture, to a large extent.
- Though the extent of the study is limited to low-rise (up to 2 storeys) vernacular residential buildings of Kerala, the guidelines formulated will be useful in the modern context of medium density and low rise[1] residential development suitable/necessary for small and large cities.

Limitations

- The study area is limited to the warm humid zones of Kerala.

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[1] Low rise- 4 storeys or up to 15m

[2] Medium density-Net dwelling density of 120-180 dwelling units/hectare or gross dwelling density of 75-120 dwelling units/hectare

- Due to practical difficulties in field studies, the case studies are limited to two regional locations and two examples.
- The analysis is based on resident's responses and on-the-spot field observations and verifications without the aid of any sophisticated instrumentation.

1.5 METHODOLOGY

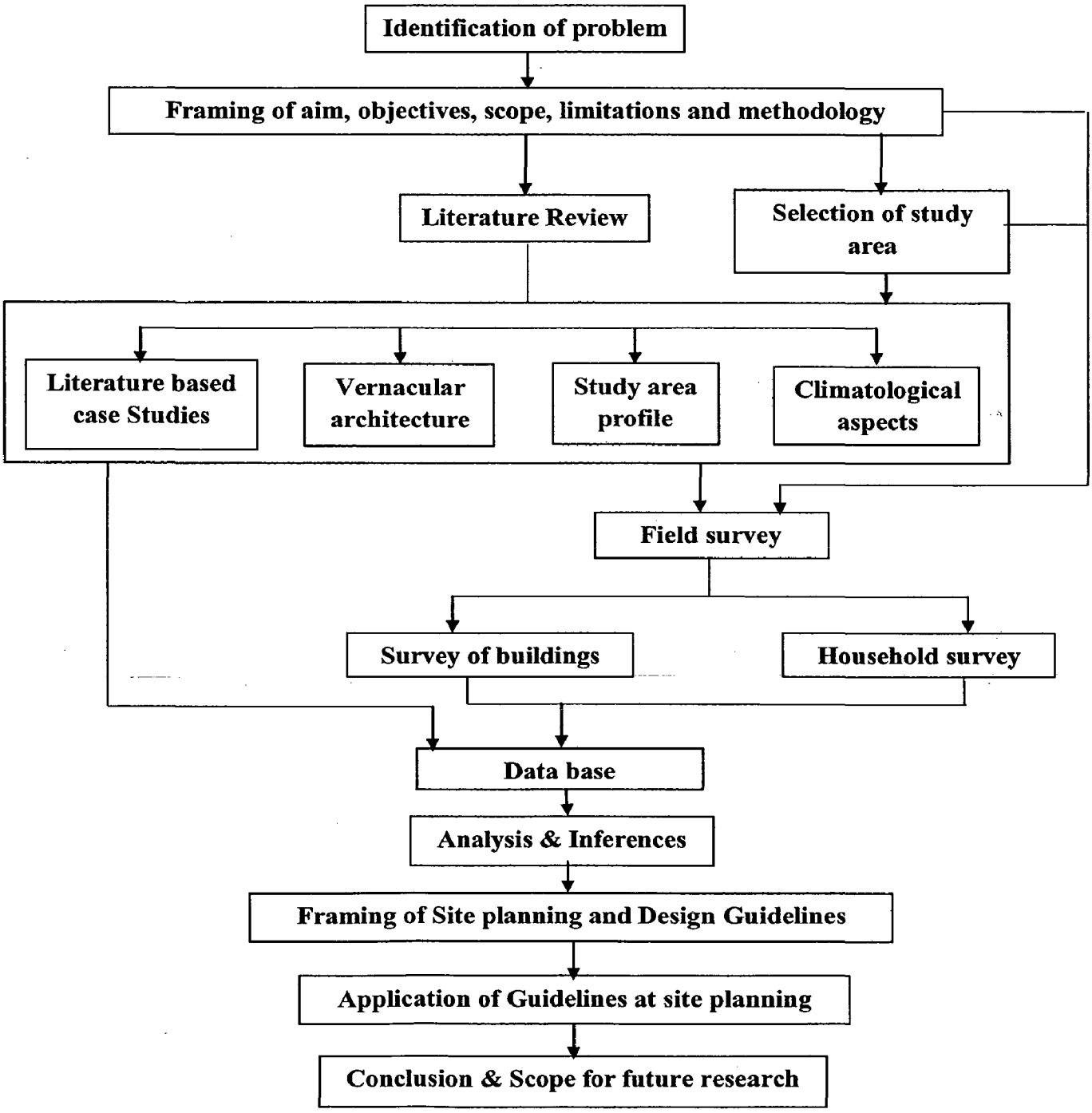


Figure 1.1-Methodology flow chart

CHAPTER 2
LITERATURE REVIEW

2.1 PREAMBLE

Warm humid climate zone, its elements and the design principles of buildings in warm humid climate are narrated here. A description about vernacular architecture in general, in India, its different typologies and the materials used are also given here.

2.2 WARM HUMID CLIMATE ZONE

This zone is found in an area around the equator extending from about 15° N to 15°S. There is very little seasonal variation throughout the year (Paul and Dieter 1993).

2.3 ELEMENTS OF WARM HUMID CLIMATE

Temperature

The annual mean temperature is about 27°C (80°F), and the range of the average monthly temperature is about 1-3°C (2-5.5°F). The diurnal temperature swing, on the other hand, is about 8°C (15°F) (Givoni, 1998). Air temperature remains moderately high between 21 and 32°C, with slight variation between day and night (Koenigsberger et al. 1996).

Humidity and precipitation

The relative humidity varies between 55% and 100%, but generally lies around 75%. Precipitation is high throughout the year and often occurs in the form of torrential rains with heavy winds and storms (Koenigsberger et al. 1996). Precipitation mainly affects on the roof and external walls (fig 2.1)

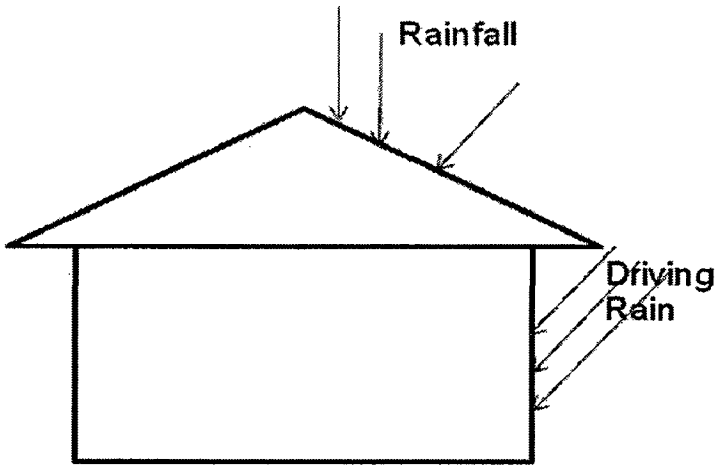


Figure 6.1-Effect of precipitation on buildings

Radiation

The sky is fairly cloudy throughout the year; in coastal regions, however, it is often clear. Accordingly, the solar radiation is to a great extent diffused and partly reflected by the high vapour content. Thus at night the accumulated heat is not readily dissipated (Koenigsberger et al. 1996).

Wind

The wind velocity is generally low except during rain squalls, when usually one or two dominant wind directions prevail. In coastal regions, however, regular thermic winds provide relief from heat and humidity. Storms are common in this region (Paul and Dieter 1993).

The two atmospheric factors which dominantly influence human comfort are- air temperature and humidity.

In warm humid climate the combination of moderately high temperature (which is lower than in hot and dry zones) or less diurnal variation of temperature with high humidity is the mail problem to cope with.

2.4 PRINCIPLES IN BUILDING DESIGN

Requirements in design and construction of buildings in warm humid climate to attain thermal comfort are

1. Provision of continuous and efficient ventilation

2. Protection from sun, rain and insects
3. Prevention of internal temperature elevation during the day and minimization during the evening and night (Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings) (Givoni, 1969)

2.4.1. Provision of continuous and efficient ventilation

1. Form and planning
2. Orientation
3. Size and placement of openings
4. Site landscaping
5. Ventilation through various phenomena

1. Form and planning

The prime concern of plan form in this climate is to maximise air movement. Open elongated plan shapes with single row of rooms is good for cross ventilation (Koenigsberger et al. 1996). Spread out planning is better than compact one (Givoni, 1969) (fig 2.2).

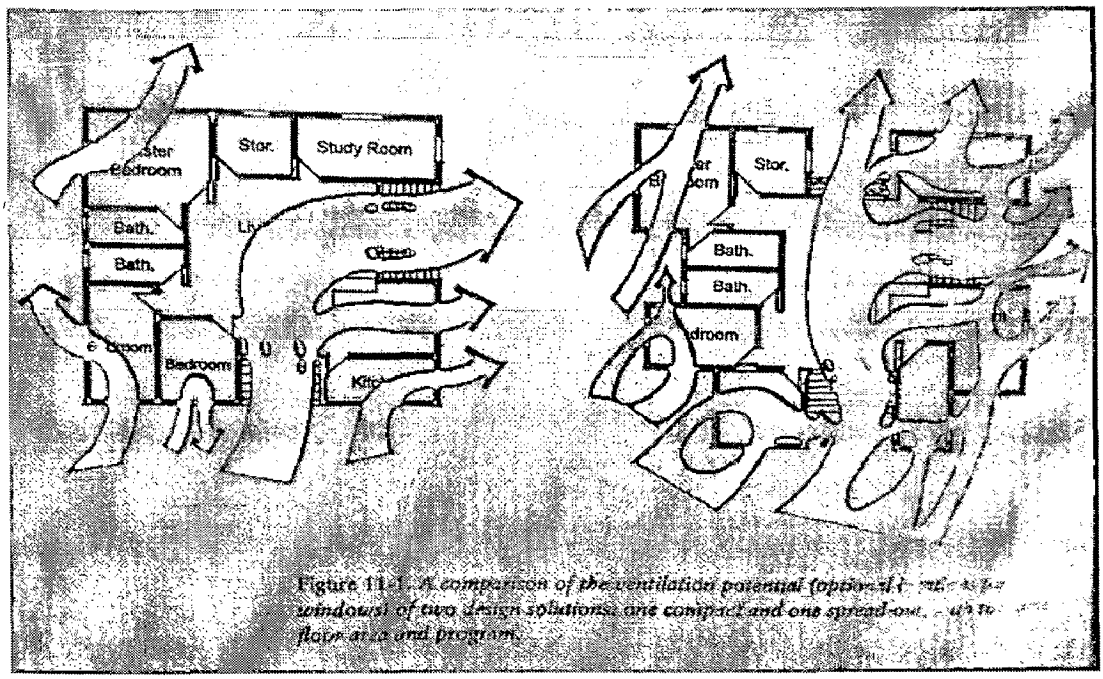


Figure 2.2- A comparison of the ventilation potential of two design solutions one compact and one spread-out, with the same floor area and program.

Source: Climate considerations in building and urban design

2. Orientation

The building should be oriented in relation to the wind direction and sun path of that particular area. Rooms should also be oriented to get maximum ventilation during the occupied time of that room. Sun path diagram and wind direction can also be perpendicular to each other in some cases. So an orientation which compromises to both sun path and wind direction should be taken as the final one. In this case wind can be directed to certain areas with the help of fins or sunshades or even through landscaping around the building. The walls which receive direct sun's radiation can be shaded or treated in such a way to reduce heat gain (Givoni, 1998). For extended plans, in a line across the prevailing wind direction, afford low resistance to air movement and is therefore the ideal solution.

3. Size and placement of openings

Windows should be large and fully openable, with inlets of a similar size on both sides of the room allowing a proper cross-ventilation (Paul and Dieter 1993). Each room should have at least two windows in different walls to enable cross ventilation. All these measures have to be designed to give minimal resistance to the airflow. Openings should be placed according to the prevailing breezes, so as to permit a natural airflow through the internal space. This airflow is most effective if concentrated at body level. Openings should be within 45° of the perpendicular to the direction of wind flow (Krishan et al. 2001).

4. Site Landscaping

A combination of grasses, low flower bed and shade trees with high trunks is the best plant combination for landscaping in warm humid climate. Vegetation should be used to maximize air flow. Trees with high trunk and wide canopy can shade the roofs. Trees should be placed such that shade can be utilized in that area and it will not block the wind. So it should not be placed densely on the windward side. Even high shrubs are not advisable. Pergolas of vines in front and above windows can be provided for effective shading (Givoni, 1998).

5. Ventilation through various phenomena

a) Venturi effect or funnel effect

When the air flow is channelled and restricted, the pressure rises and the velocity increases (fig 2.3).

Figure 2.7- Venturi effect

Source: http://www.ieindia.org/publish/ar/0403/april03ar4.pdf

b) Tunnel effect

In tunnel effect, air will be passed through several rooms thus ventilating each room. This is possible by giving openings of all rooms in straight alignment.

c) Induced ventilation

Passive cooling by induced ventilation can be very effective in warm and humid climate. This method involves the heating of air in a restricted area through solar radiation, thus creating a temperature difference and causing air movements. The draft causes hot air to rise and escape to the ambient, drawing in cooler air and thereby causing cooling (fig 2.4).

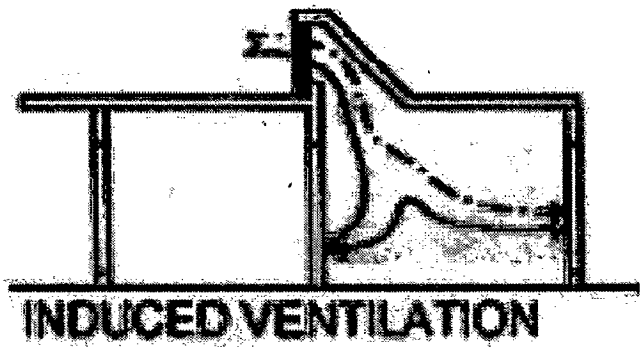


Figure 2.8-Induced ventilation

Source: http://www.ieindia.org/publish/ar/0403/april03ar4.pdf

d) **Courtyard effect** (fig 2.5)

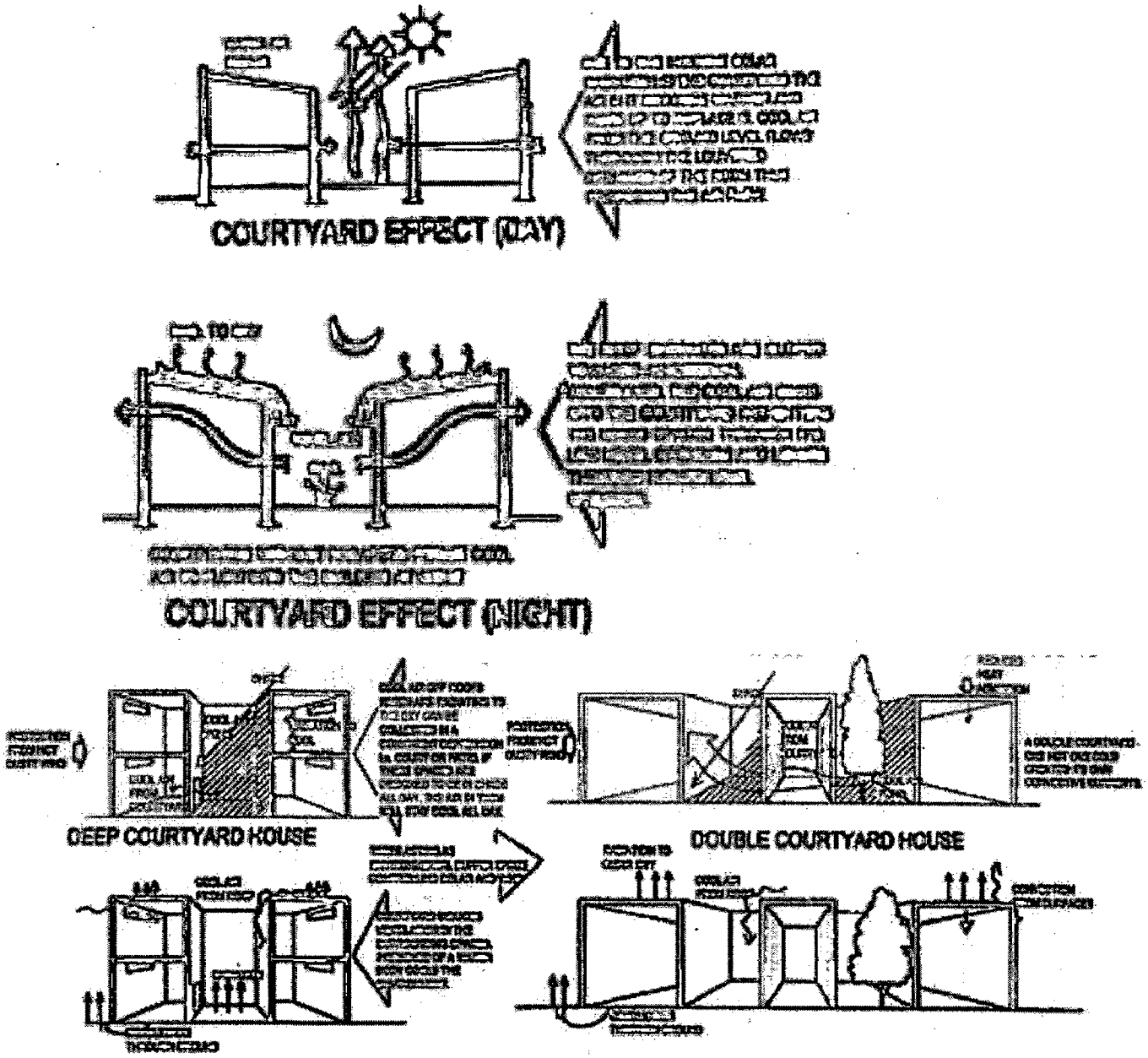


Figure 2.9- Different types of courtyard effects

Source: http://www.ieindia.org/publish/ar/0403/april03ar4.pdf

e) **Air Vent**

When air flows over a curved surface, its velocity increases resulting in lowering of the pressure at the apex of the curved roof, thereby, inducing the hot air under the roof to flow out through the vent. In this way, air is kept circulating through the room under the

roof. Air vents are usually placed over living rooms. It is most suited for single units which are just above frequently used liveable space (fig 2.6).

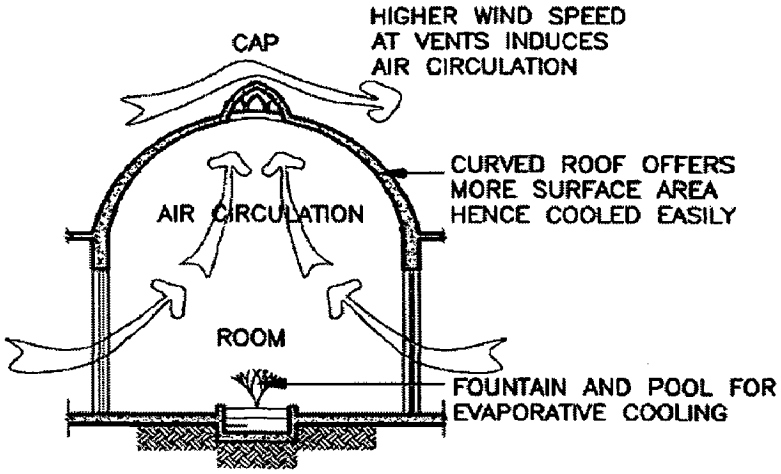


Figure 2.10- Air vent

Source: Handbook on energy conscious buildings

2.4.2. Protection from sun, rain and insects

1. Shading for walls and openings
2. Roof
3. Fly screen

1. Shading of Openings and Walls

In single storey buildings walls and openings can be shaded with the help of wide verandahs, roof extensions, overhangs, vegetation etc. In multi-storeyed building openings and walls facing north and south can be shaded by wide balconies extending along the whole facade. Eastern and western walls can be shaded by fixed shading. Horizontal narrow strips of windows can be shaded by inclined overhangs.

2. Roofs

In warm-humid areas the roof is preferably pitched to allow heavy rains to run off. Large overhangs protect the walls and openings from radiation and precipitation.

a) Single leaf construction

The roof should be made of lightweight materials with a low thermal capacity and high reflectivity. Metallic and light coloured surfaces have the best reflective capacity. Painting the surface in light colors, e.g. a yearly applied coat of whitewash, is an

economical method to increase reflectivity. In most cases a single leaf construction will not satisfy the comfort requirements.

b) Ventilated double roof

A more efficient solution is the properly ventilated double roof. The inner layer (ceiling) may be well insulated and provided with a reflective upper surface. The inner surface of the ceiling should not exceed the air temperature by more than 4°C. This can be achieved by an insulation board with a U-value of about 1.5-W/m². Where such materials are not available or cannot be afforded, even the cheapest kind of ceiling would provide a substantial improvement (fig 2.7).

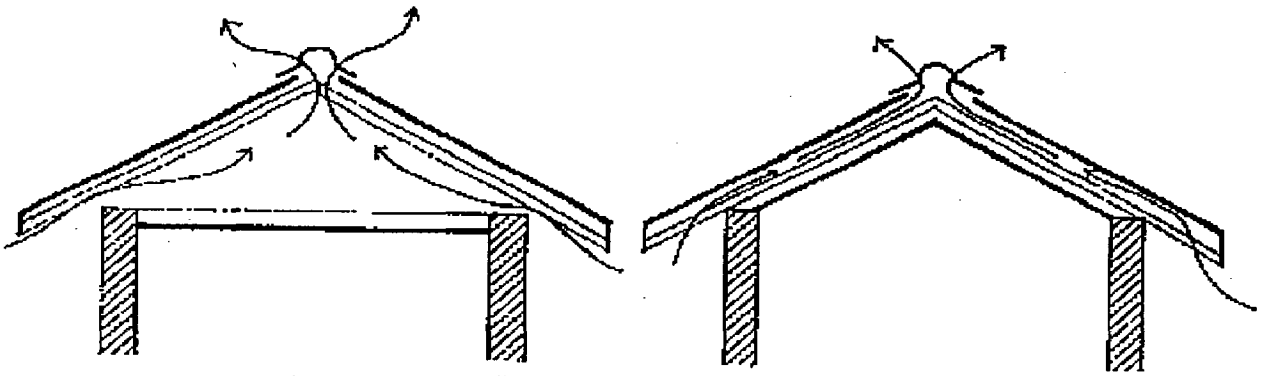


Figure 2.11-Placement of ceiling horizontally or along the roof slope

Source: http://sleekfreak.ath.cx:81/3wdev/CD3WD/CONSTRUC/SK02CE/B160_4.HTM#B160_4_4

3. Fly Screen

Fly screens are essential in this type of climate due to insects, but they may reduce the air flow. To minimize the blocking effect it is preferable to install it at some distance from the wall, rather than directly on the windows and extending over larger area than the windows. When there is a balcony adjacent to the room it is possible to ensure insect protection with less interference of ventilation by erecting a fly screen around the balcony, thus enabling the entry of air through a wider free area.

2.4.3. Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings

1. Building form
2. Orientation of building
3. Choice and characteristics of materials for building components
4. Roofing techniques

5. Shading
6. Cooling techniques

1. Building Form

Minimizing perimeter to area ratio is useful to minimize heat gain (Krishan et al. 2001).

2. Orientation of building

It is desirable to orient the building with the longest walls facing north and south, so that only short walls face east and west. Thus only the smallest wall areas are exposed to intense morning and evening sun (Sharma et al. 2003).

3. Choice and characteristics of materials for building components

The main properties to be considered for constructions and materials are:

- Reflection of radiant heat
- Absorption of radiant heat
- Re-emission of stored heat

Weather qualities of materials in a damp and humid environment, and likelihood of biological attack by insects and of fungoid growth is a criteria in choice of materials other than main criteria of prevention of daytime indoor temperature rise to above outdoor level, and minimization of such elevations during evening and night hours. The heat capacity of building should be as low as possible.

a) Foundations, basements and floors

Raise the floor and ventilate the space underneath. The floor should be of low thermal capacity (e.g. timber floor with void). The advantages are better ventilation due to the elevated space and maximum benefit of the slightly lower night temperature. Common building materials, which can be used for foundation, basements & floor is given in table 2.1.

Table 2.1- Table showing Common building materials which can be used for foundation, basements and floor, its properties and suitability

Common building materials, properties and suitability	Solid floor, concrete, stone burnt clay bricks and tiles, earth	Good materials for heat storage; help to balance indoor temperature. Suitable for hot zones with large diurnal temperature differences. Less suitable for warm-humid climates except for daytime rooms.
	Single planking timber floor, ground detached	Suitable for warm-humid climate, for comfort at night time.

source:http://sleekfreak.ath.cx:81/3wdev/CD3WD/CONSTRUC/SK02CE/B160_4.HTM#B160_4_4

b) **Walls**

Walls, both external and internal, should be as light as possible with a minimal heat storage capacity. These should obstruct the airflow as little as possible and should reflect radiation, at least in places where solar radiation strikes the surfaces.

The outer surface should be reflective, light coloured.

Walls should be shaded as much as possible. If exposed to the sun, it should be built in the form of a ventilated double leaf construction, the inner leaf having a reflective surface on its outer side and with thermal insulation.

Light and thin materials such as timber or bamboo matting are recommended. Other materials forming light panels can be used, together with a frame structure to take care of the structural requirements.

Recent research has demonstrated that if effective night ventilation can be ensured by the provision of exhaust fans, high-mass buildings can be more comfortable, especially during the daytime hours, than lightweight buildings.

Common building materials for walls, properties and suitability

Solid walls Earth, Stone, Brick

It takes best advantages of time lag, with heat emission at night. In warm-humid zones only useful for daytime rooms.

Burnt clay bricks

It has good thermal resistance, depending on the porosity. It has medium to high heat storage capacity, good humidity regulating property.

Unburnt clay bricks

It has better thermal resistance and humidity regulating property than burnt bricks. It is less resistant to mechanical stress. It needs protection from driving rain and rising moisture. Improved products with low cement content are somewhat less vulnerable.

Solid concrete blocks

It has poor thermal resistance and high heat storage capacity.

Ferrocement

It has similar properties to concrete, but less thermal storage capacity due to the reduced thickness; suitable for warm-humid zones.

Timber

Good thermal resistance, high heat storage capacity, good regulation of humidity.

Matting of bamboo, grass, leaves

Good material in warm-humid zones, with no thermal storage capacity, not airtight and thus allowing proper ventilation.

Insulation materials

Various natural and artificial materials are available and have to be selected carefully. They prevent not only heat gain, but also heat loss. The danger of overheating at night has to be considered as well.

White-washed surfaces

It is simple and low cost, yet effective method for making a surface highly reflective. The emission at night remains high.

Cavity walls

It has many advantages, especially in hot-arid zones. Reflective surface in the cavity (e.g. aluminium foil) reduces radiant heat transfer. Ventilation of the cavity takes the heat away and reduces conductive heat transmission to the interior (fig 2.8).

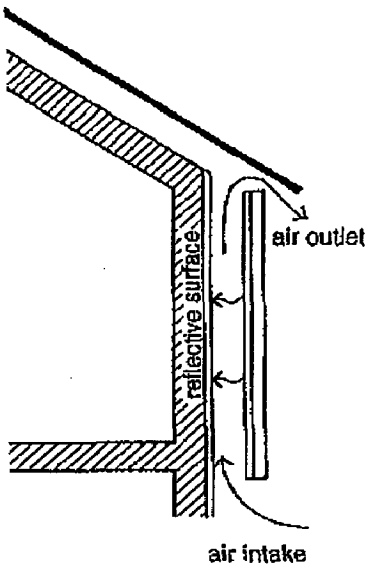


Figure 2.12-Section of cavity wall

source: http://sleekfreak.ath.cx:81/3wdev/CD3WD/CONSTRUC/SK02CE/B160_4.HTM#B160_4_4

Light weight walls, traditional matting, frame construction with thin infill panels

Indoor and outdoor temperatures remain much the same, provided the walls are shaded. If unshaded, indoor temperature rises quickly above outdoor temperature. It is suitable for warm-humid climate, taking full advantage of cooler night temperature.

Heat insulated light weight wall

Mainly used for air conditioned rooms, especially if exposed to direct solar radiation.

Multilayered construction

Where the resources are available, it can be used; a careful assessment of its thermal performance is needed.

Placing a lightweight insulating material on the outside of a massive wall or roof will give a time lag and decrement factor greater than that of the massive wall alone. On the other hand it prevents heat dissipation to the outside at night, thus making internal ventilation imperative (fig 2.9(a)).

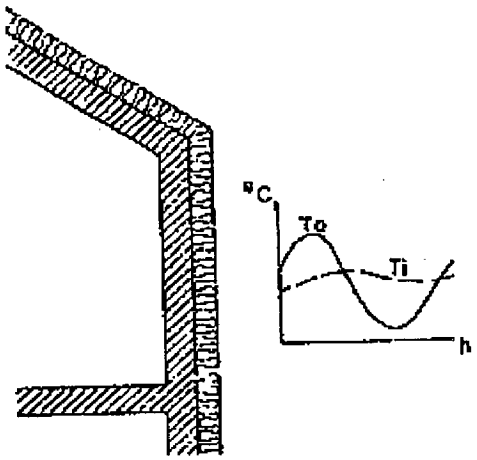


Figure 2.9(a)- Section of wall with multilayered construction

Insulation outside: night ventilation is important

source: http://sleekfreak.ath.cx:81/3wdev/CD3WD/CONSTRUC/SK02CE/B160_4.HTM#B160_4_4

Placing insulation on the inside will result in an indoor climate performance similar to the one in a lightweight structure with a highly reflective outer skin, because the balancing effect of the thermal mass of the outer wall is cut off (fig 2.9(b)).

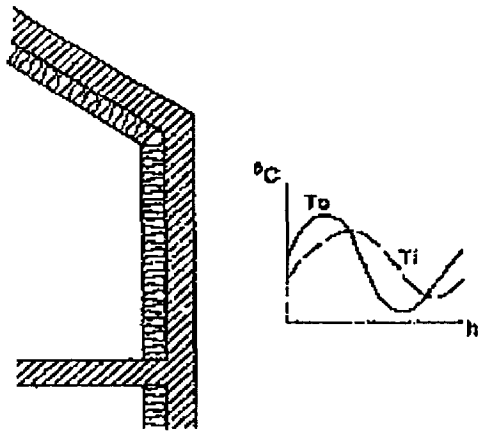


Figure 2.9(b)- Section of wall with multilayered construction

Insulation inside: high indoor temperature during the daytime if not mechanically cooled

source: http://sleekfreak.ath.cx:81/3wdev/CD3WD/CONSTRUC/SK02CE/B160_4.HTM#B160_4_4

The time lag is thus minimal and the indoor temperature is always close to the outside temperature.

Such inside insulation can be appropriate in actively cooled or heated buildings.

A ventilated and reflective outer skin is an efficient, although expensive solution, to reduce radiant daytime heat. Heat dissipation at night is more efficient than with a structure using outside insulation (fig 2.9(c)).

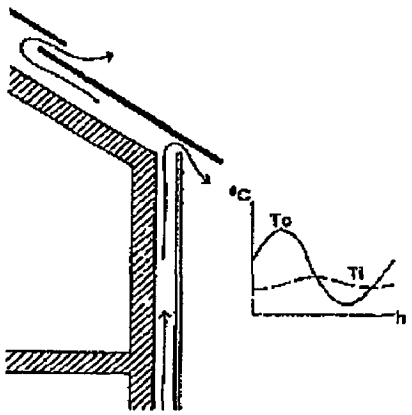


Figure 2.9(c)- Section of wall with multilayered construction

Ventilated and reflective outer skin with heavy inner structure

source: http://sleekfreak.ath.cx:81/3wdev/CD3WD/CONSTRUC/SK02CE/B160_4.HTM#B160_4_4

One way of reducing the radiant heat transfer between the two skins is the use of a low emission surface on the inside of the outer skin (e.g. aluminium painted white on the outside but left bright on the inside) and a highly reflective surface on top of the ceiling. Bright aluminium foil can be used to advantage in both situations.

c) Openings and windows

It should be large and fully openable, with inlets of a similar size on both sides of the room allowing a proper cross-ventilation. But it should be well shaded to reduce heat gain. Each room should have at least two windows in different walls to enable cross ventilation. Windows are preferably equipped with flexible louvres allowing a regulation of ventilation (fig 2.10). Door shutters may also incorporate louvres or grills. Windows with fixed glass panes are of no advantage and should be avoided.

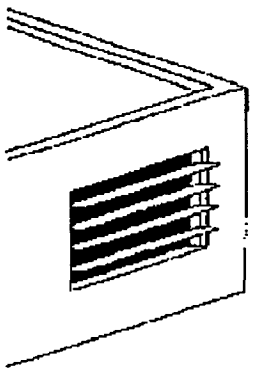


Figure 2.10-Window with glass louvers

source: http://sleekfreak.ath.cx:81/3wdev/CD3WD/CONSTRUC/SK02CE/B160_4.HTM#B160_4_4

To avoid direct solar radiation and glare, openings should be shaded by an overhanging roof, screens, lattices, grills etc.

All these measures have to be designed to give minimal resistance to the airflow. Mosquito-screens, which are essential in these regions, but reduce the airflow considerably, are therefore best installed away from windows, e.g. around the verandah or balcony (fig 2.11).

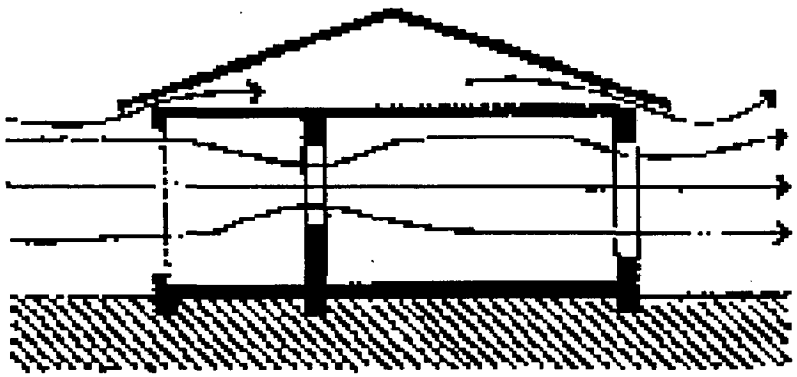


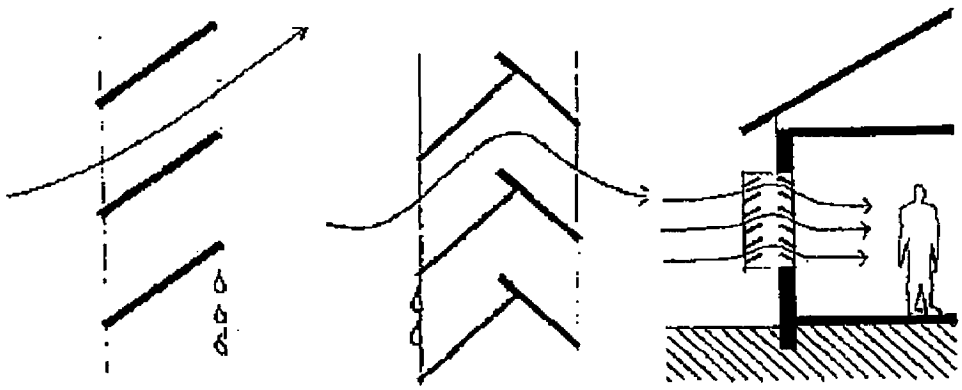
Figure 2.11-Large openings and screened-in porches.

source: http://sleekfreak.ath.cx:81/3wdev/CD3WD/CONSTRUC/SK02CE/B160_4.HTM#B160_4_4

Openings should be placed according to the prevailing breezes, so as to permit a natural airflow through the internal space. This airflow is most effective if concentrated at body level.

Louvre design

Ordinary louvres direct the wind upwards above body level. These louvres are not safe against driving rain. Modified louvres keep the wind at lower level (living area) and provide protection from driving rain, but reduce the airflow to a certain extent. Another alternative is the use of a second set of louvres to direct the air down to the occupants (fig 2.12).



Ordinary louvres *Modified louvres*

Figure 2.12-Different types of louvres

source: http://sleekfreak.ath.cx:81/3wdev/CD3WD/CONSTRUC/SK02CE/B160_4.HTM#B160_4_4

Common building material for windows, properties and suitability

Window glass:

A wide range of special heat-absorbing and heat-reflecting glass types are generally only suitable for air-conditioned buildings. Most of them are limited in their effectiveness because either their own temperature is raised, which increases the heat convected and re-radiated into the internal space, or they tend to reduce light rather than heat. In addition, availability and costs have to be considered.

Sealed double-glazed window panes can only be used for air-conditioned buildings. They are expensive and difficult to replace. In naturally cooled buildings they have little advantages.

d) Roofs

In warm-humid areas the roof is preferably pitched to allow heavy rains to run off. Large overhangs protect the walls and openings from radiation and precipitation.

The thermal performance depends to a great extent on the shape of the roof and the construction of its skin, whereas the carrying structure has little influence.

The roofs in this climate should be light, and with high U value and low heat capacities.

The shape of the roof (pitched, flat, vaulted, etc.) should be in accordance with precipitation, solar impact and utilisation pattern (fig 2.13)

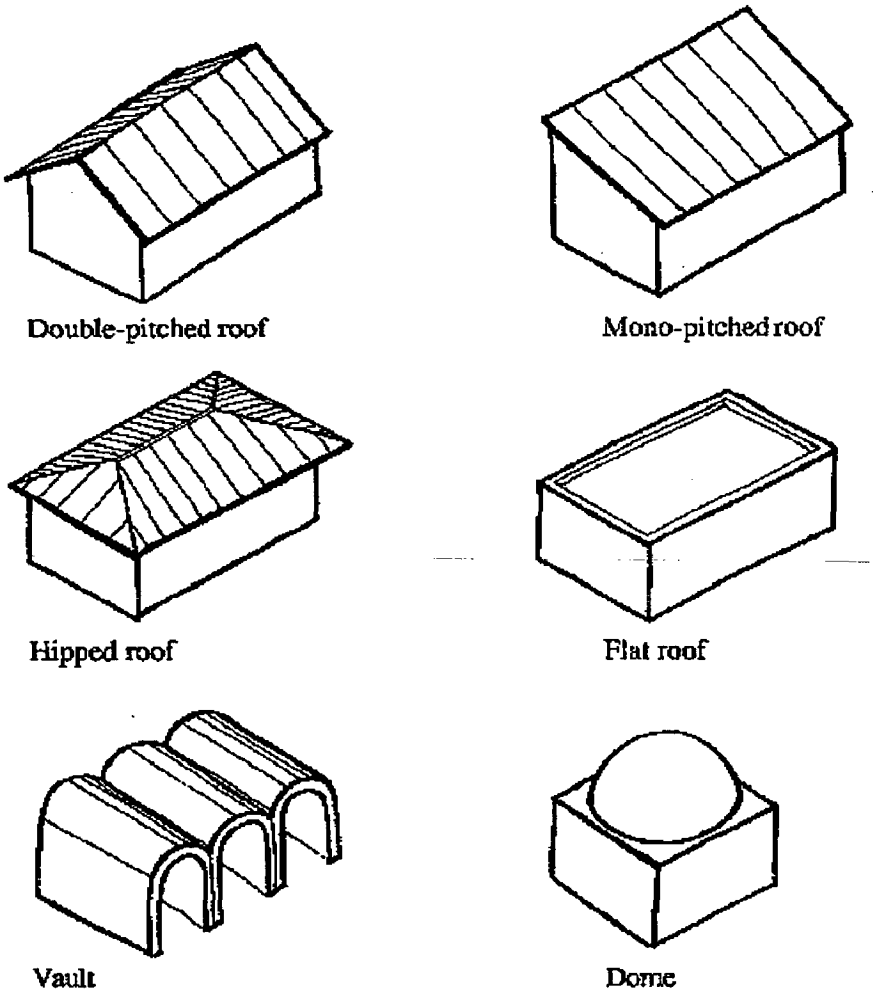


Figure 2.13-Basic roof types

source:http://sleekfreak.ath.cx:81/3wdev/CD3WD/CONSTRUC/SK02CE/B160_4.HTM#B160_4_4

Common roofing materials, properties and suitability

Earth

Good thermal insulation and emissivity, suitable in dry climates. Not suitable in warm humid climate.

Burnt clay tiles

It is a traditional material still very suitable today, with rather good thermal properties. It is relatively heavy, requiring a strong support structure; medium heat storage capacity. These are permeable to air through the gaps between the tiles.

Concrete tiles

Similar properties as clay tiles but with reduced heat resistance.

Fibre concrete (FCR) and Micro concrete (MCR) tiles

Similar properties but lighter than concrete tiles, hence less heat storage capacity.

Asbestos sheet

It has fairly good thermal performance, medium reflectivity. Disadvantages: low mechanical strength, asbestos fibre is harmful to health (carcinogenic).

Monolithic concrete slab

It has poor thermal resistance and high storage capacity. Due to the big mass relatively cool during the morning, but re-radiating the daytime heat to the interior in the evening and at night.

Natural stone (flag stone, slate)

Thermal performance of natural stone is similar to concrete tiles depending on the thickness and the surface (brightness).

Organic, vegetal roofing materials bamboo, leaves, thatch, wooden shingles

It is climatically suitable, but of relatively low durability. It is applicable for semi-permanent and self-built houses.

Single skin corrugated galvanized iron sheeting (CGI)

One of the most widely used, simple constructions, of low weight allowing an economical support structure. Has no significant thermal resistance, aged sheeting has no significant reflectivity, reradiates the received solar radiation into the building creating intolerably high indoor temperatures during the daytime. Rapid cooling at night with the problem of condensation is its property in humid climates. It has low life-span, noisy during rain. It is less suitable for warm humid climate.

Aluminium sheeting

A fairly expensive material but with good thermal reflectivity and long life span, preferable to galvanized iron sheeting. It reduces the heat load due to the low heat storage capacity and high reflectivity (Paul and Dieter 1993).

Construction details

Thin single skin roof

Solar heat transmittance and heat conductance is high.

Insulated roofs in general

Prevent heat entering through the roof but also prevent heat escaping at night, thus their use has to be carefully considered.

Insulation above a massive roof

The time lag is four times longer than with insulation placed inside, but also prevents cooling at night. Not suitable for this climate

Insulation below a massive roof

Allows excessive heat storage, for which the insulation can hardly compensate. The slab exposed to the sun receives very high temperature differences that may be harmful to the structure.

Concrete slab with screed and fibre board ceiling

Resistance to heat flow is insufficient. It is only useful for rooms used in daytime, not in the evening and at night.

Double skin roof with two light layers

The outer skin shades the inner layer and reflects as much solar radiation as possible. The accumulated heat between the two skins must be removed by ventilation. Suitable in warm-humid climate, reduces the heat load in daytime and allows quick cooling at night (fig 2.14) (Paul and Dieter 1993).

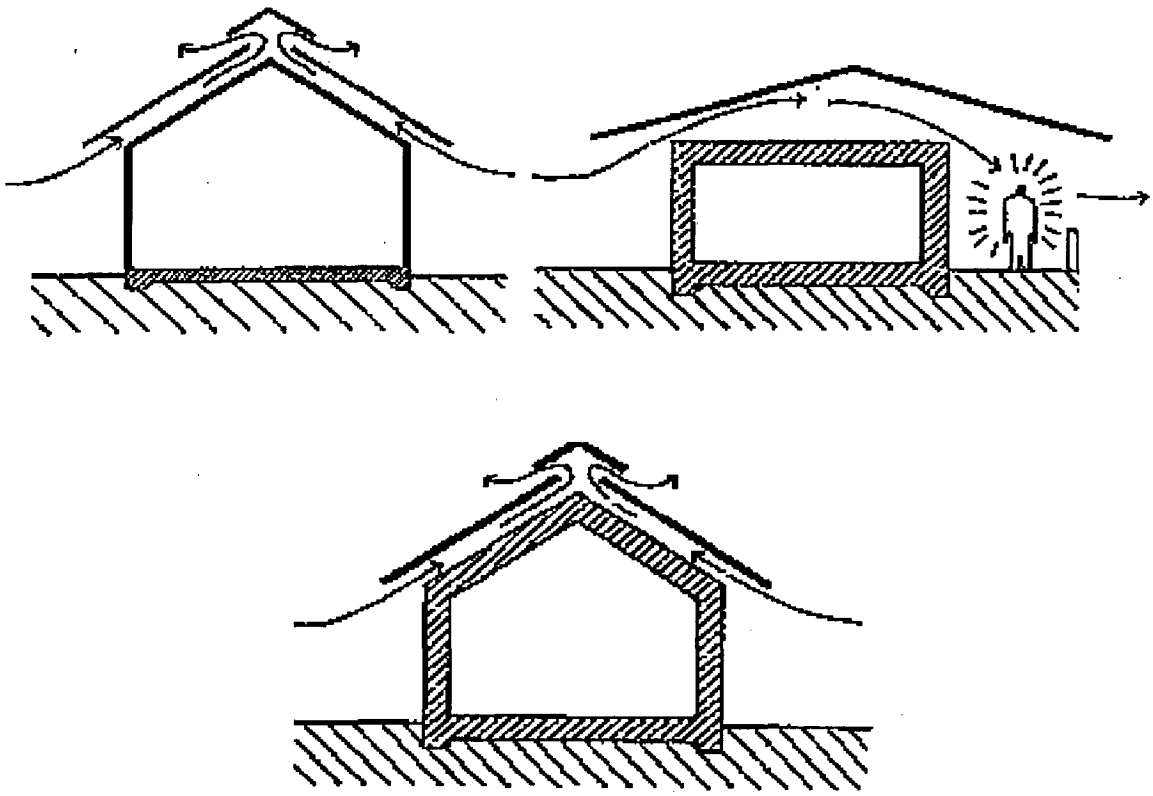


Figure 2.14-Different types of double skin roofs

source: **http://sleekfreak.ath.cx:81/3wdev/CD3WD/CONSTRUC/SK02CE/B160_4.HTM#B160_4_4**

Thus the materials which are suitable for building components in warm humid climate are as follows:-

Foundation, basement and floors

- Solid floor, concrete, stone burnt clay bricks and tiles, earth- *Less suitable for warm-humid climates except for daytime rooms.*
- Single planking timber floor, ground detached- *Suitable for warm-humid climate, for comfort at night time.*

Walls

- Solid walls Earth, Stone, Brick, Solid concrete blocks, Insulation materials- *suitable for warm humid climate only at day time*
- Burnt clay bricks, Unburnt clay bricks, Ferrocement, Timber, Matting of bamboo, grass, leaves, White-washed surfaces, Cavity walls, Light weight walls, traditional matting, frame construction with thin infill panels- *suitable for warm humid climate.*

Roofs

- Earth, Monolithic concrete slab, Single skin corrugated galvanized iron sheeting (CGI)-*not suitable or less suitable for warm humid climate*
- Burnt clay tiles, Concrete tiles, Fibre concrete (FCR) and Micro concrete (MCR) tiles, Asbestos sheet, Natural stone (flag stone, slate), Organic, vegetal roofing materials bamboo, leaves, thatch, wooden shingles, Aluminium sheeting, Double skin roof with two light layers-*suitable for warm humid climate*

4. Roofing techniques

a) Reflecting surfaces

If the external surfaces of the building are painted with such colours that reflect solar radiation (in order to have minimum absorption), but the emission in the long wave region is high, then the heat flux transmitted into the building is reduced considerably (fig 2.15).

Figure 2.15-Reflective roof surface

Source: http://www.ieindia.org/publish/ar/0403/april03ar4.pdf

b) Double roof

Building that has two roof /ceilings with an air gap in between is a good concept of passive cooling. The technique includes two concrete ceiling or any other type of roof one above the other with an air gap in between. The air gap acts as a thermal resistance for the heat flow from the roof exposed to direct sun, to the second slab below. Use of false ceiling is an example of this type of passive cooling. In some areas double roofs have gable windows for hot air to escape thus giving cross ventilation in that air gap (Sanjay and Chand 2003).

c) Ventilated Roof (Sanjay and Chand 2003) :See page no. 12

d) High Roof

This type of roof allows the warm air to collect at the top and stratification of warm air maintains cool air at the floor level, thus maintaining air temperature in a comfortable zone (Sanjay and Chand 2003).

e) Roof Ponds

Water stored on the roof acts as a heat source and heat sink both during winter and summer climatic conditions. The thermal resistance of the roof in this system is kept very small. In summer during the day, the reflecting insulation keeps the solar heat away from water, which keeps receiving heat through the roof from the space below it thereby cooling it. In the night, the insulation is removed and water, despite cooling the living space below, gets cooler on account of heat losses by evaporation, convection and radiation. Thus, the water regains its capacity to cool the living space. In winter, the insulation is removed during the day. Water and black surface of the roof absorb solar radiation; the living space continues to receive heat through the roof. During night water is covered with insulation to reduce heat losses (Sharma, 2003) (fig 2.16).

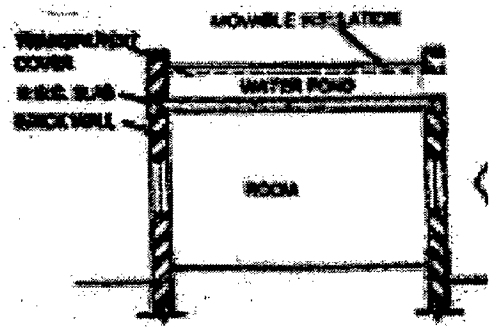


Figure 2.16-Roof ponds

Source: http://www.ieindia.org/publish/ar/0403/april03ar4.pdf

5. Shading

a) Shading by vegetation

Shading by trees and vegetation is a very effective method of cooling the ambient hot air and protecting the building from solar radiation. Trees should be planted at positions determined by lines from the centres of the windows on the west or east walls toward the position of the sun at the designated hour and date.

b) Shading by neighbouring buildings

The buildings in a cluster can be spaced such that they shade each other mutually. The amount and effectiveness of the shading, however, depends on the type of building clusters.

c) Shading by Overhangs, Louvers and Textured Facade

The devices which provide shading to an opening can be classified into three types:

(i) *movable opaque*, eg, roller blind, curtain etc can be highly effective in reducing solar gains but eliminates view and impedes air movement;

(ii) *louvers* which may be adjustable or fixed affect view and air movement to some degree and provide security; and

(iii) *fixed overhangs*: easy to attain on single storey buildings with overhanging roof. Also gives rain protection to walls and openings and has little or no effect on view and air movement.

Maximum solar radiation in summer is incident on the roof. It is, therefore, advisable to protect the roof from the sun as far as possible.

d) Shading of Roof and Walls

Surface shading can be provided as an integral part of the building element or by the use of a separate cover. Highly textured walls have portions of their surfaces in the shade. The radiation absorbing area of such a textured surface is less than its radiation emitting area and therefore it will be cooler than a flat surface. The increased surface area will also result in an increased coefficient of convective heat transfer, which will permit the building to cool down faster at night when the ambient temperature is lower than the building temperature.

An alternative method is to provide a cover of deciduous plants or creepers. Because of the evaporation from the leaf surfaces, the temperature of such a cover will be lower than the daytime air temperature and at night it may even be lower than the sky temperature.
In addition to shading, this arrangement provides an increased surface area for radiative emission and an insulting cover of still air over the roof which impedes heat flow into the building, while still permitting upward heat flow at night. Although, the system of earthen pots is thermally efficient, the method suffers from practical difficulties because the roof is rendered unusable and its maintenance is difficult (fig 2.17).
An effective roof-shading device is a removable canvas cover. This can be mounted close to the roof in the daytime and at night it can be rolled up to permit radiative cooling. The upper surface of the canvas should be painted white to minimize the amount of absorbed radiation by the canvas and the consequent conductive heat gain through it.

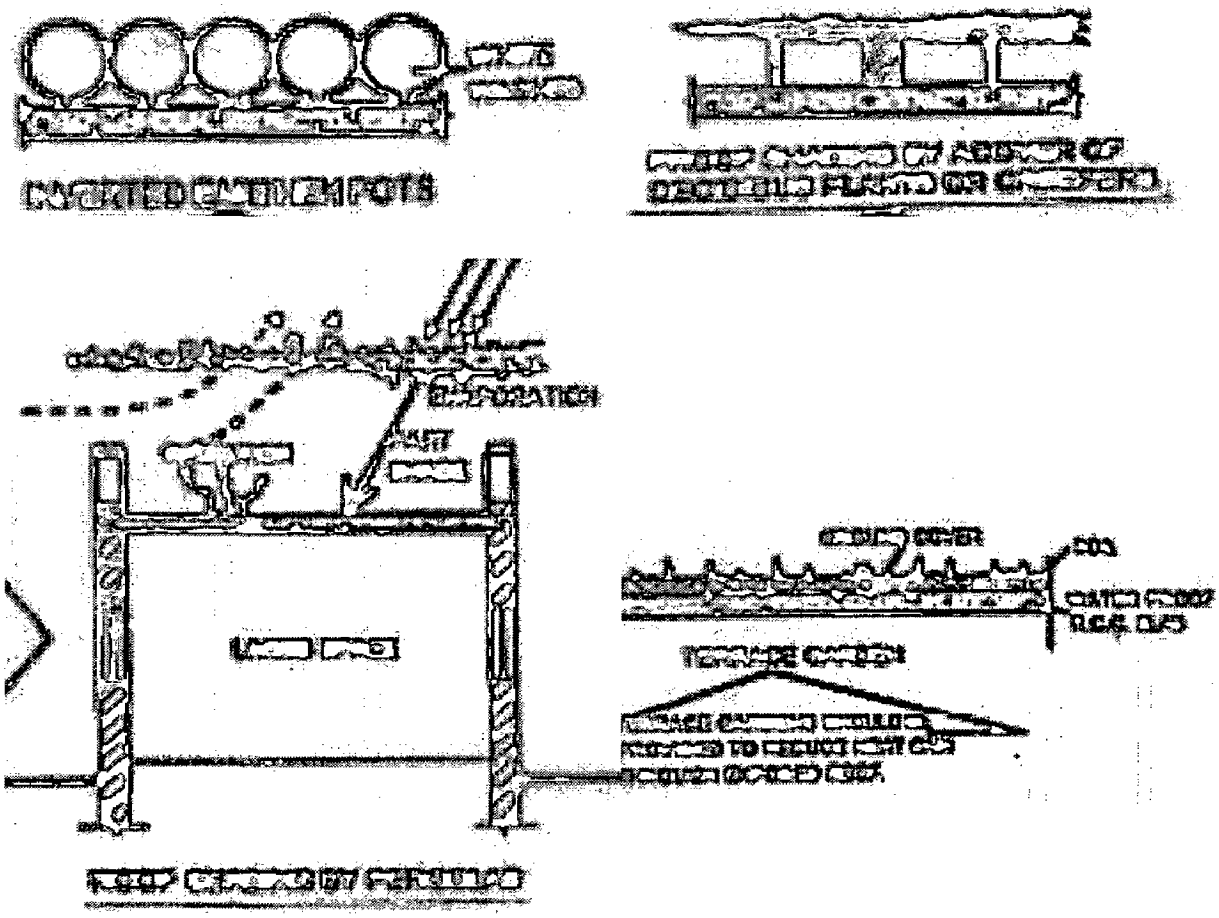


Figure 2.17-Different methods of roof shading

Source: http://www.ieindia.org/publish/ar/0403/april03ar4.pdf

6. Cooling techniques

a) Air Cooling by Tunnels

Temperature deep inside the earth remains nearly constant. Daily temperature variations hardly affect the earth's temperature at a depth of more than one meter, while the seasonal variations of the ambient temperature are strongly dampened by the earth. The earth's temperature up to a depth of 6 m to 8 m is influenced by the annual ambient temperature variations with a time delay of several months. It is seen that in Delhi the earth's temperature at a depth of about 4 m is nearly constant at a level of about 23°C throughout the year. A tunnel in the form of pipes or otherwise will acquire the same temperature at its surface causing the ambient air ventilated through this tunnel to get cooled.

b) Earth Cooling

Because of the thermal storage capacity of earth, the daily and even the annual temperature fluctuation keeps on decreasing with increasing depth below the ground surface. At a depth of 15 m, the earth has a constant temperature of 10°C. The level of water table plays an important role here. In summer and particularly during the day, the ground temperature is much lower than the ambient air temperature. If a part of the building is earth bermed, the building loses heat to the earth particularly, if the insulation levels are low. The most ancient dwellings were often dug into the ground or covered with earth. Pit houses of North American Indians, Eskimo houses with sturdy timber roofs for supporting earth and a deep covering of snow in winter, and the early Scandinavian farms are few examples of this principle.

c) Earth Tunnel Cooling

Benefits of ground temperature stabilisation for habitable rooms, food and wine stores have been known since prehistoric times. There are many examples of underground vernacular buildings. The building may be coupled with the earth either by conduction, ie, where the building envelope is in contact with the deep earth by burying or berming. A third medium by which the earth could be coupled with the building is the earth air tunnel, where ventilation supply air is drawn into the building via insulated ducts buried deep into the earth (fig 2.18).

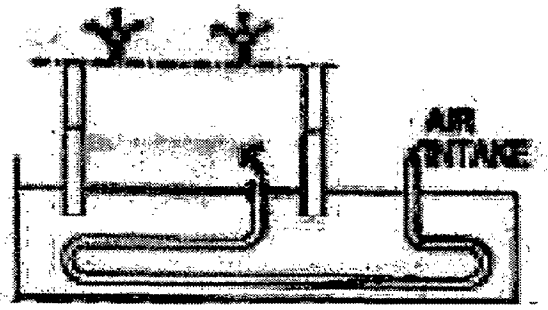


Figure 2.18-Earth tunnel cooling

Source: http://www.ieindia.org/publish/ar/0403/april03ar4.pdf

d) Desiccant cooling

Desiccant cooling is effective in warm and humid climates. In the desiccant cooling method, desiccant salts or mechanical dehumidifiers are used to reduce humidity in the atmosphere. Materials having high affinity for water are used for dehumidification. They can be solid like silica gel, alumina gel and activated alumina, or liquids like triethylene glycol. Air from the outside enters the unit containing desiccants and is dried adiabatically before entering the living space. The desiccants are regenerated by solar energy. Sometimes, desiccant cooling is employed in conjunction with evaporative cooling, which adjusts the temperature of air to the required comfort level (Nayak and Prajapati 2006)

After reviewing the design principles in warm humid climate, a chart was made showing the objectives of thermal comfort and normative indicators of the architectural means to achieve these objectives (table 2.2).

Table2.2-Chart showing objectives of thermal comfort and normative indicators of the architectural means to achieve these objectives

Principles of building design/ Thermal Comfort objectives ⇨ **Architectural means to attain principles** ⇩	*Provision of continuous and efficient ventilation*	*Protection from sun, rain and insects*	*Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings*
Building form and layout	✓		✓
Orientation	✓	✓	✓
Raised Plinth	✓	✓	✓
Openings	✓		✓
Shading		✓	✓

Wide Verandahs		✓	
Balcony		✓	
Landscape	✓	✓	✓
Roof Type		✓	✓
Wall Material			✓
Roof Material			✓
Outdoor spaces	✓		
Physical phenomena (phenomena like courtyard effect, stack effect, tunnel effect etc.)	✓		
Fly screen		✓	
Other techniques			✓

2.5 VERNACULAR ARCHITECTURE

Vernacular architecture is architecture evolved organically over time in an area to meet the needs of people. In this type local materials and local construction techniques are used. Instead of trained professionals local craftsmanship is involved in this type of construction. It might also reveal the tradition and culture of that area. These structures can easily cope up with the changing climatic conditions of that area.

2.5.1 Typologies of Vernacular architecture

These can be mainly categorized into three types namely Kachcha, Pukka and Semi-pukka.

Kachcha

In Kachcha, the structure will be short lived and made of natural materials like mud, grass, bamboo, thatch etc. It requires regular maintenance and replacement of materials.

The advantages of these structures are materials are easily available, it is easy to construct and less labour is required.

Pucca

Pucca structures are more resistant to the wear and tear. These are mainly made up of durable materials like stone, brick, clay tiles etc. and will be binded by mortar. For these structures skilled labour is requires and are more costly than kuchcha structures. These structures do not require constant maintenance.

Semi-Pucca

These structures are the combination of kuchcha and pucca style (Indian Vernacular Architecture Multimedia Information, 2010).

2.5.2 Vernacular Residential Architecture of India

It is informal architecture evolved over time mainly in rural areas to meet the needs of local people. Vernacular architecture in India is different in different parts of India. It is mainly because of the variation in climatic conditions of each region. Availability of locally available materials is also different in each and every part of India and construction techniques or craftsmanship is also dissimilar.

2.5.3 Vernacular buildings materials and technology of India

Building materials varies according to the location. In hilly areas were rocky strata are found, rubble masonry is used with mud mortar for walls. Wood beams and rafter are used with slate roofing, if it is available in that area. Houses constructed here will usually be of two stories, with livestock on ground floor and human habitation on the top floor. Usually plinths will be used to withstand from run off water. Steep sloping roofs are used to cope up with heavy monsoon.

On flat land, mud or sun baked bricks or mud mixed with hay is used for walls.

In areas where bamboo is available (mainly in north-eastern states), it is used for all parts of the houses. Thatched roofing is mostly found with grass. In south, clay tiles are used for pucca roofing and thatched for kuchcha, with coconut leaves (Indian Vernacular Architecture Multimedia Information, 2010).

CHAPTER 3
LITERATURE CASE STUDIES

3.1 PREAMBLE

Two literature case studies of vernacular residential buildings of Tamil Nadu are discussed, ie. one courtyard house and one agraharam(row housing), here.

3.2 LITERATURE CASE STUDY -1

Chettinad House – Courtyard house in Tamil Nadu

State: Tamil Nadu

District: Sivaganga

i. Planning Aspects

Site plan & features

The residence is built on a rectangular, traversal plot that stretches across two streets. The slope of the site is towards the south so all drainage system of the house are connected to the main road drainage which slopes towards the water body in the south

Orientation

House is oriented in N-S orientation

Layout

Courtyard planning is used, with a series of courtyards in a straight line. All rooms are organised around the courtyards and accessed through corridor (fig 3.1).

Spaces found in Chettinad house

- ✓ First an outer thinai - Large raised platforms on either side of the central corridor
- ✓ The platforms lead off on one side into store rooms and massive granaries and on the other, into the (Kanakupillai) or Accountant's room

- ✓ The door leads into the first open air courtyard, with pillared corridors running on each side that lead into individual rooms, each with a triangular slot cut into the wall for the evening lamp.
- ✓ Then the second courtyard with large dining spaces on either side.
- ✓ The third courtyard was for the women folk to rest and talk
- ✓ The fourth, or nalankattai comprised the kitchens, leading out to the backyard with its women's well and grinding stones.
- ✓ The wealthier the merchants the larger the house, often spreading out to a second floor.

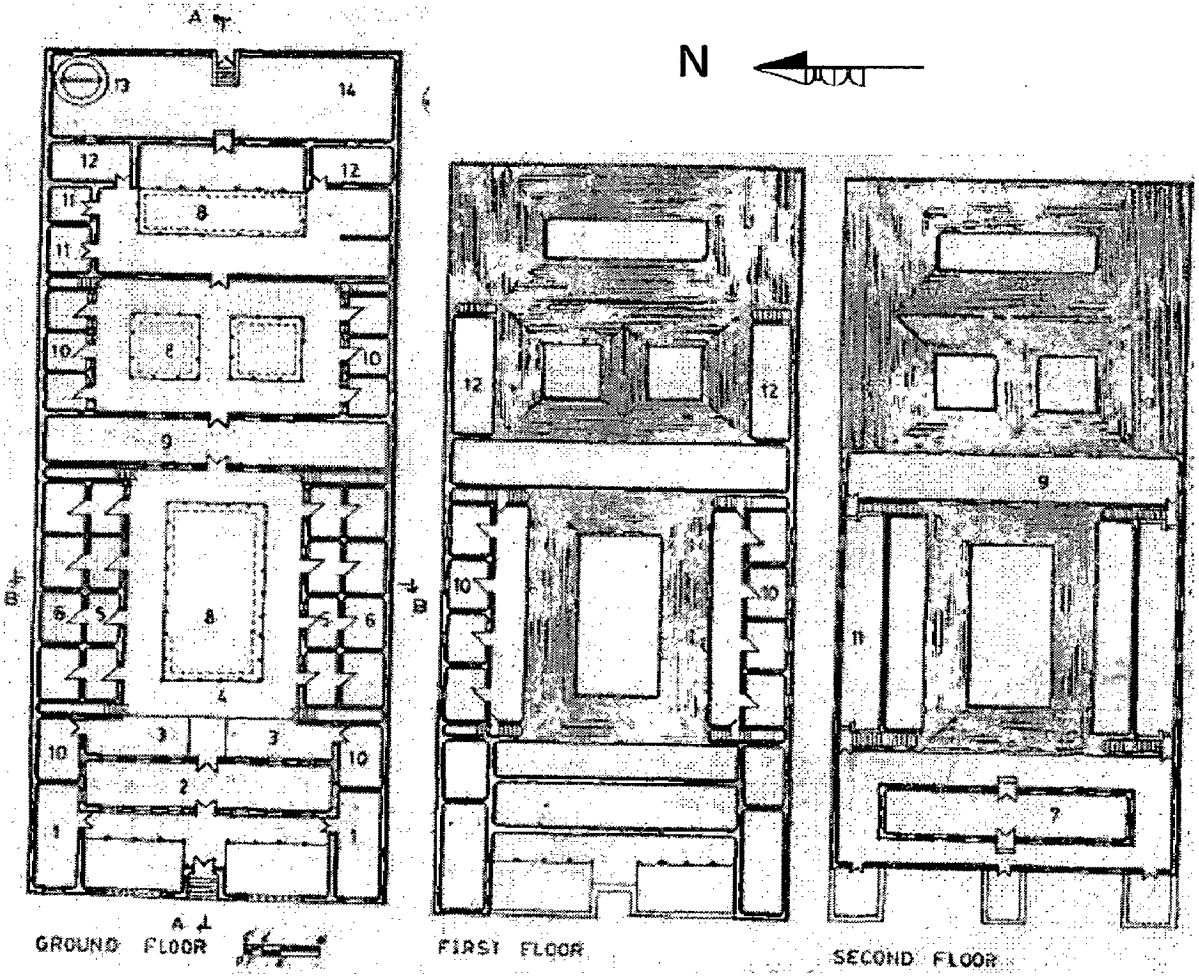


Figure 3.1-Floor plans of Chettinad house

Source: Solar Architecture An Indo- German Initiative

ii. Architectural design aspects

Building form & plan form

The building is rectangular in plan as the site. The building consists of 2 floors and attic space (fig 3.2).

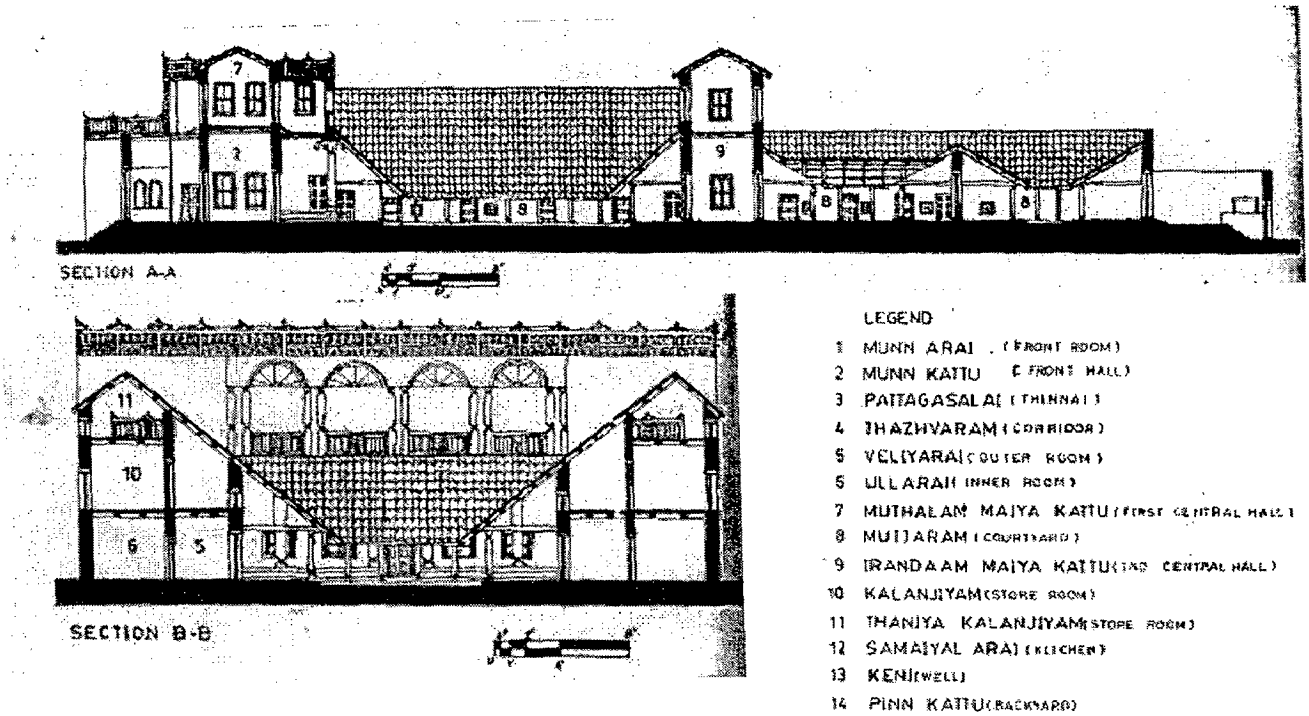


Figure 3.2-Sections of Chettinad house

Source: Solar Architecture An Indo- German Initiative

Architectural elements

Facade is rich in scale, detailed and highly ornamented (fig 3.3). The whole building built on a high plinth. The entrances are emphasized and have high compound walls. The building is covered with sloping roof. Screen walls with balustrades are provided to give scale. All the openings are placed in straight alignment. Corridors are provided around courtyards in every floor. A total of four courtyards are present in this residence. Main courtyard is oriented in E-W direction and service courtyard oriented in N-S orientation.

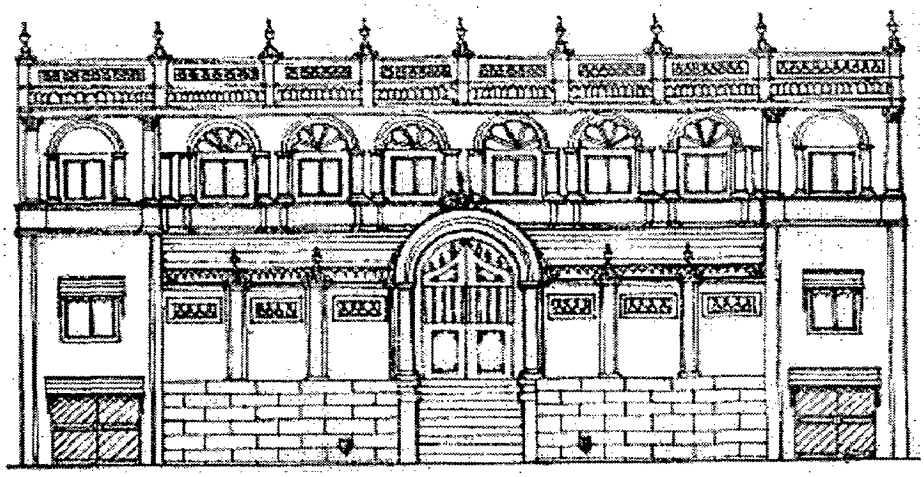


Figure 3.3-Front elevation of Chettinad house

Source: Solar Architecture An Indo- German Initiative

iii. Construction and material use

Raised plinth is made with stone. The walls are of baked bricks, with thickness 60-70cm, which are composite walls with brick jelly filling. It is plastered with a mix of lime, egg white, powdered shells and myrobalan nut. Walls were faced with mosaic tiles up to 60cm. The floors are of Italian marble or locally - crafted Athangudi tiles. The front columns are of teak and stone columns around the courtyards.

Analysis of building design and planning for thermal comfort objectives

i. Provision of continuous and efficient ventilation

Straight alignment of doors and windows induces effective ventilation. Screen walls with balustrades allow wind to pass through. Courtyard is the main source of ventilation. Figure 3.4 shows wind passing through the grill in the compound wall and ventilates the thinnai, and then the air rises up through the service courtyard to occupy the negative pressure area created by the wall. After crossing the low pressure area, the wind enters the second courtyard & ventilates the adjacent room. The rooms in the first floor blocks the incoming wind which is further blocked by the munnarai the front courtyard becomes a negative pressure zone and air rushes into it.

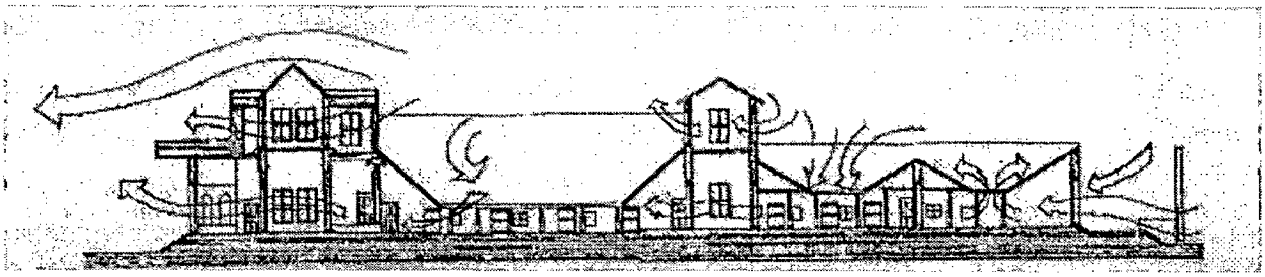


Figure 3.4- Longitudinal section showing air movement through courtyards

Source: Solar Architecture An Indo- German Initiative

The courtyard is surrounded by higher structure, hence cuts off the most strong radiation of the sun and hence it is cool for most of the time during day hence the trapped air is cooler since it get heated up and starts rising up. Once the warm air started rising up, cool air starts to descent during the night and hence in the morning it is filled with a pool of cool air (fig 3.5).

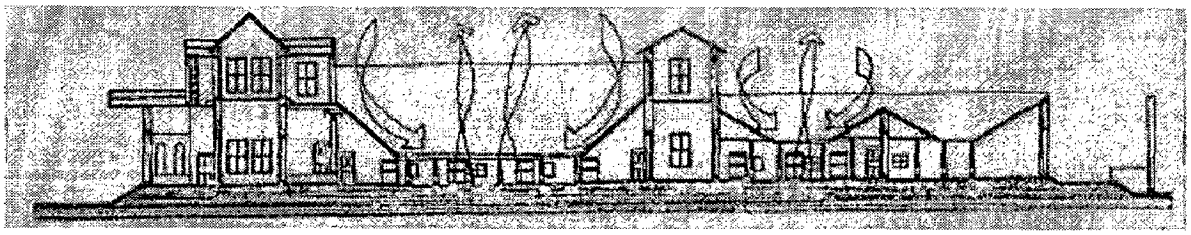


Figure 3.5- Longitudinal section showing air movement within courtyards

Source: Solar Architecture An Indo- German Initiative

ii. Protection from sun, rain and insects

Daylight in the house is in the form of reflected light from courtyard. Main courtyard in E-W orientation allows diffused sun light. Service courtyard oriented in N-S orientation provides sufficient light for services and prevents direct sun. Sloping roof helps rain water to drain off easily. Gutter is present in roof to drain off rain water. The courtyards have tiles placed exactly under the storm-water drain run right through the house, with stone stoppers carved exactly for their mouths. Raised plinth prevents wetness entering the whole structure. Chances of decay due to rain led to the provision of stone columns around courtyard

iii. Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings

Orientation in N-S direction with minimum east west frontage decreases direct solar radiation on the structure. Thinnai and recessed entrance prevents the western radiation (fig 3.6). Slope of the roof & eaves are designed in such a way that there is no direct radiation falling onto the courtyard (fig 3.6).

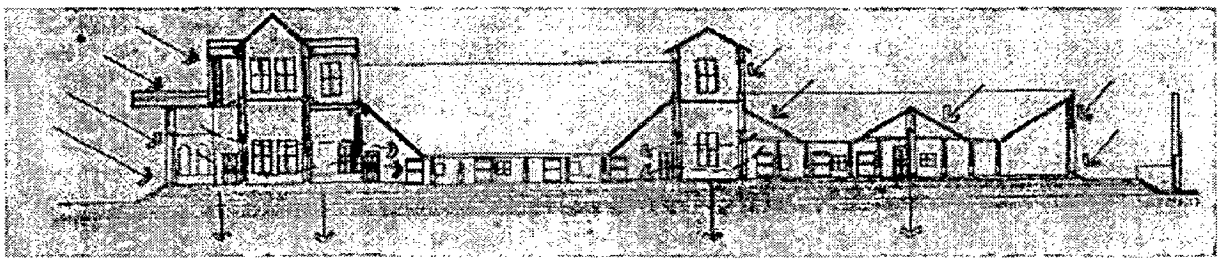


Figure 3.6- Longitudinal section showing solar heat gain of the building

Source: Solar Architecture An Indo- German Initiative

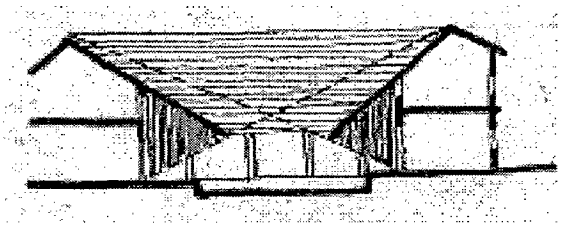


Figure 3.7-Section showing shading through roof overhang

Source: Solar Architecture An Indo- German Initiative

Corridors are provided around courtyards to protect the wall from direct radiation. Egg lime mortar plaster is used to avoid radiation. Thick walls and double roof system with roof vent to ventilate the attic space, makes the interior cool. The sunshades are made out of timber which is a bad conductor of heat and are inclined from 45°-70°, so effective in blocking direct rays.

Inferences

- The presence of courtyard makes the residence comfortable with good ventilation and day lighting with diffused day light. This makes courtyard as a major architectural element in hot climate.
- Building is comfortable with passive techniques through out the year. So passive technique has to be initiated for buildings in this climate.
- Heat gain is also reduced by the use of appropriate building materials and techniques.

3.3 LITERATURE CASE STUDY- 2

Location

State: Tamil Nadu

District: Tirunelveli

Taluk: Tenkasi

Place- Sambavarvadakarai

Established in 15th Century

i. Planning aspects

Site plan and features

The location of street temples is in a dominant position, ie at the end of the street, such that the people coming out of their houses can focus on it (fig 3.8)..

Layout

The spatial organization followed is linear (fig 3.8). The streets act as an organizing space organizing repetitive spaces (houses) on either side of it. The main feature in this planning is the street planning. Every house width is just about one-sixth its length with shared walls. The small ratio of `street-width` is to `average height of buildings (5.3m: 6.4m). This type of sideways stacking of houses ensures that the street length is lessened. All the houses have similar kind of planning. The first room is an enclosed verandah. The next is a small room where a staircase leading to the top storey is located. Following is the main living space, which also acts as the sleeping chamber during night. This living space is usually partitioned to form a storage space and in most houses the top storey ends in between this space with the remaining part rising to the ceiling height of the first storey to accommodate the clerestory windows at the top. The kitchen with a high ceiling follows this space and beside it is a small skylight. The next space is semi enclosed that houses the cattle and washing area. Wells if any are also situated in this space. Following this is the backyard with some vegetation, enclosed by a low compound wall.

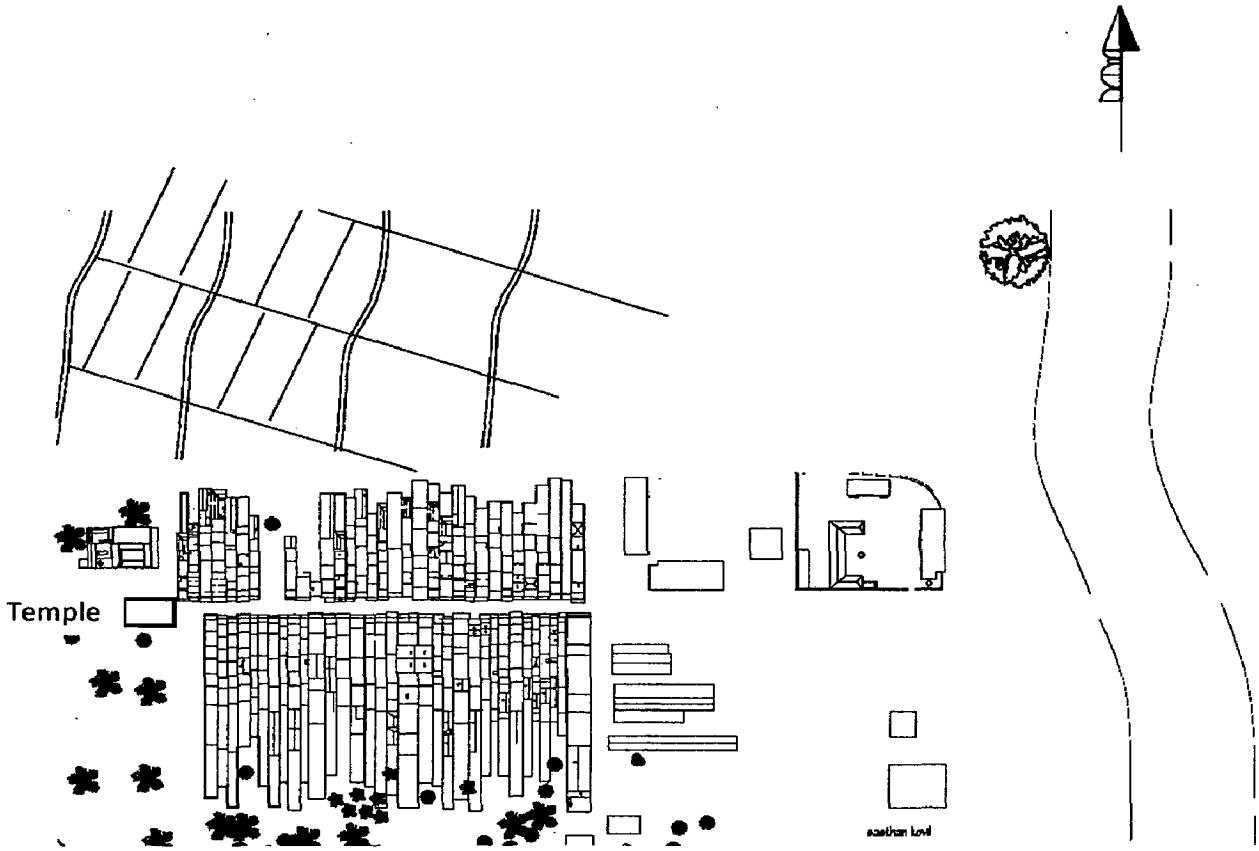


Figure3.8-Site plan of agraharam at Sambavarvadakarai

ii. Architectural design aspects

Building form and plan form

Individual row houses have a rectilinear plan. Facade of most of the buildings where ornamented, but was unable to appreciate because of the less street width. Some British architectural features were present in the facade.

Architectural elements

Most of the houses had raised plinths. The doors connecting all the rooms are placed along a straight axis from the entry to the exit. i.e. the backyard is visible from the entry. The windows are placed next to the doors in the internal walls. Enclosed verandah is provided in front 'thinnai' (because of security reason). A small skylight (0.6m X 1.0m) is also provided, because of security reason. Hipped roofs are found in most of the houses

Services

The toilet is located at the rear end of the house. Soaking pit is dug for sewage disposal. The pit is cleaned manually when it reaches its full capacity. Sullage water from the wash area is drained out through a sloped drain running throughout the length of the house from the wash area to the end of the house. In some houses this sullage is used to water the plants in the backyard. Previously the river Chittar running adjacent to the agraharam was the only source of water. Nowadays, with the river dried up, water supplied by the corporation and bore well underground water is the only sources of water in the village

iii. Construction and material use

The houses are built of brick masonry with wall thicknesses ranging from 35 cm to 46 cm. Staggered arrangement of bricks is bonded with lime mortar. Madras terrace roofing is used for ceiling. Timber false ceiling is provided underneath a masonry ceiling. Hipped timber roofs are covered with mangalore pattern tiles.

Analysis of building design and planning for thermal comfort objectives

i. Provision of continuous and efficient ventilation

The main source of ventilation is the doors placed in straight alignment, which induces tunnel effect. A small skylight provided ensures cool interiors at all seasons, through courtyard effect or stack effect. Clerestory windows let out the risen hot air.

ii. Protection from sun, rain and insects

Hipped roofs protect the walls from direct sun and rain. The main sources of lighting are through the clerestory windows, the small skylight and the doors. Sloping roof provided eases the drain off of rain water

iii. Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings

Shorter side of individual row houses are facing north and south sides, thus the west side of each house is shaded by the next house, since west and east walls are common walls. So heat gain is reduced. Verandahs in front protect walls from direct radiation. Sloping roof will also reduce heat gain.

Inferences

- These houses are comfortable all the year round
- Courtyard can be provided in place of skylight which will allow more day light and also induced ventilation

CHAPTER 4
STUDYAREA PROFILE

4.1 PREAMBLE

An introduction to the study area is discussed here. The typologies of vernacular residential buildings found in Kerala, its evolution, materials used and architectural elements found in these buildings are also reviewed.

4.2 KERALA

4.2.1 Location

Kerala is a small strip of land lying at the south-west corner of India. It lies to the north of the equator between 8° 18' and 12° 48' north latitude and 74° 52' and 77° 24' east longitude.

4.2.2 Neighbouring areas

Kerala is bordered by land on three sides and by the Arabian sea at the west. It shares its border with the state of Karnataka at the north and the rest of Kerala shares it border with Tamil Nadu.

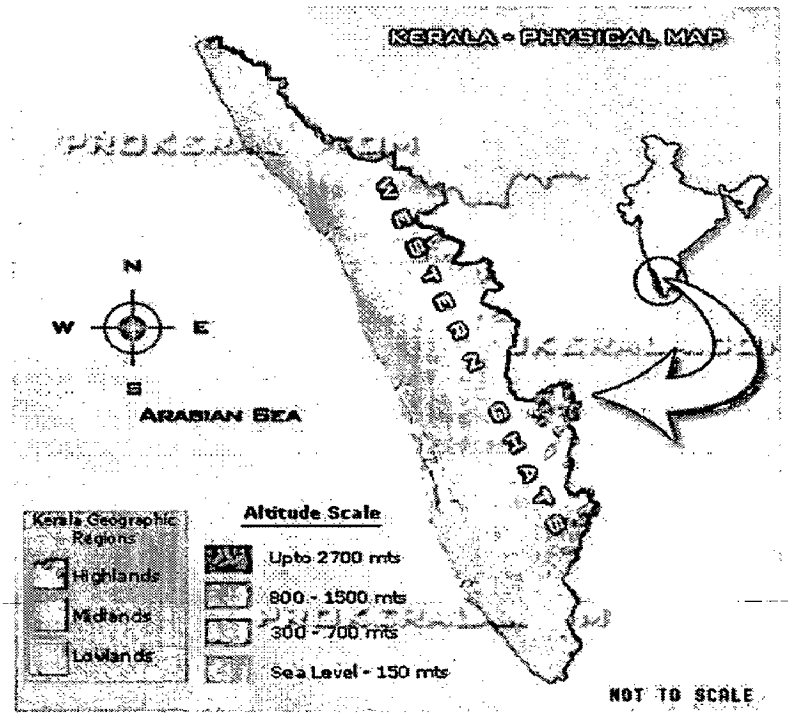


Figure 4.1-Physiographical map of Kerala
Source:http://www.prokerala.com/kerala/maps/thumbnails/kerala-physical-map.gif

4.2.3 Physiography

Kerala is divided into three geographical regions- Highlands, Midlands & Lowlands (fig 4.1)

The forested **Highlands** slope down from the Western Ghats (also known as the **Sahyadri)** which rise to an average height of 900m, with a number of peaks well over 1800 m in height. This is an area abound in tea, coffee, rubber and spice plantations and wildlife reserves.

The **Midlands**, lying between the mountains and the lowlands, is made up of undulating hills and valleys. It is 16200 sq.km in area ie, about 40 percent of the total land area. This

area is rich with cashew, coconut, arecanut, tapioca, banana, rice, ginger, pepper, sugarcane and vegetable plantations.

Lowlands are also known as the Coastal Area. It covers an area of almost 4000 sq.km. The lowland of Kerala is a costal belt relatively flat and is networked by endless backwaters and the deltas of forty-four rivers.

According to another physiographic classification, in terms of broad geographic surfaces and altitudinal characteristics, there are five physiographic zones. Those are high ranges with elevation above 600m, foothill zone between 300-600m, upland regions between 100 - 300 m, midland between 20 - 100 m and coastal areas and low land below an altitude of 20 m.

4.2.4 Climate

At low and medium elevations ranging between 0-700m, Kerala experiences warm humid climate. While the temperature reduces for the region of elevation 700-1400m above msl and it still reduces when the elevation of the land is above 1400m. These higher altitudes experience a cool and invigorating climate the year-round. Kerala enjoys 4 seasons - Winter, Summer, South-West Monsoon and North-East Monsoon.

Kerala receives an average annual rainfall of 3107 mm - some 7,030 crore m^3 of water. Parts of Kerala's lowlands may average only 1250 mm annually while the cool mountainous eastern highlands of Idukki district - comprising Kerala's wettest region - receive in excess of 5,000 mm of orographic precipitation (4,200 crore of which are available for human use) annually (table 4.1). Kerala's rains are mostly the result of seasonal monsoons. As a result, Kerala averages some 120-140 rainy days per year. In summers, most of Kerala is prone to gale-force winds, storm surges, and torrential downpours accompanying dangerous cyclones coming in off the Indian Ocean.

Table 4.1-Average monthly rainfall in Kerala

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	14.6	16.6	36.1	110.9	252.6	653.2	687.2	404.7	252.3	270.7	158.6	45.9

Source: http://www.prokerala.com/kerala/climate.htm

Kerala's average maximum daily temperature is around 36.7 °C; the minimum is 19.8 °C. The temperature normally ranges from 28° to 32° C (82° to 90° F) on the plains but drops to about 20° C (68° F) in the highlands.

Winter Season in Kerala: In the highlands of Kerala, where the climate is cool throughout the year, winter temperatures often fall below 10°C. Winter season in Kerala witnesses the lowest amount of rainfall (table 4.2).

Table 4.2-Temperature and average rainfall of Kerala during winter

Temperature during Winter in Kerala:	Maximum : 28°C Minimum : 18°C
Average Rainfall during the season :	25 mm

Source: http://www.prokerala.com/kerala/climate.htm

Summer Season in Kerala: Relatively higher temperature, low rainfall and slightly humid weather are the characteristics of the summer season in Kerala. Erratic rains accompanied by lightening and thunder are another feature of the season (table 4.3).

Table 4.3-Temperature and average rainfall of Kerala during summer

Avg Temperature during Summer in Kerala:	Maximum : 36°C Minimum : 32°C
Avg Rainfall during the season :	135 mm

Source: http://www.prokerala.com/kerala/climate.htm

South West Monsoon in Kerala : Southwest monsoon is the main rainy season in Kerala (table 4.4).

Table 4.4-Temperature and average rainfall of Kerala during south west monsoon

Average Temperature during this season :	Maximum : 30°C Minimum : 19°C

Average Rainfall during the season :	2250 - 2500 mm

Source: http://www.prokerala.com/kerala/climate.htm

North East Monsoon in Kerala: Heavy afternoon rains accompanied by thunder and lightening, is the main characteristic of the season. Days are warm and humid but there is not much variation in temperature (table 4.5).

Table 4.5-Temperature and average rainfall of Kerala during north-east monsoon

Average Temperature:	Maximum : 35°C Minimum : 29°C
Average Rainfall during the season :	450 - 500 mm

Source: http://www.prokerala.com/kerala/climate.htm

4.3 TRADITIONAL RESIDENTIAL BUILDINGS OF KERALA

4.3.1 Traditional Domestic Architecture

The evolution of residential architecture of Kerala, follows the same direction as that of temple architecture. The primitive models started with huts of thatched roof on bamboo frames in circular or square and rectangular plan forms. The final product after functional consideration is rectangular form with hipped roof.

There are five types of traditional domestic architecture in Kerala, namely: (1) the wretched humble house which belongs to ordinary folks and tribal people/ *adivasis* (*cheri*, *chala*, *kudi*, *variyam* or *pisharam* or *pumatham*); (2) the *Ekasala*, an I-shaped single rectangular hall house, belongs to farmers or middle-class non-farmers; (3) the *Nalukettu*, a courtyard house, belongs to landlords; (4) the great mansion *Ettuketu* and *Patinjarukettu* (double *ettukettu*) or much bigger structures, belong to very rich landlords; (5) commoner houses are simple ordinary houses scattered abundantly in the cities and villages.

Ekasalas are the most commonly found residential forms in Kerala. The *Ekasala* is a single hall house, *dvisala* a two-hall house, *trisala* a three-hall house, and *catusala* a four-hall house/courtyard house, which is also known as *Nalukettu*. This is the most developed

form of typical Kerala house. Each hall will be facing one of the cardinal directions. The generally house structure in Kerala is that of the single hall house or *Ekasala*. Later it was divided with partitions to form interior divisions.

The core unit of *ekasala* consists of generally three rooms connected to a front passage. It is the most frequent spatial structure in single hall houses. The projecting eaves cover a verandah all round. The central room is used as prayer room and grain store and the two side rooms are used as living rooms. The core unit may be raised to an upper storey with a steep stair located in the front passage. The building may also be extended horizontally on all the four sides adding *alindams* or side rooms for activities such as cooking, dining, additional sleeping rooms, front hall for receiving guests etc. If needed *ekasala* may also be provided with ancillary buildings for cattle keeping, barn, bathing rooms near tanks, outhouse for guests, gate house etc. By such extension the building may become much larger than a *nalukettu* in space, but it is still categorized as *ekasala* with reference to its core unit.

The spatial division found in both huts and the more elaborate middle class single mass house basically originates from the one hall house. The hall can be arrayed and constituted into a row of halls for different functional spaces linked by a veranda, or divided into arrayed inner rooms. Additional space was added to the three arrayed rooms in the form of an additional gallery that run behind the rooms, thus imaging 9x9 spatial grids. Three arrayed rooms and 9x9 spatial grids are becoming archetypical in the spatial partitioning and division of the single hall. This was the scheme for the traditional-vernacular structure used in commoner houses.

Depending on the needs the house can be *ekasala*, or *dwisala* or *trisala* or *catusala*, the *nalukettu*. *Nalukettu* is a combination of four halls along four cardinal directions, centered around the courtyard or *anganam*. The four halls enclosing the courtyard may be divided into several rooms for different activities such as cooking, dinning, sleeping, studying, storage of grains etc. Depending on the size and importance of the household the building may have one or two upper storeys (*malika*) or further enclosed courtyard by repetition of the *nalukettu* to form *ettukettu* (eight halled building) or a cluster of such courtyards.

The *nalukettu* is the principal structure of a garden compound. The garden may contain cattle sheds, bathing tanks, wells, farm buildings, grain stores etc., as ancillary structures, the whole being protected with a compound wall or fence. An entrance structure (*padippura*) may contain one or two rooms for guests or occasional visitors who are not

entertained in the main house. Position and sizes of most of these areas inside and outside the house are decided according to *vasthu*.

Nalukettu of different parts of Kerala are different in the arrangement of areas and in its building materials (Cherian n.d.; Susilo, n.d.).

Another building typology found in Kerala is row housing. Row houses in Kerala are *agraharams*, where Brahmins migrated from Tamil Nadu, started living in as a community. Some of these *agraharam* layouts are about six hundred years old. It had street planning with rectilinear buildings arranged in row with common sharing wall. *Agraharams* usually had temple at the either end of the street. These settlements were planned more likely in the vicinity of water body like river, pond etc.

The construction techniques used in these row houses were more or less similar to the domestic architecture of that part of Kerala. Some of the spaces or areas in these structures were also similar. It also had verandah, small courtyard and other similar architectural elements. These are also climatically responsive structures.

Agraharams in Kerala are mainly found in the central part. Numerous *agraharams* are there in Palakkad district and some in Thrissur too. It is also found in the south of Kerala, ie in Thiruvanathapuram.

4.3.2 Architectural elements used in traditional buildings

Several architectural elements used in traditional buildings were evolved considering climate of Kerala. Plinth was raised from the ground for protection against dampness and insects in the tropical climate .There will be external verandahs and internal verandahs around courtyard, which is open. While both the western and eastern verandahs are left open to ensure good inlets for day and night breeze, the northern and southern verandahs can be enclosed or semi-enclosed or even open. The verandahs have extended overhanging eaves that protect the building from rain and the sun's glare as well as provide a sitting area attached to the house. The walls are being shaded by sloping roof. Thus it was protected from the sun and driving rain. The enclosed courtyard is usually sunk such that cooler air settles down (Vyas, 2005).

Roofs have steep pitches almost 40-45 degrees. Further gable windows are there at the two ends to provide attic ventilation when ceiling was incorporated for the room spaces. This ensured air circulation. Even in the absence of the ceiling these gables have an

opening with a decorative *jali* from where hot air rises and flows out. The roofs enclose a large insulated air space thus, keeping the lower areas cooler. Tropical feature of shingle is also seen in Kerala roofs. Bend roof construction is another feature found in some parts of Kerala (Susilo, n.d.).

The main door faces only in one cardinal direction and the windows are small and are made like pierced screens of wood or latticed windows as the reaction to the sun's glare. Usually the openings are placed in straight alignment for cross ventilation thus enhancing the thermal comfort inside the building (Vyas, 2005).

Traditional residences have open lay-out living spaces.

4.3.3 Materials used in traditional buildings

Locally available materials were mainly used for the traditional constructions. The natural building materials available for construction in Kerala are stones, timber, clay and palm leaves. Granite is a strong and durable building stone; however its availability is restricted mostly to the highlands and only marginally to other zones. Laterite on the other hand is the most abundant stone found as outcrops in most zones. Soft laterite available at shallow depth can be easily cut, dressed and used as building blocks. It is a rare local stone which gets stronger and durable with exposure at atmospheric air. Laterite blocks may be bonded in mortars of shell lime, which have been the classic binding material used in traditional buildings. Timber is the prime structural material abundantly available in many varieties in Kerala - from bamboo to teak. The skilful choice of timber, accurate joinery, artful assembly and delicate carving of wood work for columns, walls and roofs frames are the unique characteristics of Kerala architecture. Clay was used in many forms - for walling, in filling the timber floors and making bricks and tiles after pugging and tempering with admixtures. Palm leaves were used effectively for thatching the roofs and for making partition walls.

From the limitations of the materials, a mixed mode of construction was evolved in Kerala architecture. The stone work was restricted to the plinth even in important buildings such as temples. Laterite was used for walls. The roof structure in timber was covered with palm leaf thatching for most buildings and rarely with tiles for palaces or temples. The exterior of the laterite walls were either left as such or plastered with lime mortar to serve as the base for mural painting. The indigenous adoption of the available

raw materials and their transformation as enduring media for architectural expression thus became the dominant feature of the Kerala style (Cherian, n.d.).

4.4 INTRODUCTION TO AREAS OF FIELD STUDY

The field study is conducted for two vernacular building types of Kerala namely courtyard houses and row houses in the low lands and midlands, since it experiences warm humid climate.

The main study area for selecting the case studies is taken from the centre of Kerala, ie from Thrissur and Palakkad district (fig 4.2), since both courtyard houses and row houses are found in this area. Courtyard houses are studies from Thrissur and row houses are studied from Palakkad.

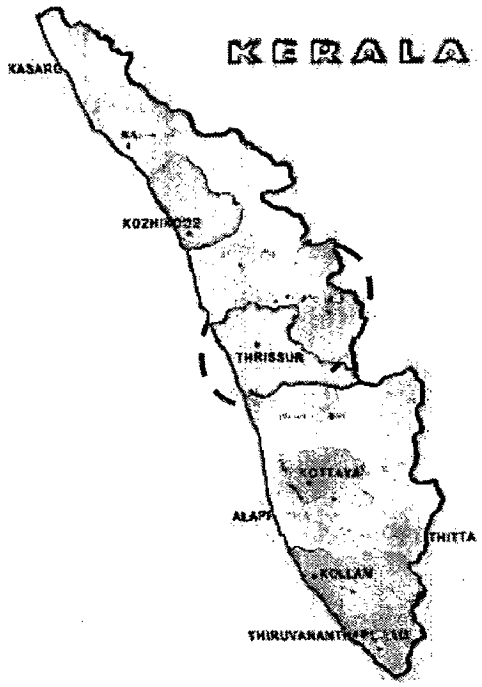


Figure 4.2-District map of Kerala showing Thrissur & Palakkad districts

Source:http://www.topnews.in/files/kerala_map.JPG

4.4.1 Thrissur

In Thrissur district all the three geomorphological features exist namely lowland, midland and highland. The study area in Thrissur district consists of three places with courtyard houses. Two of the study areas are in mid lands, ie one is Kanjani which is 13m above msl and Kodungallur with altitude of 8m from msl. Next study area lies in midland, Thrissur with altitude of 47m above msl (fig 4.3).

Climate

a) Temperature

The maximum temperature ranges from 29.3 to 36.2^{0}C where as the minimum temperature ranges from 22.1 to 24.9^{0}C. The average annual maximum temperature is 32.30^{0}C and the average annual minimum temperature is 23.3^{0}C. Generally March and April months are the hottest and November, December, January and February months are the coldest.

Figure 4.3-Map of Thrissur and Palakkad showing locations of case studies from study area

Sources: http://enchantingkerala.org/kerala-maps/thrissur-district-map.jpg & http://enchantingkerala.org/kerala-maps/palakkad-district-map.jpg

b) Relative Humidity

The humidity is higher during monsoon months from June to October and is around 93% during morning hours and 76% during evening hours.

c) Wind Velocity

The wind speed is more during December and January months and it is less during October. The prevailing wind direction is from south west to north east.

d) Rainfall

The rainfall occurs more during southwest monsoon season during June to September and followed by northeast monsoon season during October to December. The average annual rainfall ranges between 2180.0 and 3484.0 mm in the district and mean annual rainfall for the district is 2924.4 mm (table 4.6). In general, the rainfall increases from south to north and west to east.

Table 4.6-Monthly rainfall(mm) of Thrissur

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	7.0	10.0	24.1	89.4	295.9	717.9	760.4	436.4	257.5	262.8	140.0	42.2

Source: http://www.tsr.kerala.gov.in/barefacts.htm

4.4.2Palakkad

Palakkad consists of both midlands and highlands. Three areas are taken for row housing study from this district, all lying in midlands. One is Kalpathy with altitude of 90m above msl and others are Kizhakkencherry and Vadakkencherry, both of altitude 73m above msl (fig 4.3).

The climatological data of Palakkad is shown in table 4.7.

Table 4.7-Climatological data of Palakkad

Monthly rainfall (m.m)												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	0.1	29.3	205	85.3	43.1	508.2	290.6	464.3	160.1	13.7	82.7	34.4
Temperature												
Max :	33.3	35.5	37.5	36.6	33.6	29.7	28.1	28.7	30.4	31.2	32.1	32.1
Mini :	21.7	22.6	24.1	25.1	24.6	23.2	22.2	22.9	23	23.2	22.9	22.1
Relative Humidity												
Max :	69	67	70	78	81	89	92	91	88	85	78	72
Mini :	19.4	17.9	20.5	27.5	27.5	28.3	28.7	28	28.1	28.1	25.9	21.8
Source : Meteorological Centre, Thiruvananthapuram												

Source: http://www.kerala.gov.in/district_handbook/Palakkad.pdf

The prevailing wind direction from April to October is from west to east and from November to March is from east to west.

CHAPTER 5

SURVEY ON BUILDINGS AND USER RESPONSE

5.1 PREAMBLE

A total of six case studies are done from the study area, three courtyard houses and three agraharams(row housing community). From each agraharam two individual row houses of different categories are taken for detailed study. From Kalpathy agraharam a single storied and a double storied, from Kizhakkencherry agraharam one with onaamkettu(single block) alone and next with separate onaamkettu and randamkettu(two blocks or stages) and from Vadakkencherry agraharam one with courtyard and next without courtyard are studied. Visual survey and questionnaire survey were done. A questionnaire survey was conducted for 10-20% of residences from each row housing community, which were selected randomly (See annexure-I for sample questionnaire). And analyses of these surveyed residences are done here.

A methodology derived from literature review is followed to analyse all the surveyed buildings. Initially the planning aspects, architectural design aspects and construction and material use are reviewed. In the case of row houses, planning aspects are given for the whole row housing community and architectural design aspects and construction and material use are given for individual buildings taken for survey, from each row housing community. Following the analysis of building design and planning aspects for thermal comfort objectives is done through the following principles (a) Provision of continuous and efficient ventilation, (b) Protection from sun, rain and insects, (c) Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings. Subsequent to it activity analysis is done.

For row houses, household and visual survey analysis is also done.

5.2 COURTYARD HOUSE-1(DETACHED HOUSE WITH ONE COURTYARD AND SINGLE STOREYED) - 'NALUKETTU'

Location- Kanjani, Thrissur (Central Kerala- lowland)

i. Planning Aspects

Site plan & features

The building is built on a rectangular plot of 50 cents or half an acre (2094 sq m.), with roads running on 3 cardinal directions, i.e, on east, west and south. The square shaped building is placed at the centre of the site. The building is surrounded with numerous trees like coconut trees, and shading trees like mango trees, jackfruit tree, tamarind tree etc. The site is sloping from west to east, thus the water from the site drains towards east. Prevailing wind direction of this region is from south-west to north-east.

Layout

The building has courtyard planning with courtyard at the centre of the building. The building is surrounded by verandah on all four sides. Rooms used in the night are on the west side, with store rooms and bathroom on the western most ends. Hall, the room which is habitable in the day time, is in the south east side. Kitchen is in the north east side (fig 5.1).

Orientation

The building is oriented towards cardinal directions.

Plan concept

Courtyard planning is used for this building.

ii. Architectural design Aspects

Building form and plan form

The building is square shaped with courtyard within. The building is covered with sloping roof on all four sides with courtyard portion left open to sky. The building is single storeyed with attic above wooden ceiling (fig 5.1).

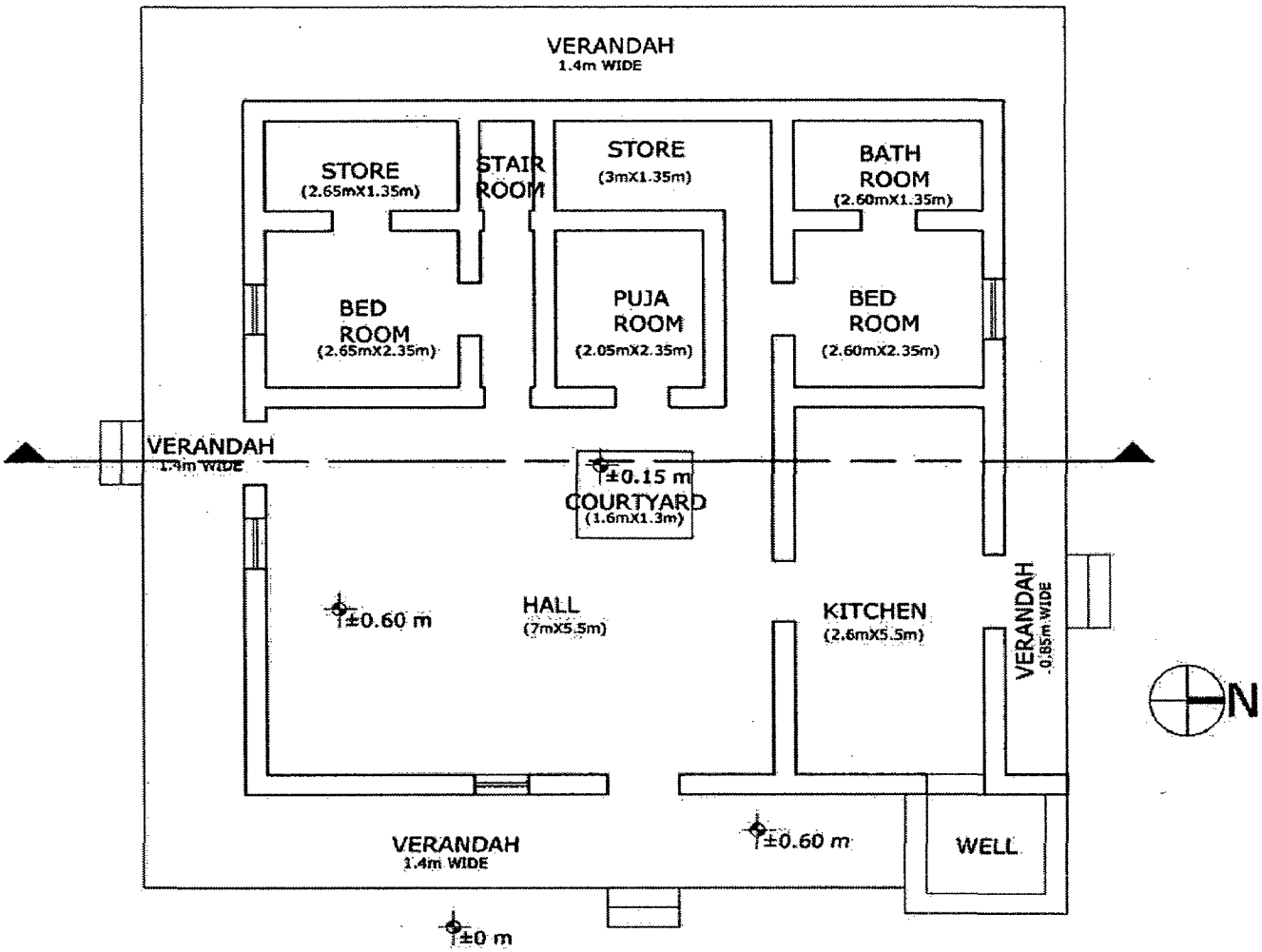


Figure 5.1- Ground floor plan of single storeyed courtyard house

Architectural elements

Verandah is provided all around the building. The whole building is covered with sloping roof. Openings are provided opposite to each other. Small courtyard of dimension 1.6mX1.3m and sunk by 45cm is provided at the centre of the building (fig 5.1, fig 5.2).

Functionality of spaces

Private spaces like rooms are provided, towards the west side. Hall which is provided on the south east is used as a multi use space. Verandah, which is mainly for shading the walls, is also used as an outdoor living space. Attic space is used for storage purpose.

iii. Construction and Materials use

Plinth is of laterite stone. The walls are of laterite stone and plastered with lime mortar. The roof is sloping with mangalore pattern tile. The rafters, reapers and ridge in roof are of wood. Rooms on west have wooden ceiling *'thattu'* above, ie.all the rooms except hall and kitchen. The flooring is of cement with oxide finish. Wooden columns are used all around (fig 5.2).

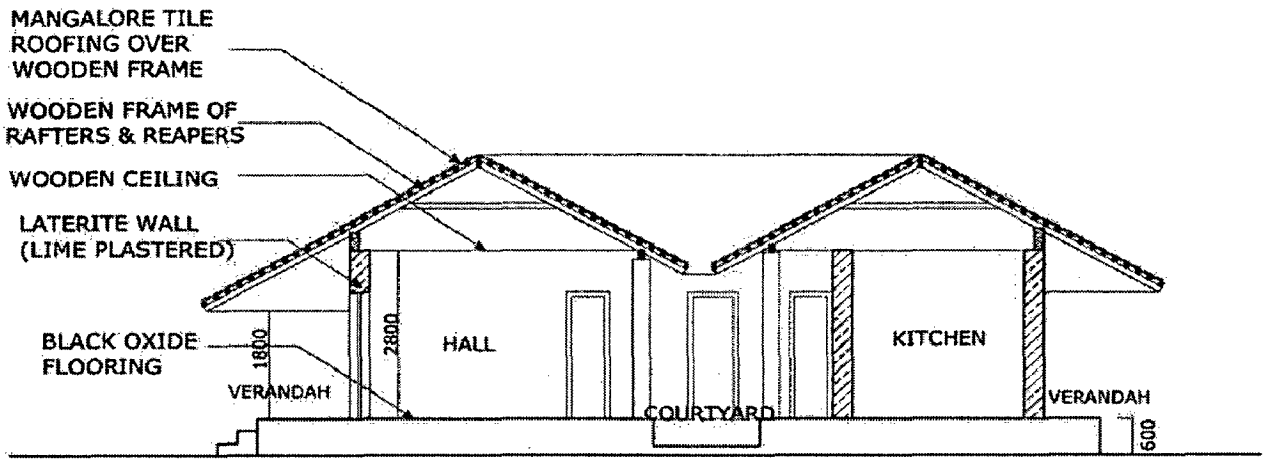


Figure 5.2-Section of single storeyed courtyard house

Analysis of building design and planning for thermal comfort objectives

a) Provision of continuous and efficient ventilation

Courtyard increases ventilation through stack effect. All the habitable rooms have openings placed opposite to each other of which at least one opening on the exterior wall for cross ventilation. Since it is detached house, it has sufficient external surrounding space which can increase ventilation. Prevailing wind, from south-west, enters the building and ventilates the structure. Since it is a square building, oriented towards cardinal directions, all the winds including prevailing and local winds can easily enter the building and ventilate the structure.

b) Protection from sun, rain and insects

Adequate day light is available from the courtyard and overhangs of the sloping roof into the courtyard protects from direct sun. Sloping roof is provided, which makes it easy for rain water to drain off. Large roof overhangs protects the walls from sun and rain. No additional shading devices are required for walls and openings. External shaded

verandahs are also provided all around the building which prevents direct solar radiation on the walls. Proper drainage provided from the courtyard to the exterior of the house, prevents dampness entering the structure. Raised plinth also prevents dampness.

c) Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings

Verandah running all around the building protects the walls from sun's direct radiation, thus reducing the solar heating. Raised plinth provided reduces heat reradiating from ground. Sloping roof with its more surface area and inclination ensures the structure with less heat gain. Wooden ceiling is provided above habitable rooms used at night and above store. These spaces will be cooler than other areas. Layer of air above the wooden ceiling act as an insulator and makes the space below cool. The hot air will be removed through the gaps between roof tiles. The room without false ceiling is being ventilated by courtyard effect, which allows the hot air to rise up and makes the building cool, by drawing cool air from the surroundings.

Activity area analysis

1.4m wide verandahs are provided on east, west and south side, which provide shade and also used as outdoor living spaces during daytime, which has enough daylight and ventilation. Hall is provided in the south east side, which is mostly used during daytime and will be cool at this time due to its location. The most heated part, west side, is bounded by store rooms and bath rooms, which is used less. Bedrooms are provided next to these less used rooms, thus with reduced heat, and are provided with openings on opposite sides for cross ventilation. Kitchen is provided on the north-east part, since the prevailing wind direction of this area is from south west to north east. Verandah located next to kitchen, ie. on the north side is less wide because direct sun's radiation will not fall on the north side most of the time. Well is provided next to kitchen, where water is required in plenty.

Table 5.1-Chart showing objectives of thermal comfort and normative indicators of the architectural means to achieve these objectives in courtyard residence-1

Principles of building design/ Thermal Comfort objectives ⇨ **Architectural means to attain principles ⇩**	*Provision of continuous and efficient ventilation*	*Protection from sun, rain and insects*	*Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings*
Building form and layout	Courtyard planning Square plan		
Orientation	Oriented towards cardinal directions, so wind from all directions can enter	Oriented towards cardinal directions and influenced by sunpath	Oriented towards cardinal directions and reduces heat gain
Raised Plinth		Raised plinth prevents dampness	Less radiation reflected from surroundings
Openings	Provided opposite to each other and induces cross ventilation		Openings in prevailing wind direction increases rate of cooling
Shading		Sloping roof shades the openings and walls	Shading by vegetation and sloping roof
Wide Verandahs		Wide verandahs protects the walls from intense solar radiation	

Landscape		Trees around the building protects from sun's radiation	
Roof Type		Sloping roof- which helps the rain water to drain off easily	Sloping with it inclination and area, absorbs less of sun's radiation.
Wall Material			Walls with laterite which is insulating because of its thickness
Roof Material			Mangalore pattern clay tile will absorb less heat.
Outdoor spaces	Verandahs on east and south side- outdoor living space		
Physical phenomena	Courtyard effect- enhances ventilation		
Fly screen		Not provided	
Other techniques			Double roof construction in some parts of building

5.3 COURTYARD HOUSE-2(WITH ONE COURTYARD AND DOUBLE STOREYED)- 'NALUKETTU'

Location- Thrissur (Central Kerala-midland)

i. Planning Aspects

Site plan & features

This residence is built on a rectangular plot, with entry to the site from the road running on the west side of the plot. The slope of the site is towards south and east, with ponds on both sides for collecting drained rainwater from the site and helps in rain harvesting. The site is covered with lot of coconut trees and other shady trees. The building is located at the centre of the site, with plenty of unbuilt space around the building. Prevailing wind direction is from south-west to north-east.

Layout

The building has a courtyard with 4 salas around ie '*Catusala*' or *Nalukettu*. *'Sala'* or hall in front is divided into three spaces with *'ara'* or store in the centre. One more *sala* is connected to the *catusala*. Area or hall on the east side of the courtyard is known as *'kizhakkini'* , on the west side *'padinjaattini'*, on the north side *'vadakkini'* and on the south side *'thekkini'* (fig 5.3).

Orientation

House is oriented in N-S orientation.

Plan concept

Courtyard planning is used for the residence, with all the rooms or spaces planned around the courtyard for maximum utilization of courtyard.

ii. Architectural design Aspects

Building Form& plan form

The building has a rectangular plan form and a rectangular extension to it. The building consists of 2 floors and an attic space (fig 5.3, fig 5.4, fig 5.6 and fig 5.7).

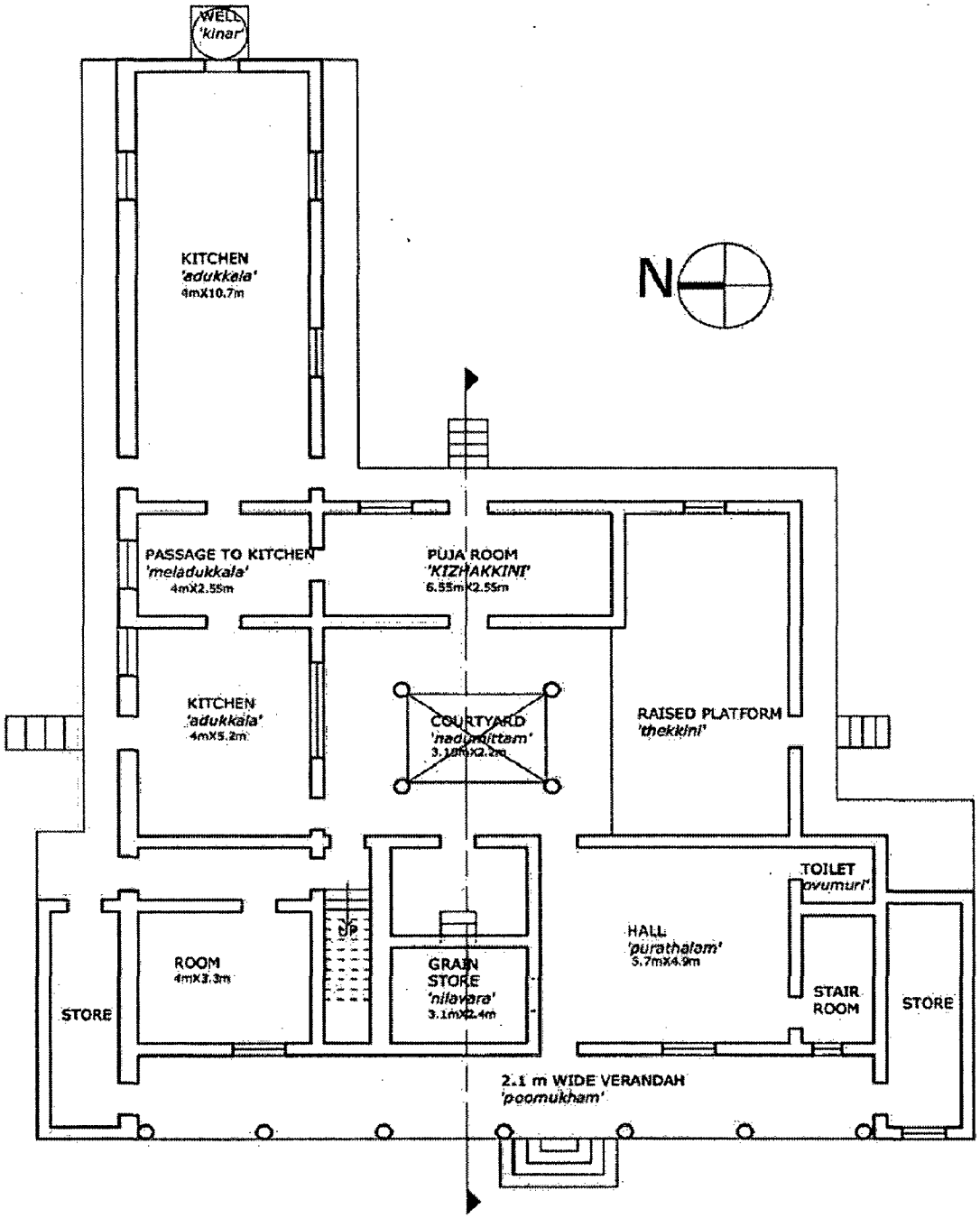


Figure 5.3- Ground floor plan of double storeyed courtyard house

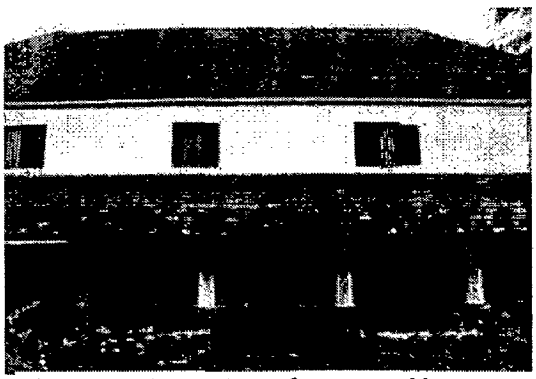


Figure 5.4-Front view of courtyard house-2

Figure 5.5-View of front verandah or *'poomukham'* of courtyard house-2

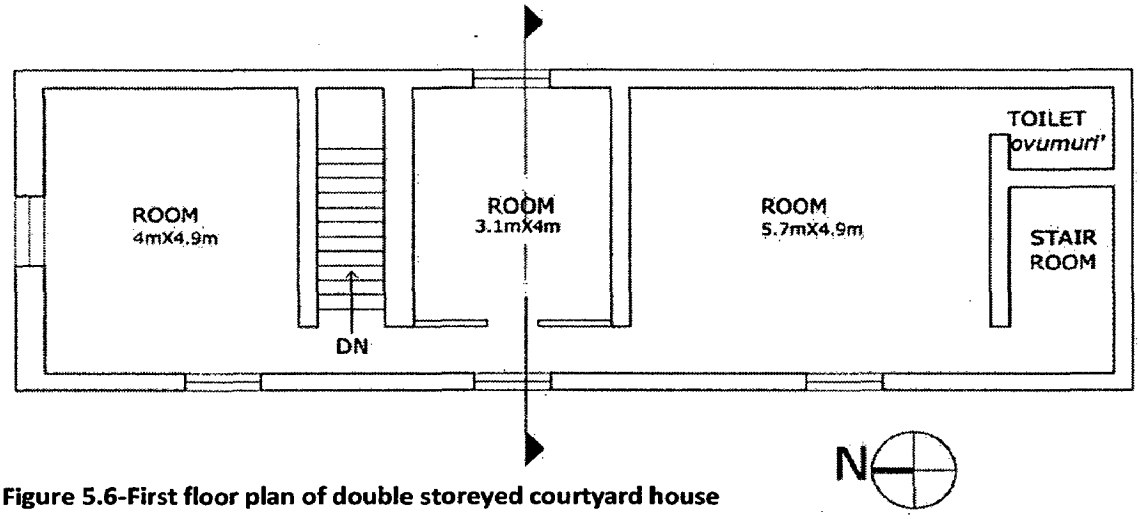


Figure 5.6-First floor plan of double storeyed courtyard house

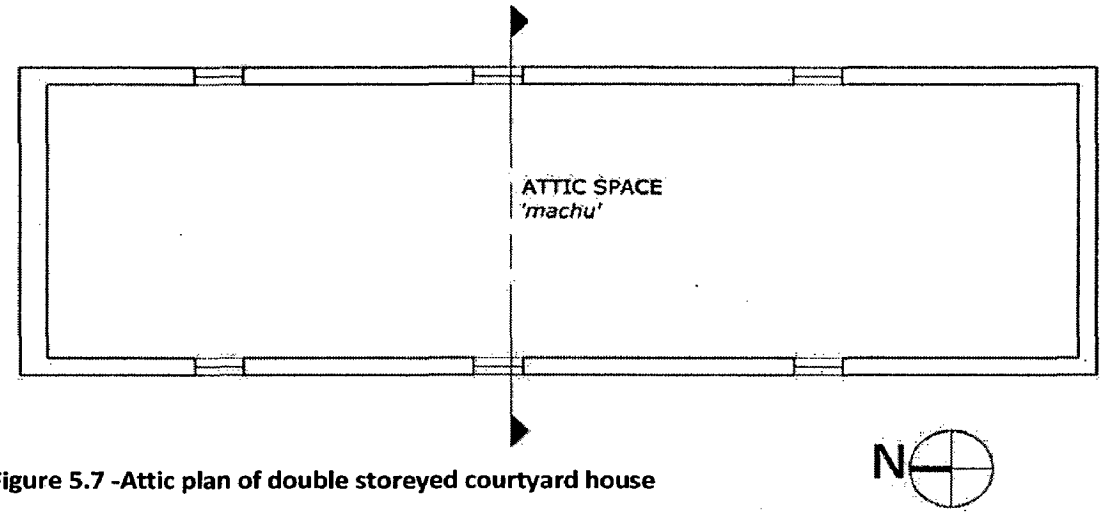


Figure 5.7 -Attic plan of double storeyed courtyard house

Architectural elements

Verandah is provided all around the building. These verandahs are shaded with the wide overhangs of sloping roof. Doors are provided in straight alignments or opposite to each other. Minimum of three openings are found in most of the rooms. Courtyard of 3.15mX2.2m is in the centre of the building, which is sunk by 60 cm (fig 5.8). Two wooden steep staircases are also provided in this residence (fig 5.3).

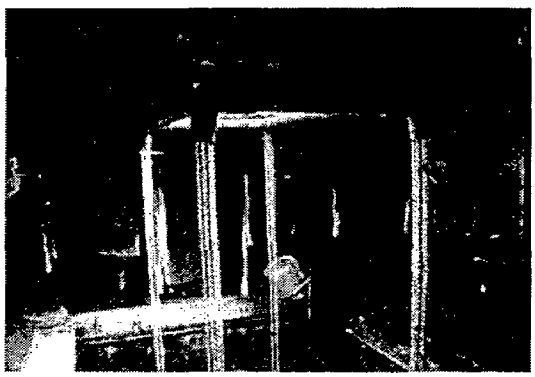


Figure 5.8-View of courtyard in courtyard residence-2

Functionality of spaces

Verandah in front is used as an outdoor living space. Most of the rooms provided in this residence are in the form of halls. Some of

those spaces have been converted to private spaces. Most of these spaces provided are multi functional. For example, dining space is used as living space and resting space during the daytime. Separate sleeping areas are provided in the first floor, where it is not possible for multiuse, since it is on the first floor. Storage spaces are provided separate in this residence, *'nilavara'*, at an elevated position, which was used for storing grains and *'nilavarakundu'* below it to store the valuables. Two kitchen spaces are provided on north east side. One kitchen space is also used for dining, so this is also a multifunctional space. Only urinals were provided inside the house in the olden days, which has now been converted to toilet spaces (fig 5.3).

iii. Construction and Materials use

Raised plinth and walls are of laterite stones. Plastering is of lime over the wall masonry. Roof is hipped roof with steep slopes. Mangalore tile is used as roofing material over wooden frame. Wooden ceiling is provided over some areas. Floor finish is of clay tile in some areas and cement flooring with oxide finish in other areas. Laterite columns are provided in the front and wooden columns around the courtyard (fig 5.9).

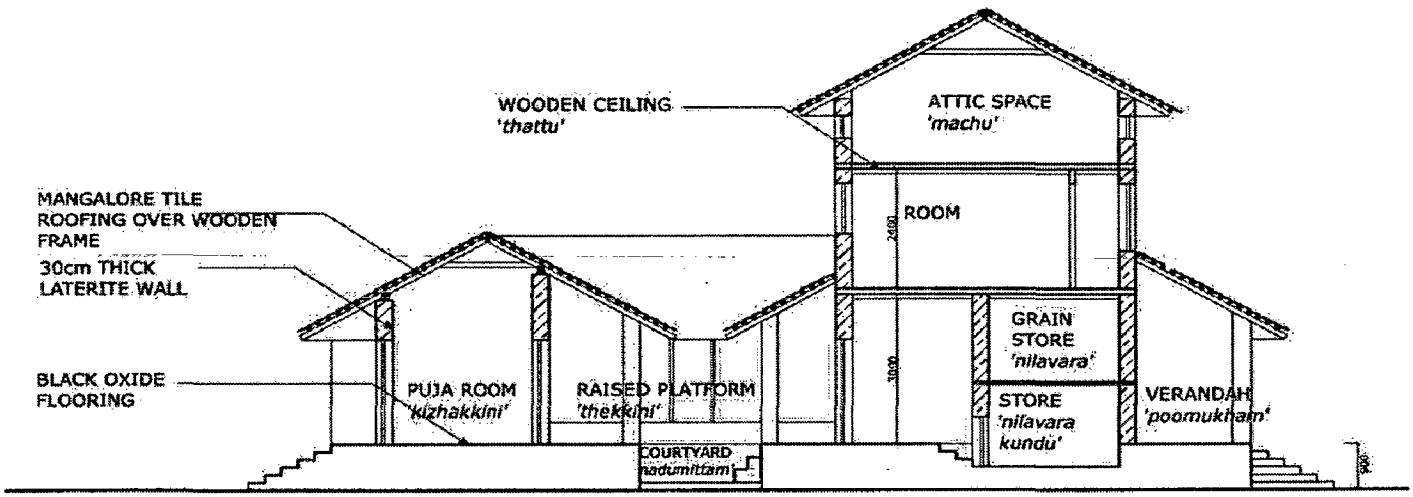


Figure 5.9- section of double storeyed courtyard house

Analysis of building design and planning for thermal comfort objectives

a) Provision of continuous and efficient ventilation

Courtyard induces ventilation through stack effect. Rooms are organised around courtyard and one extended from the normal courtyard planning, which has windows placed opposite to each other for cross ventilation. All the rooms have openings placed on

the exterior wall and on the wall towards the courtyard for air to flow from out side and from courtyard. Most of the rooms have three openings, which will also increase ventilation in those rooms. This residence is detached with enough external surrounding space which in turn increases ventilation.

b) Protection from sun, rain and insects

Sloping roof is provided, which makes it easy for rain water to flow off. Adequate day light is available from the courtyard and the roof overhang in the courtyard protects the inside space from direct sun. Large overhangs of roof protect the walls from rain and sun. External verandahs are also provided which protects the walls from rain and sun. Proper drainage is provided from the courtyard to the exterior of the house which prevents dampness. Raised plinth also prevents dampness entering the structure.

c) Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings

The building is in North-south orientation and thus reduces heat gain of the structure. Inner verandahs around the courtyards and external verandah in the front part protects the walls from direct solar radiation. Wider verandah is provided in west side, which protects the wall from west sun. Raised plinth is provided; hence heat reradiating from ground will be low. Sloping roof ensures less heat gain than flat roof due to its shape and less exposure to solar radiation. Double roof (tiled roof above and wooden ceiling below) is provided above first floor. The layer of air in between double roof acts as an insulator. Thus the space below remains cool. Materials used for construction are locally available and it increases the degree of comfort. Cavity walls with laterite and sand as filling material are used for outer walls. This will reduce heat gain through external wall.

Activity area analysis

Verandah in front is the widest of all since it on west side, which is used as an outdoor living space, is well shaded from west sun by the width of verandah and sloping roof above it. It is provided with adequate daylight. It is also well ventilated by the prevailing wind, which is from south west to north east. Since the verandah provided is open, it allows the inner habitable with sufficient daylight during the daytime. All the habitable rooms are well ventilated and well lit with the help of the courtyard. No habitable rooms in the ground floor are on the extreme west side. The sleeping areas provided in the first

floor have one external wall as west wall. But the rooms are only used during night time and are cross ventilated, with the help of more than one window. Kitchen is located in the north east side. It is located according to the wind direction, which is from south west to north east. This position allows the hot air to escape to the surroundings rather than spreading inside the habitable areas.

Table 5.2-Chart showing objectives of thermal comfort and normative indicators of the architectural means to achieve these objectives in courtyard residence-2

Principles of building design ⇨ / **Architectural means to attain principles** ⇩	*Provision of continuous and efficient ventilation*	*Protection from sun, rain and insects*	*Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings*
Building form and layout	Detached building with courtyards ventilation by courtyard effect		Courtyard planning with wide overhanging roofs
Orientation	N-S orientation	N-S orientation	N-S orientation
Raised Plinth	60cm, More wind movement	Prevents dampness	Prevents reradiated solar radiation
Openings	Provided in straight alignment		
Shading		Shading by landscape and roof	Shading by landscape and roof
Wide Verandahs		Prevents direct solar radiation	
Landscape		Talls trees, provide shade	
Roof Type		Sloping roof- easy drain off of water	Sloping roof-Slope and shape reduces

		and shading from sun	heat gain
Wall Material			Single layered and cavity walls with laterite-insulating
Roof Material			Permeable clay tile roofing
Outdoor spaces	Verandah		
Physical phenomena	Courtyard effect		
Fly screen		absent	
Other techniques			Double roof construction, insulating cavity wall

5.4 COURTYARD HOUSE(WITH TWO COURTYARDS AND DOUBLE STOREYED)- 'ETTUKETTU'

Location- Kodungallur, Thrissur (Central Kerala-lowland)

i. Planning aspects

Site plan & features

The residence is built on a rectangular plot of 30 cents with road running along west side of the plot. The building is surrounded by trees like coconut trees, mango trees, jackfruit trees, banana, etc. A temple is situated on the east side of the plot. The rectangular building is located towards the east side of the plot. Prevailing wind direction of this region is from south-west to north-east.

Layout

The residence is detached and has two courtyards. All the rooms are organised around these two courtyards (fig 5.11).

Orientation

The building is oriented in E-W direction

Plan concept

The building has used courtyard planning concept with two courtyards. All the spaces are arranged around these two courtyards.

ii. Architectural design Aspects

Building form and plan form

The building is rectangular in plan with two courtyards. It is double storeyed with attic space above first floor. Sloping roof covers the entire built space with courtyards open to sky (fig 5.10, fig 5.11& fig 5.14).

Figure 5.10-Front view of courtyard residence-3

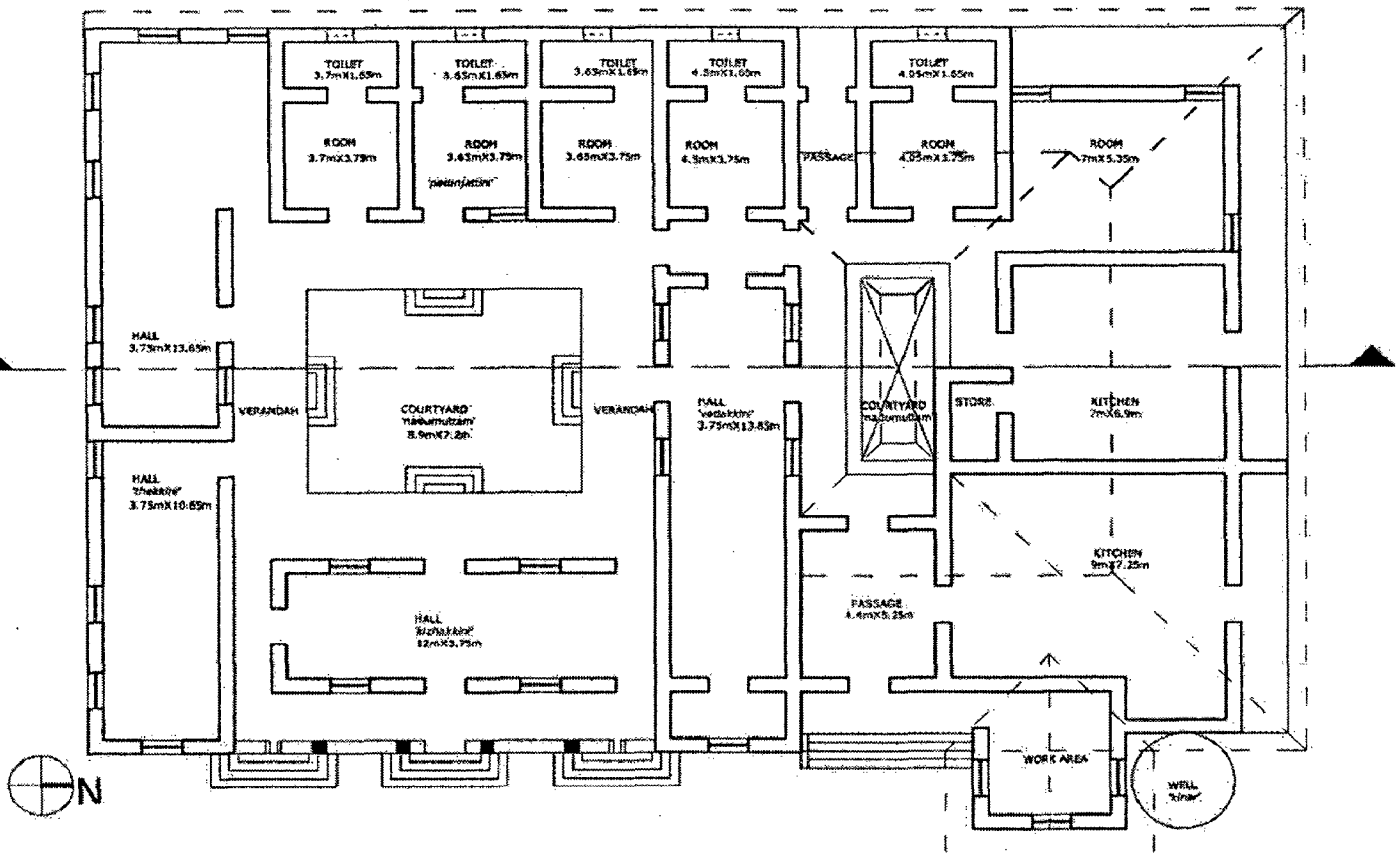


Figure 5.11-Ground floor plan of double storeyed courtyard house with two courtyards

Architectural elements

Raised plinth of 75 cm is provided. Internal and external verandahs are provided. External verandah is provided in the east side, ie. in the front and on the north side, ie. near the kitchen. Internal verandahs are provided around both courtyards. Openings are aligned straight and placed opposite to each other. One courtyard is of dimension 8.9mX7.2m and the smaller one is 2.4mX6.5m (fig 5.12 & fig 5.13). Roof is sloping.

Figure 5.12-View of large courtyard in courtyard house-3

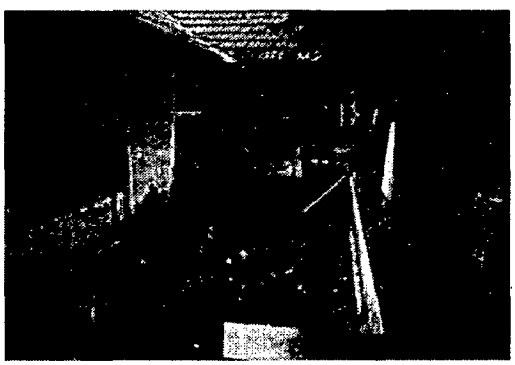


Figure 5.13-View of small courtyard in courtyard house-3

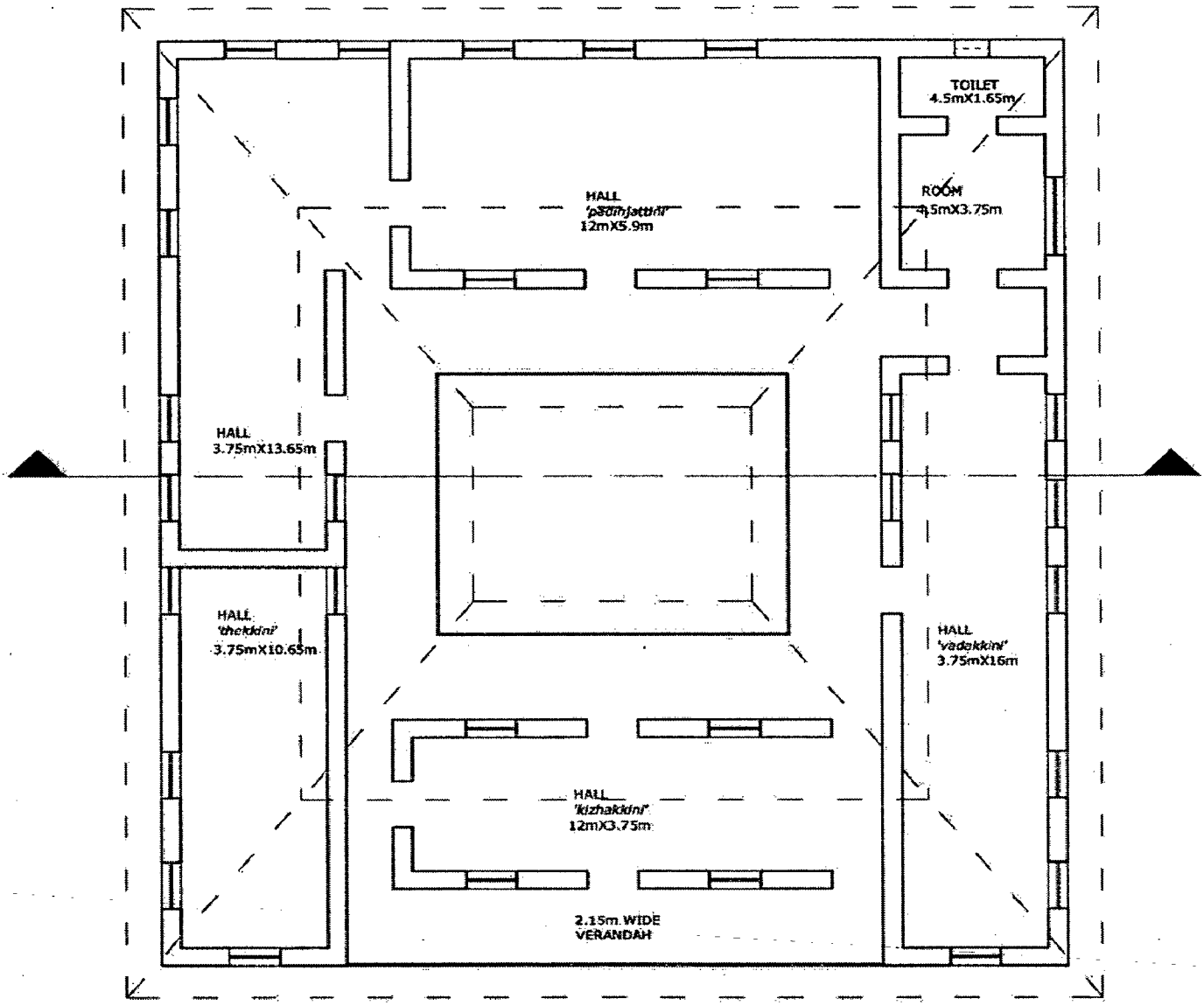


Figure 5.14-First floor plan of double storeyed courtyard house with two courtyards

Functionality of spaces

Most of the spaces found in the residence, around the courtyard, are in the form of halls in front and private rooms with toilets in the back. All these halls are multifunctional spaces. More than one kitchen is provided, which was to serve the additional population who were residing in the olden days. About 40-50 people were staying in this residence before. Separate storage spaces are provided in the residence. Large courtyard with *tulsi* plant is used for prayers.

iii. Construction and Materials use

Laterite stone is used for foundation. Laterite stone with lime plastering is used for wall masonry. Mangalore tile roofing is provided over wooden frame. Wooden ceiling is given for all habitable rooms. Flooring is of clay tiles and cement flooring of black oxide finish. Laterite columns are provided in the front and around large courtyard and wooden columns around small courtyard and in the first floor. Staircase is of wood (fig 5.15).

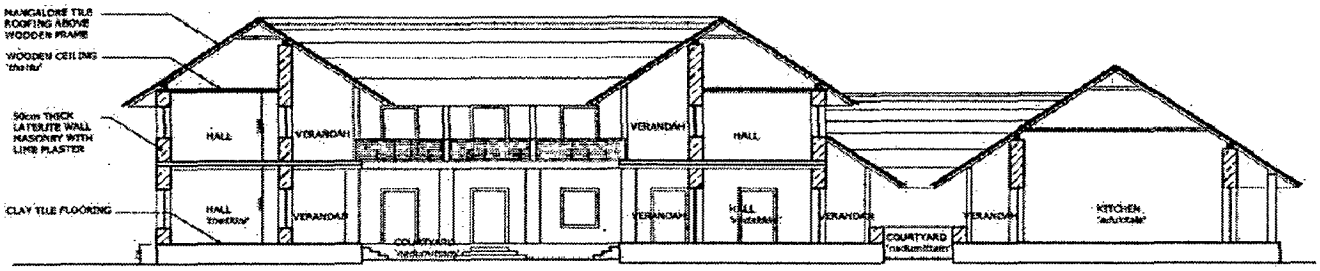


Figure 5.15- Longitudinal section of double storeyed courtyard house with two courtyards

Analysis of building design and planning for thermal comfort objectives

a) Provision of continuous and efficient ventilation

One courtyard is of dimension 8.9mX7.2m and another one is smaller compared to the first one (2.4mX6.5m), which will be shaded most of the time. This initiates two effects namely courtyard effect and double courtyard effect. In double courtyard effect, the shaded small courtyard creates a high pressure region and air will be flown from smaller courtyard to the bigger one, with low pressure (because it is heated up). All rooms are organised around these two courtyards thus efficient ventilation is present in all the areas. All the openings are aligned straight (opposite to each other), thus providing enough cross ventilation which is required for warm humid climate. The residence is detached with enough external surrounding space which in turn increases ventilation.

b) Protection from sun, rain and insects

The building is covered with sloping roof which allows rain water to drain off easily. Roof overhang of 90cm is provided, which protects the walls from rain. Proper drainage provided from the courtyards to the exterior of the house protects the structure from dampness. Raised plinth prevents dampness. Outer verandahs and inner verandahs around courtyards protect walls from direct sun. The vegetation around the building protects the building from sun.

c) **Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings**

Inner verandahs around the courtyards and external verandah in the front protect the walls from direct solar radiation. Floor finish is not provided for both the courtyards, which receive direct sunlight. As soil is present in the courtyards, it will not reflect the intense solar radiation to the building, instead it will absorb, thus minimising the solar heating. The plinth is raised to 60cm, so less amount of reflected heat radiation enters the structure. Sloping roof with its inclination and large surface area absorbs less solar radiation. Double roof construction with mangalore clay tile roof above and wooden ceiling below leaves air gap in between. This layer of air acts as an insulating layer and thus heat will not enter the inner habitable space. Wooden ceiling for ground floor, make the spaces below cooler, because of the insulating property of wood. Shading by vegetation minimises solar heat gain. Thick laterite walls also acts as an insulating layer and reduces heat gain of the structure. The flooring material (clay tiles) provided in verandah around big courtyard is not reflective, which will also reduce heat gain of the walls.

Activity area analysis

Verandah in east, which is utilised as outdoor living space, is well shaded. It is used generally used in afternoon when direct solar radiation will not fall on east side. It is also shaded in the morning by the trees in front of the residence. North verandah is less wide because direct solar radiation falling on north wall is less. The rooms next to the verandah are well lit through the windows opened to the verandah, since verandah is open. All habitable rooms are well lit and ventilated with the help of two courtyards. These rooms are well shaded too, by the presence of verandahs around the courtyards. All these spaces are arranged around the courtyards. The west end is provided with toilets and verandah, which is least used. This act as an insulating layer and prevents heat gain into the habitable rooms next to the toilets. Kitchens are provided on the north east side, since the wind direction is from south west to north east. This helps the hot air to escape easily to the outside space.

Table 5.3-Chart showing objectives of thermal comfort and normative indicators of the architectural means to achieve these objectives in courtyard residence-3

Principles of building design ⇨ / **Architectural means to attain principles** ⇩	*Provision of continuous and efficient ventilation*	*Protection from sun, rain and insects*	*Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings*
Building form and layout	Rectangular with two courtyards		
Orientation	E-W	E-W	E-W
Raised Plinth	75cm, more air movement	Prevents dampness	Prevents reradiated solar radiation
Openings	Provided in straight alignment		
Shading		Through vegetation and roof	Through vegetation and roof
Wide Verandahs		Prevents direct solar radiation	
Landscape		Tall trees gives shade	
Roof Type		Sloping roof- easy drain off of water and shading from sun	Sloping roof-Slope and shape reduces heat gain
Wall Material			Laterite-insulating
Roof Material			Permeable clay tile roofing
Outdoor spaces	Verandah		

Physical phenomena	Courtyard effect and double courtyard effect		
Fly screen		absent	
Other techniques			Double roof construction

5.4.1 Comparison of thermal performance of detached traditional building with courtyard and modern detached building of same locality

Temperature difference of outside and inside in this traditional courtyard house was found to be 6°C but that of modern concrete house, in the same locality, was 4°C, at the same time of the day (table 5.4). This makes it clear that traditional courtyard houses are cooler and more comfortable than modern RCC houses.

Table 5.4-chart showing comparison of thermal performance of detached traditional building with courtyard and modern detached building of same locality (Kodungallur)

Residence	Traditional courtyard house(detached)	Modern house (detached)
Time & Date	1.30pm, 28-01-2010	1.30pm, 28-01-2010
Outside temperature	36°C	36°C
Inside temperature	30°C	32°C
Temperature difference	6°C	4°C

5.5 COMPARISON OF CASE STUDY COURTYARD HOUSES

The three courtyard houses which have been studied are compared in table 5.5, in terms of architectural means used to attain the design objectives for warm humid climate.

Table 5.5-Chart showing comparison of case study courtyard houses

Architectural means for attaining design objectives	Residence 1	Residence 2	Residence 3
Building form and layout	-Square plan -1 courtyard (sunken) -Single storeyed -Courtyard inside hall	-Rectangular plan with extension -1 courtyard(sunken) -Double storeyed -All spaces around coutyard	-Rectangular plan -2 courtyards(sunken) - Double storeyed - All spaces around 2 courtyards coutyard
Orientation	Cardinal directions	N-S orientation	E-W orientation
Raised Plinth	60cm	60cm	75cm
Openings	Opposite to each other	Opposite to each other	Opposite to each other
Shading	Roof and vegetation	Roof and vegetation	Roof and vegetation
Wide Verandahs	-Outer verandah- around the building -Wide verandahs on E,W,S and narrow on N	Outer verandah (around the building), inner verandah around courtyard -Widest on west side	Outer verandah, inner verandah (ground and first floor)around courtyard - Wide verandah on east and narrow on North
Balcony	Absent	Absent	Present in first floor on east side
Landscape	Tall trees and other small vegetation all around the building	Tall trees and other small vegetation all around the building	Tall trees and other small vegetation all around the building

Roof Type	-Sloping roof -Double roof in some areas	-Sloping roof -Double roof above first floor	-Sloping roof - Double roof above first floor
Wall Material	Laterite(Lime plastered)	Laterite and external walls thick laterite wall with insulation in between(Lime plastered)	Laterite(Lime plastered)
Roof Material	Mangalore pattern tile over wooden frame, and wooden ceilings in some areas	Mangalore pattern tile over wooden frame, and wooden ceilings in some areas	Mangalore pattern tile over wooden frame, and wooden ceilings in some areas
Outdoor spaces	Verandah as sit out in front and side	Verandah as sit out in front	Verandah as sit out in front
Physical phenomena	Courtyard effect	Courtyard effect	Courtyard effect and double courtyard effect
Fly screen	Absent	Absent	Absent

The planning aspects, architectural design aspects and construction and material use of these three vernacular courtyard houses of Kerala are almost same. But the small differences in it make differences in the degree achievement of the three design objectives of thermal comfort.

Ventilation is better in the case of second and third residence as all the openings are opened towards outside or towards the courtyard. But the most efficient ventilation is in the third residence because of the two courtyards present in it. These two courtyards induce more ventilation through double courtyard effect, which is caused by the pressure difference due to the presence of one shaded courtyard and the other big courtyard.

Protection from sun and rain is same in all cases as same architectural elements are used in all the cases. Protection from insects is not given in any of the three residences.

Reduction in solar heating of the building is least in the second residence as it is oriented in N-S direction and the outer walls are thick and insulating.

5.6 NEW KALPATHY AGRAHARAM (ROW HOUSING-1)

Location- Kalpathy (3km from Palakkad town), Palakkad (Central Kerala-midland)

The total population of this agraharam is about 600. There are 132 dwelling units in this agraharam. Net dwelling density of this agraharam is 56 dwelling units per hectare and gross dwelling density is 46 dwelling units per hectare. The total length of this agraharam is about 400m.

i. Planning aspects

Row houses are placed on both sides of the street, facing each other, with temples on both ends of the street (Vishwanathaswamy temple on the west end and Manthakkara Maha Ganapathy temple on the east end). The street is running in east west direction. This type of settlement growth is mainly seen near water body. Here in this case it is Kalpathy River flowing through the north side of the settlement (fig 5.16). Wind direction is from east to west.

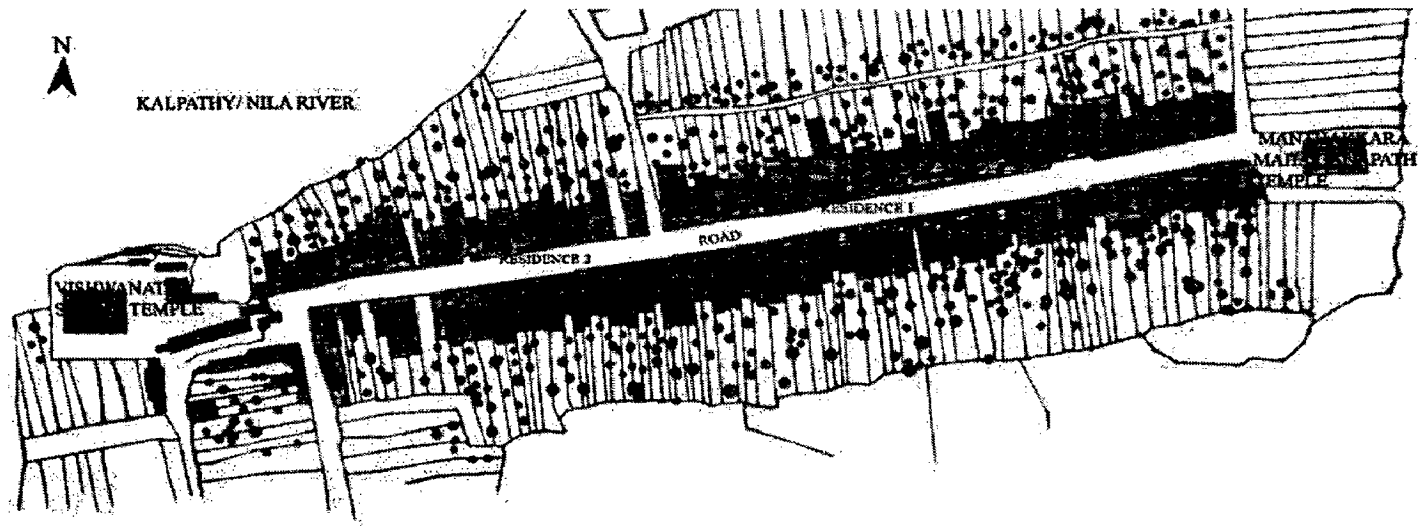


Figure 5.16- Street plan of New Kalpathy agraharam

The row houses in Kalpathy agraharam follow a grid pattern, and built along the cardinal directions. The houses are arranged in two rows facing each other with shared walls and roofs with a slope of 35 –40 degree. Most of the houses are narrow with rectilinear plan, width ranging from 3m to

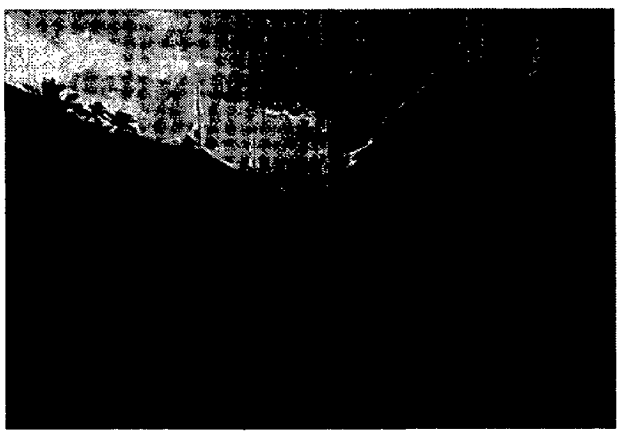


Figure 5.17 View of Kalpathy agraharam from west

10m, and most follow a typical plan. There is a clear demarcation of public, semi –public and private areas. All the buildings in this agraharam were initially thatched houses with timber or mud walls (which contained jaggery and other ingredients). A little later the walls were of hand made bricks, and the roofs were replaced with *odu*(tiles). Subsequently some of these were renovated; replacing the tiled sloped roof with flat/ sloped concrete roof.

What is essentially found in an agraharam is called *onaamkettu*.

The type of rooms found are:

-*Thinna*(like a sit-out)

-*Nezhi*, and by it is a *machu* and *ara*(a store room)

-*Koodam*(where everyone gathers and the most used for circulation).

-There is normally also a lane which has a connection to all the rooms.

-*Adukala*(kitchen)

The affluent could have also the *rendaamkettu*, that is:

-Work area

-Bathroom

-A cow shed

-The rear yard is called the *kollai,* which is where the bathroom will be

-*Thodi* (which is at last of 5 –10 cents)

-Service lane

5.6.1 Household and Visual survey

Analysis of the surveyed data of residences in New Kalpathy Agraharam shows the following results.

Household Data

a) Earning population

The total response average reveals that about 50% of the population are earning.

b) Occupation of Head of Household

Major population of this agraharam comprises of retired people (fig 5.18).

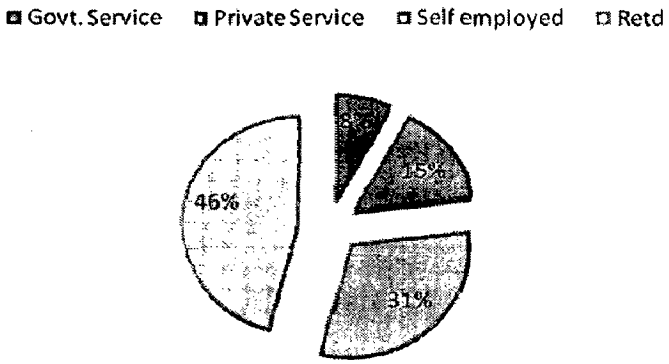


Figure 5.18- Graph showing occupation of head of household in New Kalpathy Agraharam

c) Household income

About 84% ie. the majority of the households in the agraharam are having total monthly income of less than 15,000 rupees/month and only 16% of the households have a monthly income between Rs. 15,000-50,000 (fig 5.19).

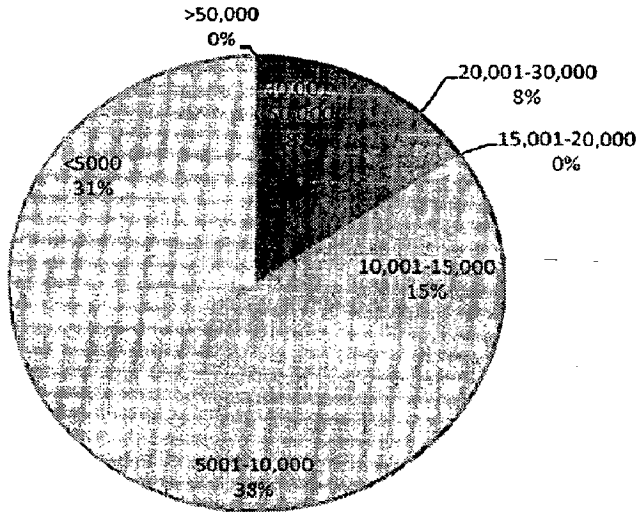


Figure 5.19-graph showing total income of household in New Kalpathy Agraharam

Particulars of residence

d) Tenure

Ownership is the predominant form of tenure (85%) and only 15% of housholds live as tenants (fig 5.20).

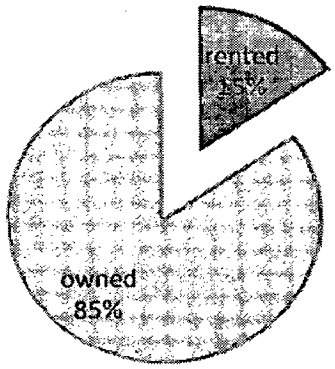


Figure 5.20-graph showing tenure of house in New Kalpathy Agraharam

e) Type of Residence

From the visual survey it is found that majority of residences in this agraharam are double storeyed (fig 5.21).

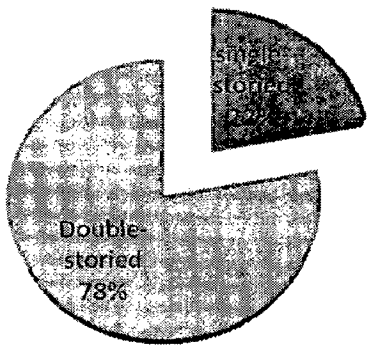


Figure 5.21-graph showing type of residence in New Kalpathy agraharam

f) Building materials

Flooring Material

Major percent of houses used cement flooring with oxide finish and timber false ceiling, which is easily available and thermally comfortable (fig 5.22).

Wall Masonry

69% of houses used brick masonry, which is easily available in that area. 23% of houses which used mud were old structures, which had only mud as an option those days. 8% of houses which used laterite are new constructions (fig 5.22).

Roofing Material

Majority of the houses used mangalore pattern tiles for roofing. New constructions used RCC for roofing (fig 5.22).

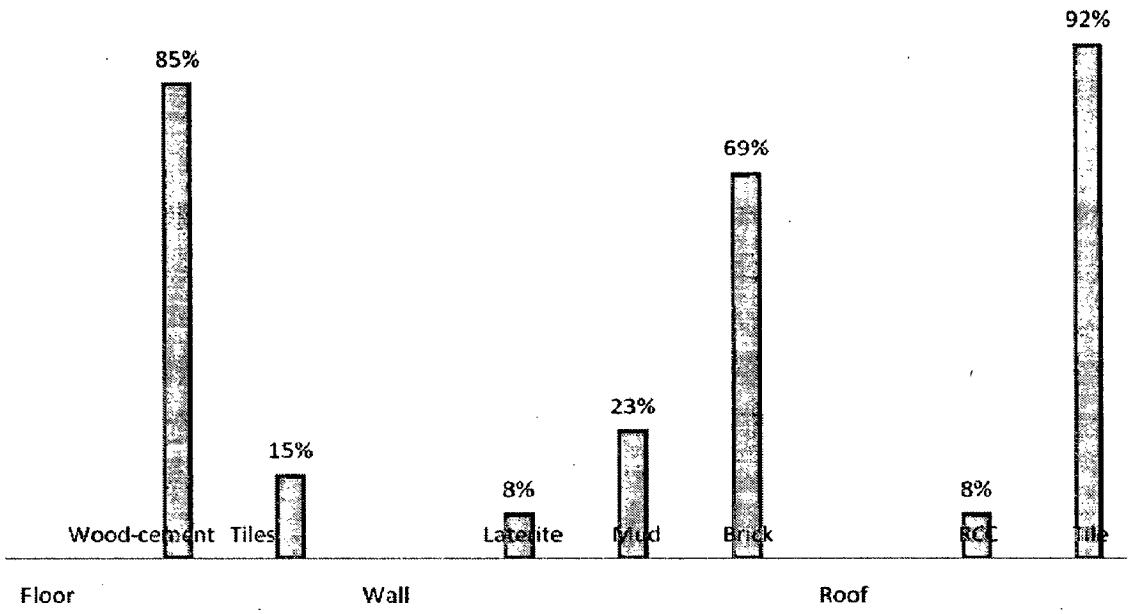


Figure 5.22-graph showing building materials used in house of New Kalpathy agraharam

g) Number of habitable rooms in residences

Most of the residences in this agraharam have 3-4 habitable rooms ie rooms excluding toilet, kitchen, store (fig 5.23).

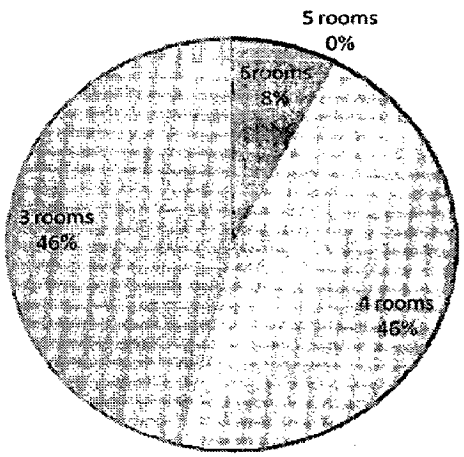


Figure 5.23-graph showing number of habitable rooms in houses of New Kalpathy agraharam

h) Floor area (in sqm)

From visual survey it is observed that greater part of residences in this agraharam are of area 101-150sqm and then of 51-100sqm. So majority of houses come under the category of 51-150sqm of floor area, ie. 73% of residences (fig 5.24).

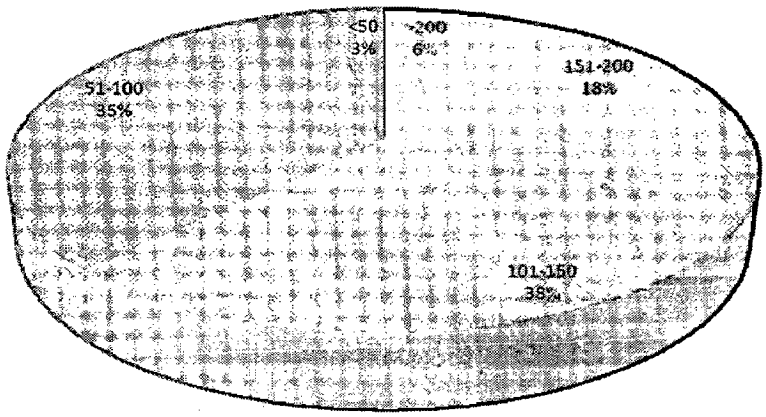


Figure 5.24-graph showing floor area of houses in New Kalpathy agraharam

i) Plot area (in sqm)

From the visual survey it is revealed that most of the residences are in plots of area 200-300sqm and then of 300-500sqm (fig 5.25).

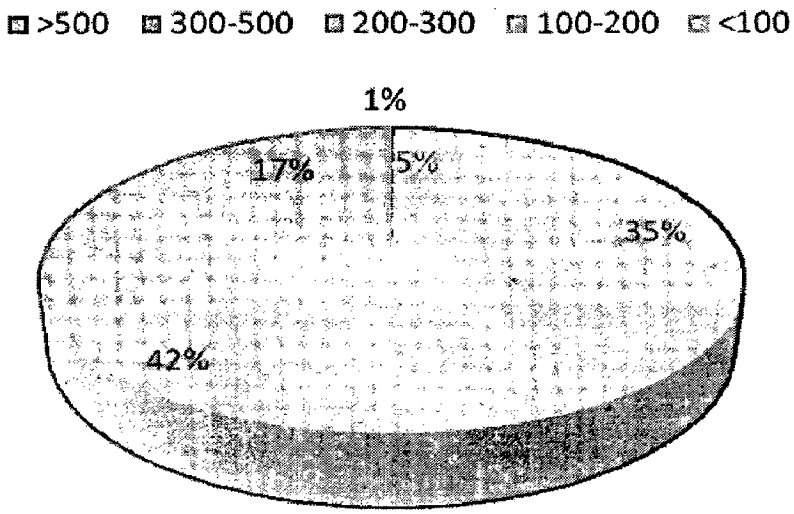


Figure 5.25-graph showing plot area of houses in New Kalpathy agraharam

j) Orientation of residence

100% of residences in this agraharam are oriented along N-S major axis. With its smaller wall areas or exposed walls are facing north and south, the residences are found to be cooler. It is because the direct solar radiation will not fall on any of the walls, since the west and east walls are shared.

k) Adequacy of the existing dwellings

100% of people responded that the areas of agraharam dwellings are catering to the present needs of living.

Thermal Comfort conditions in the agraharam

l) Residence cool and comfortable without fan and cooler

100% of the people responded that residence is cool and comfortable without fan and cooler. Majority of the responses make it clear that it is more comfortable in part of the house for 3-6 months. These areas are mostly the rooms with ceiling, which are mainly of wood and others of hurdi blocks. The rooms with ceiling were found cool and comfortable for most of the time throughout the year. These are good insulators (fig 5.26).

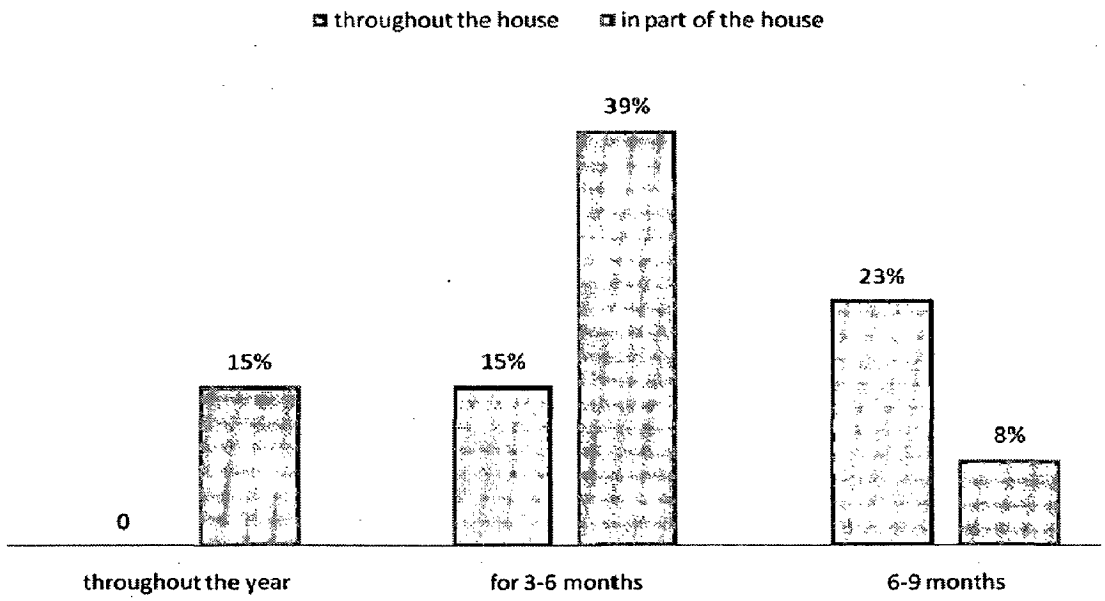


Figure 5.26-graph showing the percentage of residence cool and comfortable and its duration in New Kalpathy Agraharam

m) Floor cool during day time and night time

92% of the responses specified that GF is cooler during daytime. During night time GF was found cooler by 62% of the respondents and 30% found FF cooler during night time. So from these responses it is clear that GF is cooler both during day time and night time (fig 5.27).

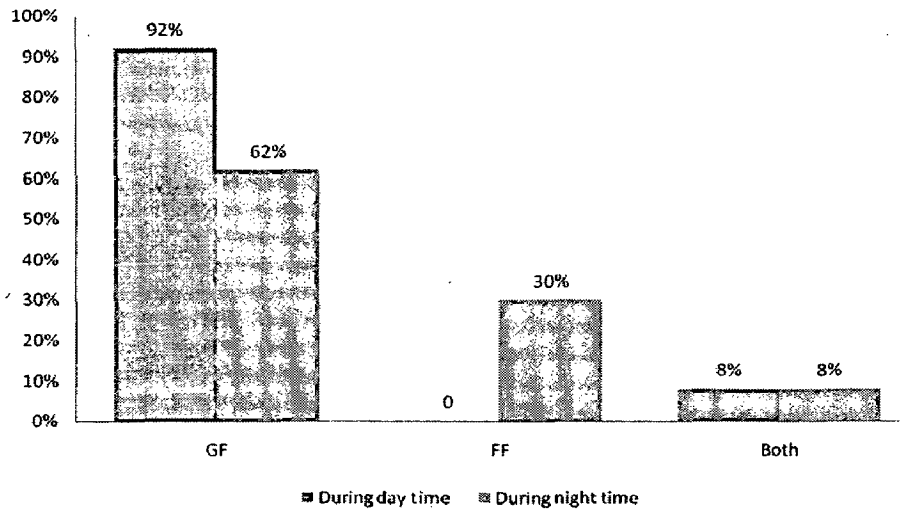


Figure 5.27-graph showing floor which is cool and comfortable during day time and night time of houses in New Kalpathy agraharam

n) Average duration of use of fan/cooler

The largest part of responses (46%) bring out the inference that fan/cooler is used for 6-9 months, for a duration of less than 12 hours. 30% of population responded that fan/cooler is used throughout the year for less than 12 hours ie. at night time because of mosquitoes (fig 5.28).

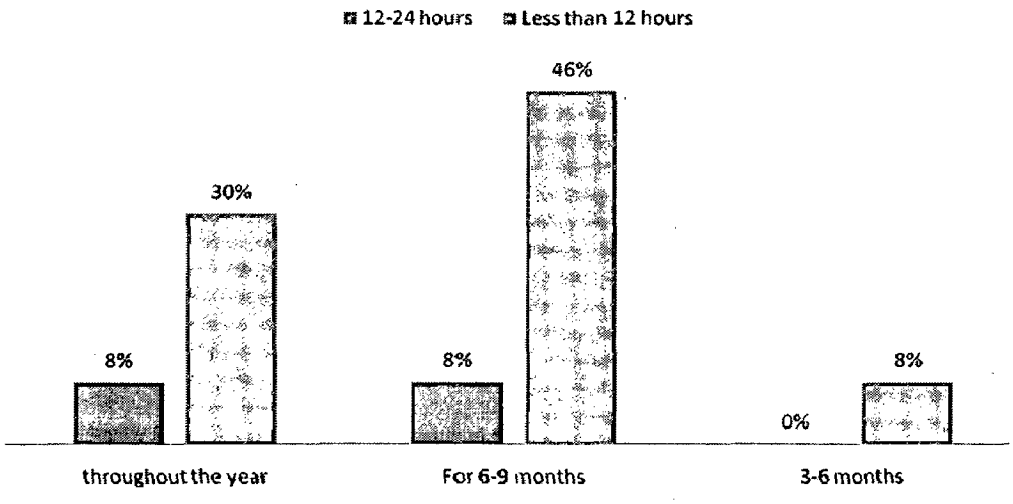


Figure 5.28-graph showing average duration of use of fan/cooler in houses of New Kalpathy agraharam

o) Use of artificial light during day time

54% of respondents are not using artificial light during day time. The rest of the houses are using artificial lights in store, toilet and other rooms with false ceiling, throughout the year. It is mainly required because these are row houses so windows can be provided only on the two exposed sides of the building (fig 5.29).

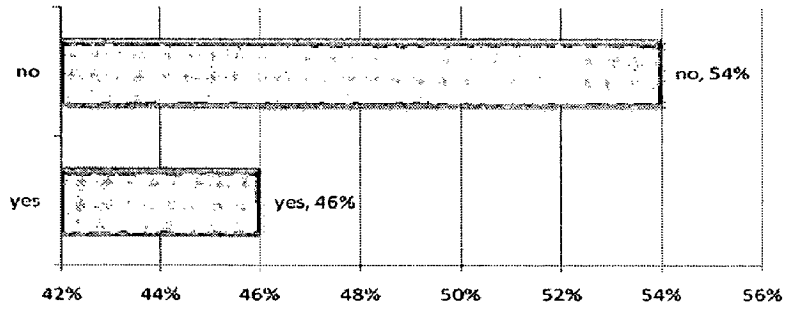


Figure 5.29-graph showing use of artificial light during daytime in houses of New Kalpathy agraharam

Electricity consumption

p) Electrical appliances used by the household

100% of the houses used electric light and fan, which are the necessary electrical appliances required for daily life.Majority of the houses have fridge, television and mixer/grinder, which are the common appliances found these days (fig 5.30).

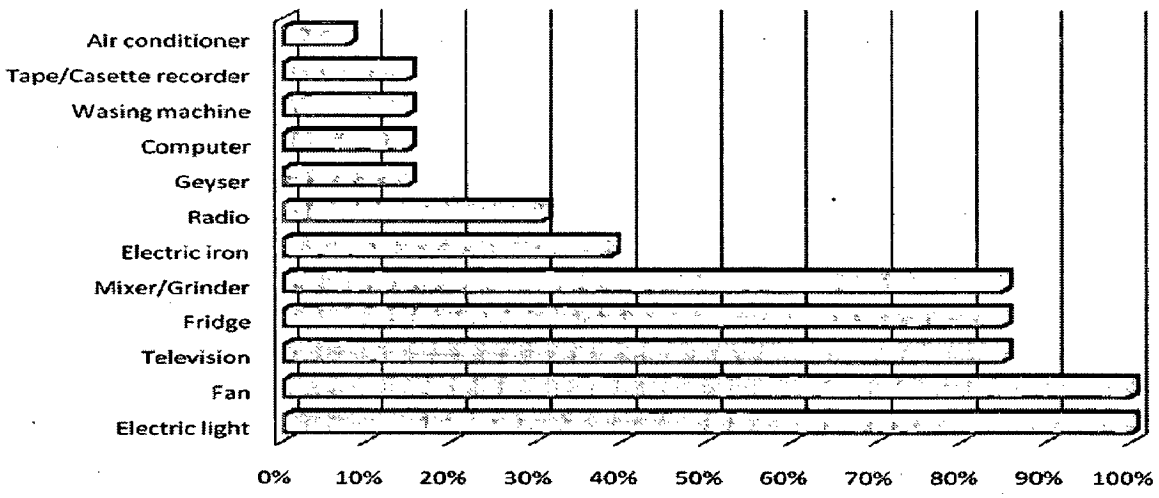


Figure 5.30-graph showing electrical appliances used by the household in New Kalpathy agraharam

q) Monthly electricity consumption (in kWh)

Majority of houses in agraharam uses 51-100 KWH of electricity every month (fig 5.31).

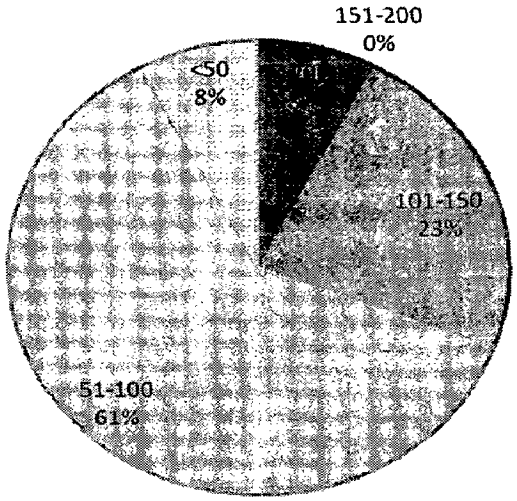


Figure 5.31-graph showing monthly electricity consumption in households of New Kalpathy agraharam

69% of the households responding to the questionnaire stated that they will not move out of agraharam even if oppourtunity arises (fig 5.32).

77% of the respondents reported that they live in the agraharam because they own their house here and 23% because of good location/ environment, out of which 15% are rented (fig 5.32).

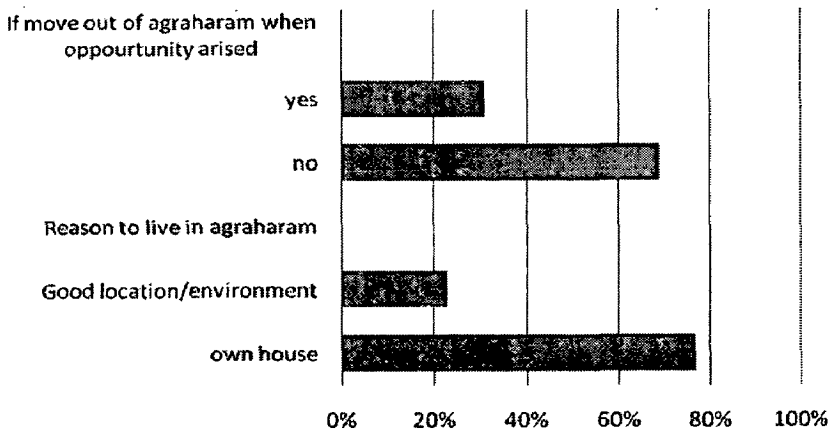


Figure 5.32- graph showing the percentage of people who like to move out of agraharam and reason to live in New Kalpathy agraharam

5.6.2 Residence 1

Residence-1 is double storied, in one block and with a courtyard.

ii. Architectural aspects

Building form and plan form

Total built up area of the residence is 205.3sqm and the plot area is 310.6 sqm (7.68 cents).This building has a rectilinear plan. Width and length of the house are 7.15m and 26.55m respectively. Rooms are arranged one after the other, with a passage connecting all the rooms. The residence is double-storied with attic space above. The building is having sloping roof. Courtyard and open space are present with in the building .The building has a rectilinear plan (fig 5.33).

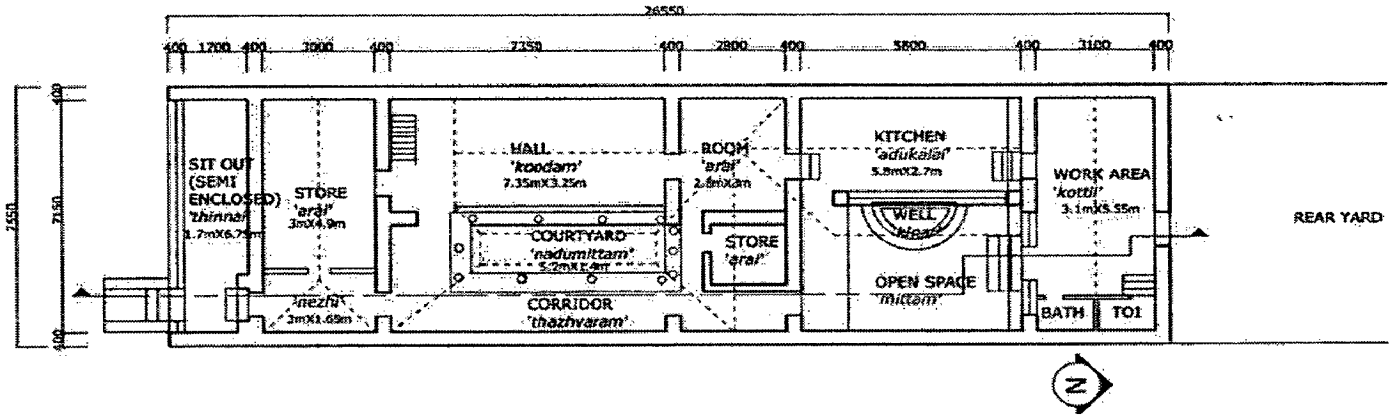


Figure 5.33-Plan of residence 1 in New Kalpathy Agraharam

Architectural elements

The whole building is covered with sloping roof. All longitudinal and cross walls are load bearing walls and wooden partition walls are also present. Floor is of cement and terracotta tiles.

Functionality of spaces

The spaces are divided as semi public and private areas. Semi public space include the semi enclosed *'thinnai'* and the next space in line, the buffer space *'nezhi'* and *'ara'* beside it. Following the semi public space are the private spaces. In private space, the main space is the hall or *'koodam,* the largest space in the house, which is multifunctional in use. Its location adjacent to kitchen is very important. Courtyard or *'nadumittam',* is

present adjoining the *'koodam,* which provided sufficient ventilation and day lighting to the *'koodam'*. Kitchen is provided towards the end of the building. Open space, *'mittam'*, is provided adjacent to the kitchen, which helps in ventilation of the kitchen. Well or *'kinar'* is provided near the kitchen for easiness. Toilets are provided at the end of the structure, which is ventilated through the external wall (fig 5.26).

iii. Construction and Materials use

The roof is of mangalore pattern tiles over wooden frame, ie. rafters and reapers. All longitudinal and cross load bearing walls are of brick masonry. Some of the partition walls are of wood. Flooring in ground floor is of cement with oxide finish and in first floor of terracotta tiles. The ceiling above some areas of first floor is of wood (fig 5.34).

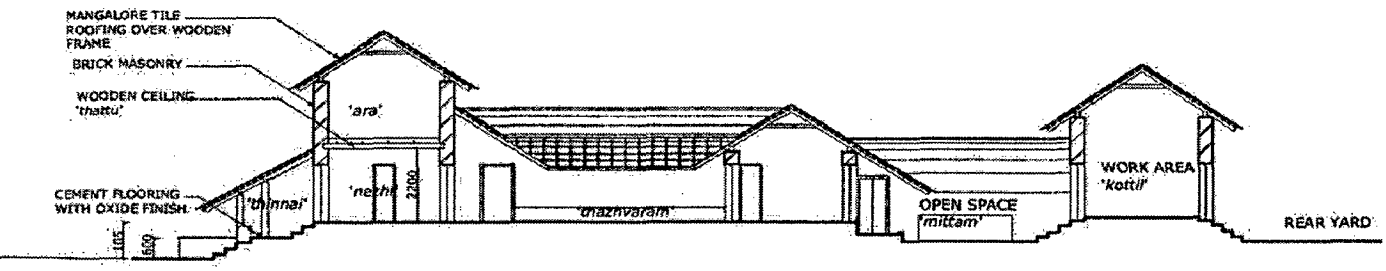


Figure 5.34-Longitudinal section of residence 1 in New Kalpathy Agraharam

Analysis of building design and planning for thermal comfort objectives

a) Provision of continuous and efficient ventilation

The courtyard, *'nadumittam'* near the *'koodam'* and the open space, *'mittam'* adjacent to the kitchen enhance ventilation throughout the building through courtyard effect. Most of the openings, mainly doors, are provided in a straight alignment, which in turn initiates continuous and efficient ventilation through tunnel effect. Local wind is from east in the evening time. It mainly flows through the road which is running east-west on the south side of the residence. The verandah in the south side of the residence traps wind and it ventilates the whole structure. Mangalore pattern tile roofing is permeable to air, through the gaps between the tiles, which help the hot air below the tiles to escape.

b) Protection from sun, rain and insects

Since the longitudinal side walls are shared and the front wall is protected by *'thinnai'*, there is no direct solar radiation through walls. The wood and tile sloped roof is the only

surface which is exposed to sun, but the heat is dissipated through openings provided on the wall by ventilation. Overhangs protect the structure from both sun and rain, and even draining off water is made easy with the slope. Semi enclosed '*thinnai*' on the south side protects the wall from direct sun's radiation and precipitation. Raised plinth prevents dampness. Narrow courtyard oriented in N-S longer axis, with roofs of large overhang, prevents direct sun entering the structure, for most of the day. Proper drainage provided from the courtyard to the exterior of the house, which in turn prevents dampness. Glass tiles are used in between roof tiles for day lighting inside the building at the same time not allowing sun's direct radiation. Narrow courtyard oriented in N-S longer axis, with roofs of large overhang, prevents direct sun entering the structure, for most of the time of the day.

c) Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings

External verandah in the form of *thinnai* in the south side protects the walls from sun's direct radiation and thus reducing heat gain. Raised plinth of 60 cm is provided, which reduce the reflected radiation from ground. Openings are on north and south walls and no windows on east and west walls, which reduces direct heat gain. Sloping roof with its slope and shape reduces heat gain. Wooden ceiling is provided over some spaces in ground floor. West side is shaded by the adjacent residential unit, by shared longitudinal side walls. Walls are painted white, in turn reflect the solar radiation falling on it and thus heat gain reduced. Clay tiles are used for roofing with medium heat storage capacity. These are permeable to air through the gaps between the tiles, which will help the hot air below the tiles to escape to outside air. Rate of cooling in the evenings maximised in the structure by taking maximum advantage of the evening winds.

Activity area analysis

Verandah, used during day time as an outdoor living space provided on the south side which is a semi enclosed space, thus shaded and with enough of ventilation by means of local winds. Another area which is used in the daytime, '*koodam*' is kept adjacent to courtyard, which in turn will be lit during daytime with diffused daylight. Ventilation is also enhanced in that area with the help of courtyard effect. Kitchen, which is also used mainly during day time, is sunlit from the open space adjacent to it, '*mittam*'. A well is provided in the *mittam,* which can easily be accessed from kitchen and toilets, where well

water is used mostly. Sleeping areas, in ground floor and first floor, are provided with wooden ceiling, which makes it cooler and more comfortable to sleep in. In first floor, the rooms have windows for ventilation (fig 5.35).

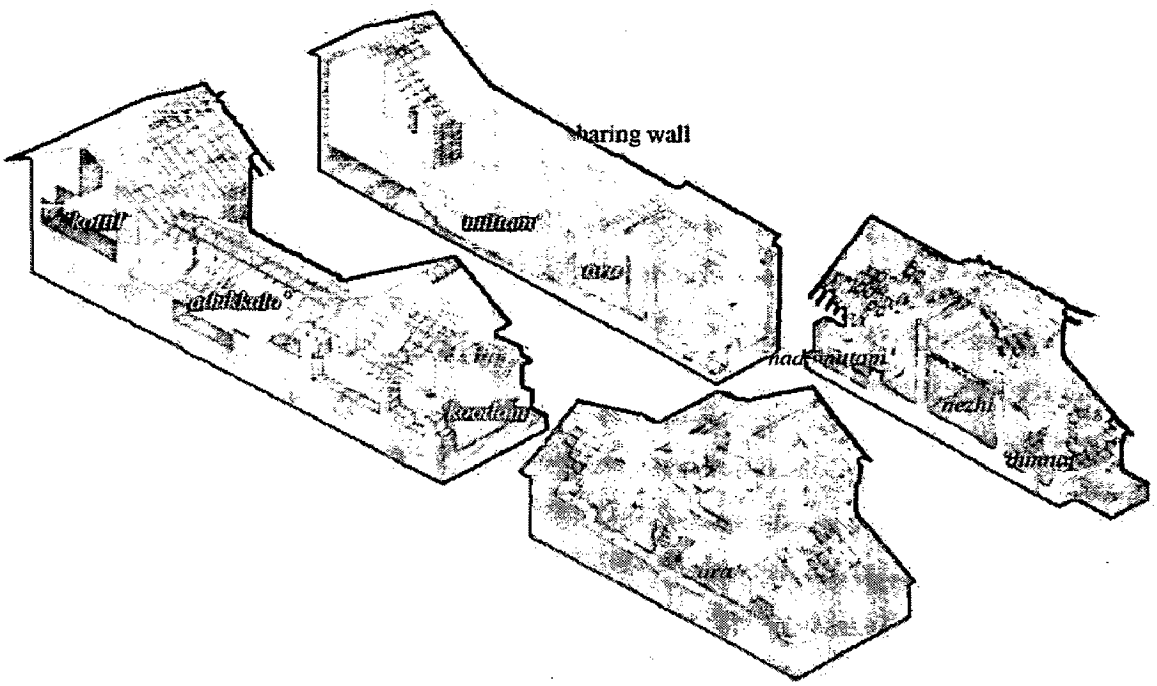


Figure 5.35- Exploded view of residence 1, New Kalpathy agraharam

Table 5.6-Chart showing objectives of thermal comfort and normative indicators of the architectural means to achieve these objectives in residence-1 of Kalpathy agraharam

Principles of building design ⇨ / **Architectural means to attain principles** ⇩	*Provision of continuous and efficient ventilation*	*Protection from sun, rain and insects*	*Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings*
Building form and layout	Rectilinear plan, with one courtyard and an open space	Exposed walls only on front and rear, shared side walls	
Orientation	N-S for whole agraharam, E-W for this residence- ventilation through	N-S for whole agraharam, so protection from sun	N-S for whole agraharam, less hest gain

	local wind		
Raised Plinth	60cm, better air movement	Prevents dampness	Prevents reradiated solar radiation
Openings	Provided in straight alignment		
Shading		Sloping roof & adjacent buildings as shared side walls	Sloping roofs with wide overhangs
Wide Verandahs		In the form of *thinnai* prevents direct solar radiation	
Landscape		Shades only rear wall	
Roof Type		Sloping roof- easy drain off of water and shading from sun	Sloping roof-Slope and shape reduces heat gain
Wall Material			Thick brick walls of 40cm
Roof Material			Permeable clay tile roofing
Outdoor spaces	Thinnai or semi enclosed sit-out in front		
Physical phenomena	Courtyard effect and tunnel effect		
Fly screen		absent	
Other techniques			Shared side walls

5.6.3 Residence 2

Residence-2 is single storied, in one block and without courtyard.

ii. Architectural aspects

Building form and plan form

Total built up area of this house is 124sqm and the plot area is 445 sqm (11 cents).The building has a rectilinear plan. It is single storied with attic space above some spaces. Width and length of the house are 6.15m and 19.33m respectively. All the rooms in the building are arranged one behind the other Sloping roof is used for the entire structure (fig 5.36 & fig 5.37).

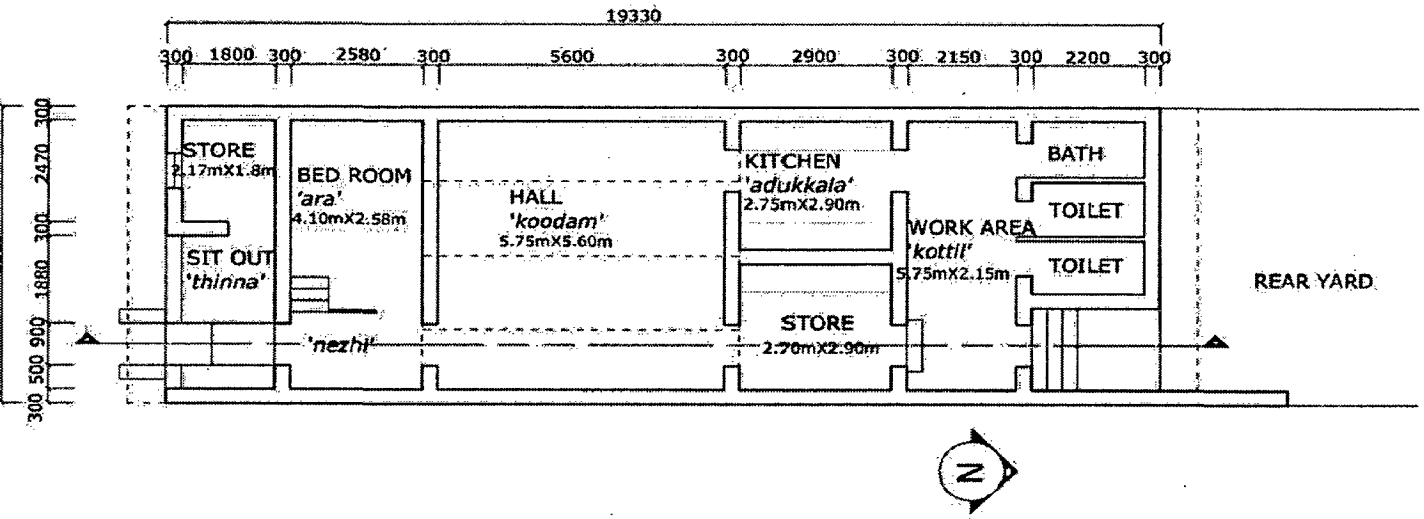


Figure 5.36-Ground floor plan of residence 2, in New Kalpathy Agraharam

Architectural elements

The entire structure is covered with sloping roof. Some parts of the building are covered by double roof. The building comprises of longitudinal and cross, load bearing walls and wooden partition wall. Floor is of cement with oxide finish and of terracotta tiles (fig 5.37).

Figure 5.37-Front view of residence-2, New Kalpathy agraharam

Functionality of spaces

Semi public, semi enclosed *'thinnai'* provided in front is used as an outdoor living area during day time. Next, the buffer space or ante room, *'ara'*, which is used as sleeping space at times. The largest central space is the hall or *'koodam'*. This is used as multifunctional space. Activities such as dining and living during day time and sleeping at night time take place in *'koodam'*. Religious rituals, domestic social functions and family gatherings happen in *'koodam'*. Kitchen is next in line. Its adjacency with *'koodam'* makes it more efficient. Toilets are provided at the end of the structure. One wall of it is external which provides ventilation to the toilets

iii. Construction and Materials use

The roof is of mangalore pattern tile over wooden frame, ie. rafters and reapers. The false ceiling is with hollow terracotta tiles over wooden frame. All the load bearing walls are of brick masonry and some partition walls are of wood. Floor is of cement with oxide finish and of terracotta tiles (fig 5.38).

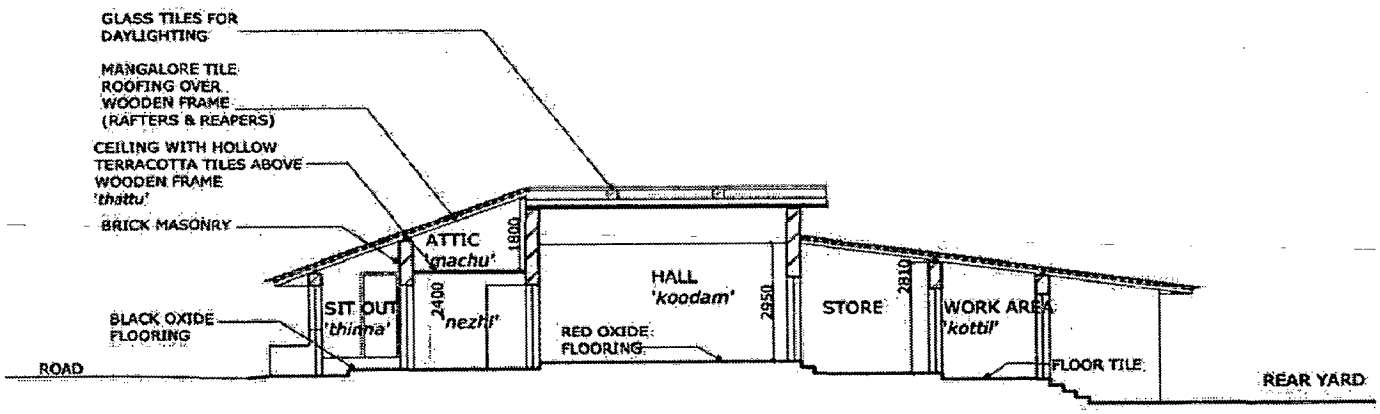


Figure 5.38-Longitudinal section of residence 2, in New Kalpathy Agraharam

Analysis of building design and planning for thermal comfort objectives

a) Provision of continuous and efficient ventilation

All the doors from front to back are provided in a straight alignment, which causes ventilation throughout the building through tunnel effect. Local wind is from east in the evening time. It mainly flows through the road which is running east-west on the south side of the residence. The verandah in the south side of the residence traps wind and it ventilates the whole structure.

b) Protection from sun, rain and insects

Since the longitudinal side walls are shared and the front wall is protected by *'thinnai'*, there is no direct solar radiation through walls. The wood and tile sloped roof is the only surface which is exposed to sun, but the heat is dissipated through openings provided on the wall by ventilation. Overhangs protect the structure from both sun and rain, and even draining off water is made easy with the slope. Semi enclosed verandah on the south side protects the wall from direct sun's radiation and precipitation.

c) Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings

External verandah in the south side protects the walls from sun's direct radiation and thus reduces heat gain. Openings are only on north and south walls. It reduces direct heat gain. Shared longitudinal side walls of row house shades the west wall from direct sun's radiation. Sloping roof with its slope and shape reduces heat gain. Layer of air in the attic space, above *edanazhi* and *ara*, acts as an insulating air to prevent heat gain. Thus the area below attic space remains cool and comfortable year round.

Activity area analysis

Sit out or *'thinnai'* on the south side, ie. in the front of house is semi enclosed and thus well lit during daytime and ventilated with the help of local winds. Hall or *'koodam'* which is generally used in the daytime is provided with natural day lighting through glass tiles provided in between clay tiles. This hall is also used for sleeping at night. *'Arai'* which is also used now for sleeping is having ceiling of clay tiles below main roof, thus making the space below cool and comfortable for sleeping. Bathroom and toilets are provided on the north end, which is at the back of the residence. During day time, it can be used without any artificial lights.

Table 5.7-Chart showing objectives of thermal comfort and normative indicators of the architectural means to achieve these objectives in residence-2 of Kalpathy agraharam

Principles of building design ⇨ **Architectural means to attain principles** ⇩	*Provision of continuous and efficient ventilation*	*Protection from sun, rain and insects*	*Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings*
Building form and layout	Rectilinear plan, rooms arranged one behind the other	Exposed walls only on front and rear, shared side walls	
Orientation	N-S for whole agraharam, E-W for this residence-ventilation through local wind	N-S for whole agraharam, so protection from sun	N-S for whole agraharam, less hest gain
Raised Plinth	absent		
Openings	Provided in straight alignment		
Shading		Sloping roof & adjacent buildings-shared side walls	Sloping roofs with wide overhangs
Wide Verandahs		In the form of thinna in front-Prevents direct solar radiation	
Landscape		Far from rear wall, so no shading	
Roof Type		Sloping roof- easy drain off of water and shading from sun	Sloping roof-Slope and shape reduces heat gain

Wall Material			Brick masonry-locally available
Roof Material			Permeable clay tile roofing
Outdoor spaces	Thinnai or semi enclosed sit-out in front		
Physical phenomena	tunnel effect- through straight aligned openings		
Fly screen		absent	
Other techniques			Double roof construction, shared side walls

5.6.4 Comparison of thermal performance of traditional agraharam and modern building of same locality

Temperature difference of outside and inside in a traditional row house in New Kalpathy agraharam was found to be 6°C but that of modern detached concrete house, in the same locality, was just 1°C (table 5.8). This makes it clear that traditional row house is more cool and comfortable than modern RCC house.

Table 5.8-chart showing comparison of thermal performance of traditional agraharam and modern building of same locality in Kalpathy agraharam

Residence	Residence 2- Traditional row house	Modern house (detached)
Time & Date	2pm, 24-01-2010	5.15pm, 24-01-2010
Outside temperature	37°C	33°C
Inside temperature	31°C	32°C
Temperature difference	6°C	1°C

5.7 KIZHAKKENCHERRY GRAMAM (ROW HOUSING-2)

Location- Kizhakkencherry (30 km from Palakkad)

District- Palakkad (Central Kerala-midland)

There are 49 row houses in Kizhakkencherry agraharam. Total population of this agraharam is about 270. Net dwelling density of this agraharam is 17 dwelling units per hectare and gross dwelling density is 15 dwelling units per hectare (fig 5.30). The total length of this agraharam is about 210m.

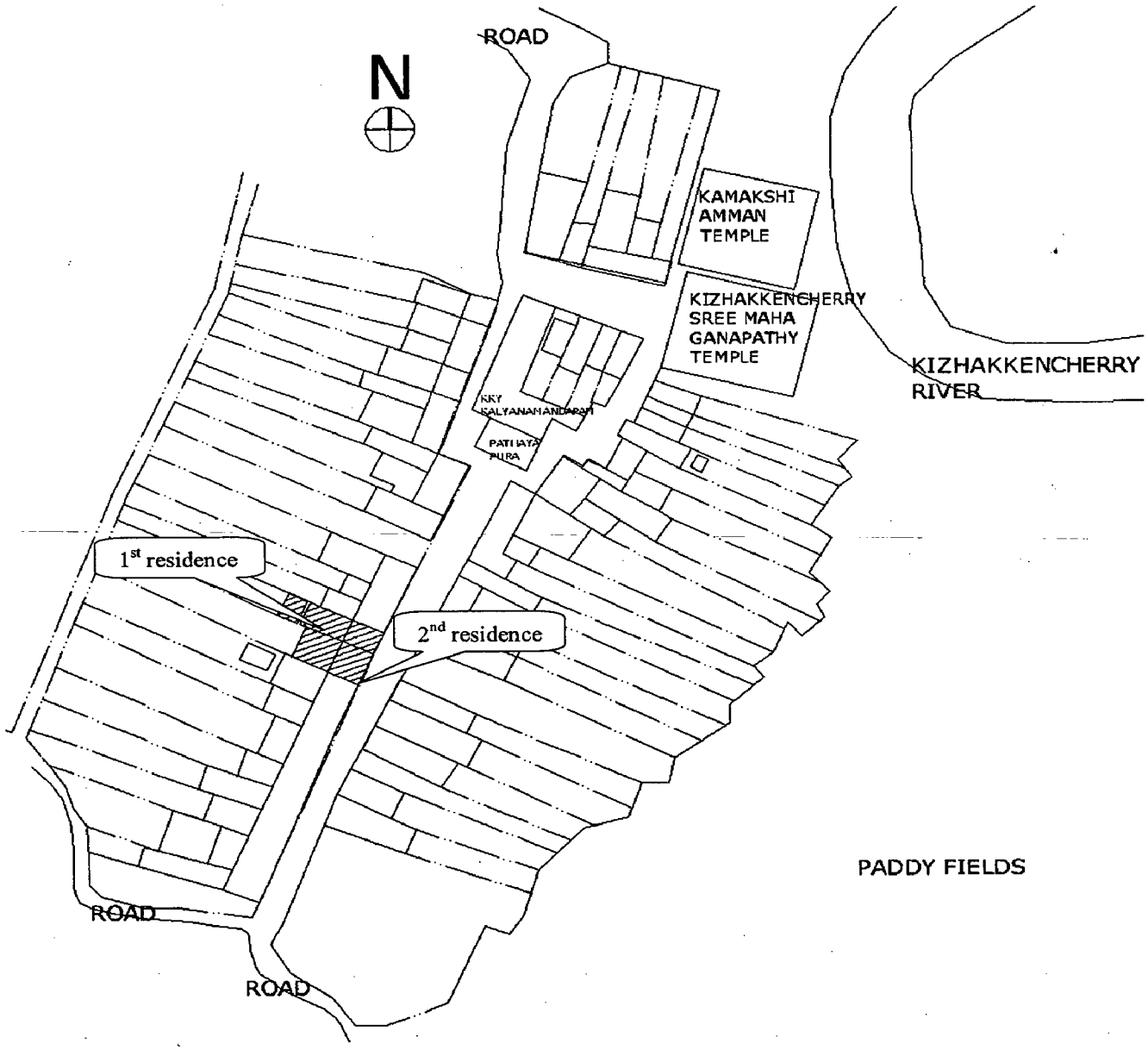


Figure 5.39-Site layout of Kizhakkencherry agraharam

i. Planning aspects

Row houses are provided on both sides of the street with two temples in between (Kizhakkencherry Sree Maha Ganapathy temple and Kamakshi Amman temple) and in the middle of this settlement is the grain store and marriage hall. Street is running in north south direction. Most of the row houses are having shorter walls facing east-west direction and some are also facing south. This type of settlement growth is mainly seen near water body. Here in this case it is Kizhakkencherry river, which is flowing through the north east side of the settlement. Wind direction is from east to west (fig 5.39 & fig 5.40).

Figure 5.40-View of Kizhakkencherry agraharam from south

5.7.1 Household and visual survey responses

Analysis of the surveyed data of residences in Kizhakkencherry Agraharam shows the following results.

Household data

a) Earning population

The total response average reveals that about 50% of the population are earning.

b) Occupation of Head of Household

Majority of head of households are retired people. Next to it is private service and self employed (fig 5.41).

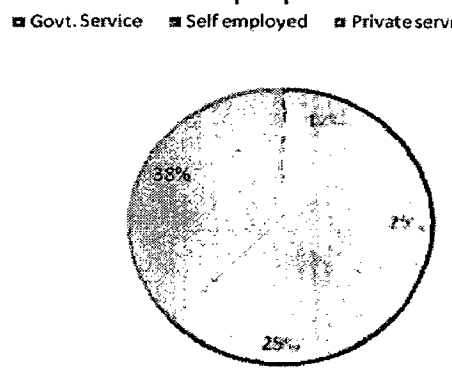


Figure 5.41-Graph showing occupation of head of household in Kizhakkencherry Agraharam

c) Total income of household

50% of the households have a monthly income of less than 10,000 Rs./month and the other half have a monthly income above 15,000 Rs./month (fig 5.42).

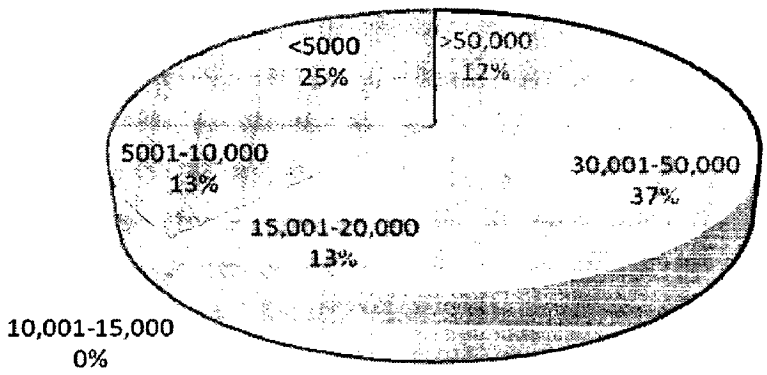


Figure 5.42-graph showing total income of household in Kizhakkencherry Agraharam

Particulars of residence

d) Tenure

About nine in ten houses in this agraharam are owned by the people staying in the agraharam (fig 5.43).

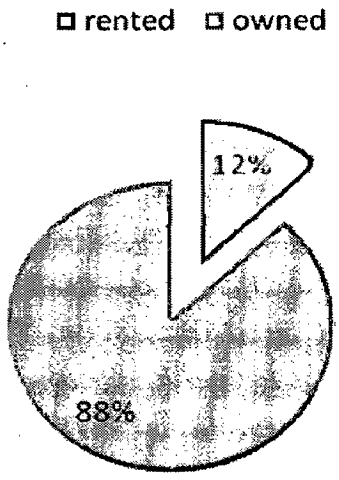


Figure 5.43-graph showing tenure of house in Kizhakkencherry Agraharam

e) Type of Residence

Visual survey revealed that more than nine of every ten houses in this agraharam are double storeyed structures (fig 5.44).

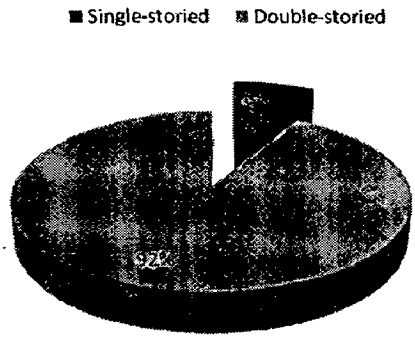


Figure 5.44-graph showing type of residence in Kizhakkencherry Agraharam

f) Building materials

Flooring Material

Three-quarter of the residences have used wood-cement for floor (fig 5.45).

Wall Masonry

Brick masonry is used by all houses for its wall(fig 5.45).

Roofing Material

About nine of every ten houses in the agraharam are having tiled roof.Rest of the houses are new with concrete roof (fig 5.45).

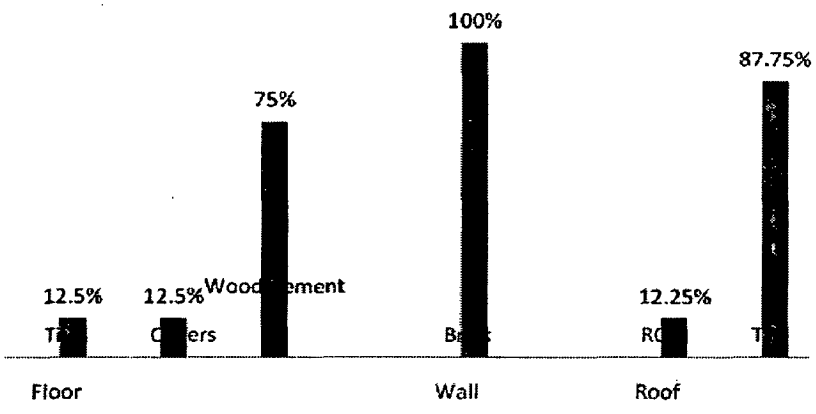


Figure 5.45-graph showing building materials used in house of Kizhakkencherry Agraharam

g) Number of habitable rooms in residences

Majority of the houses are having 4 habitable rooms (fig 5.46).

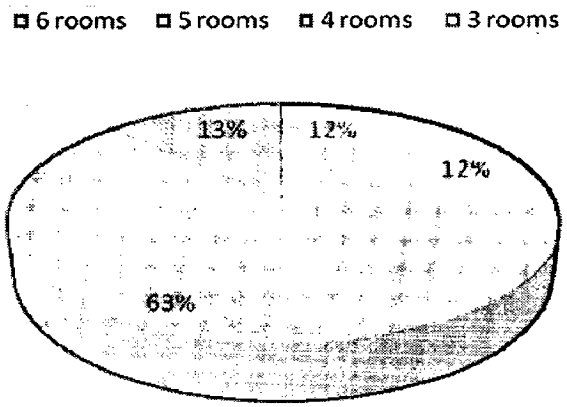


Figure 5.46-graph showing number of habitable rooms in houses of Kizhakkencherry Agraharam

h) Floor area (in sqm)

From the visual survey it was observed that equal number of houses measured floor area of 151-200sqm, >200 sqm, 101-150sqm and 51-100sqm. Out of these, more houses are under the category of 151-200sqm, ie. 27% of residences. No houses are having area less than 50 sqm. This reveals that most of the residences are medium sized or large houses in this agramaram (fig 5.47).

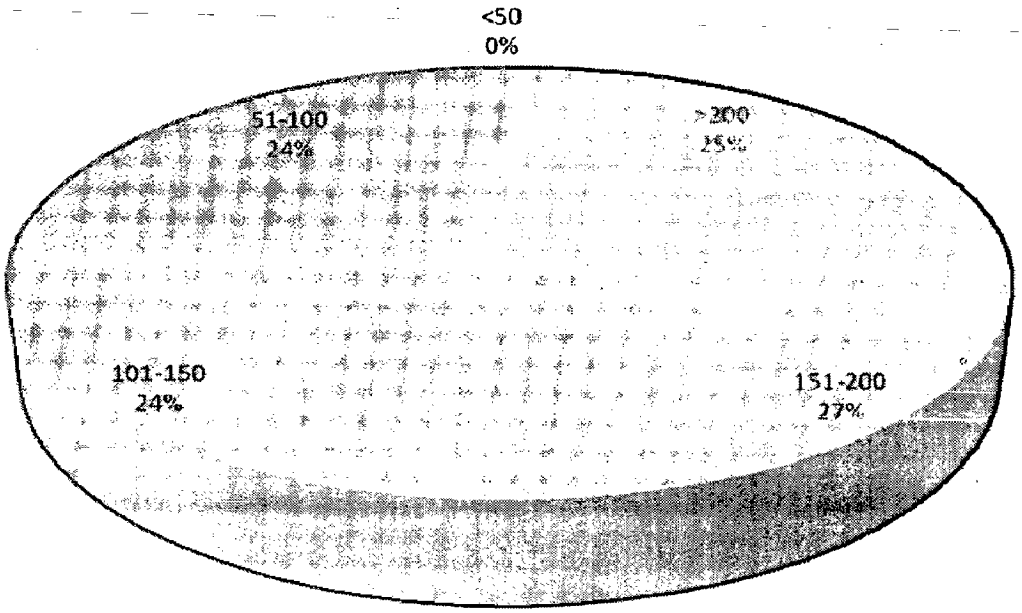


Figure 5.47-graph showing floor area of houses in Kizhakkencherry Agraharam

i) Plot area (in sqm)

The visual survey revealed that 90% of the residents are having plots of area more than 300 sqm and out of which one half is having an area more than 500sqm (fig 5.38).

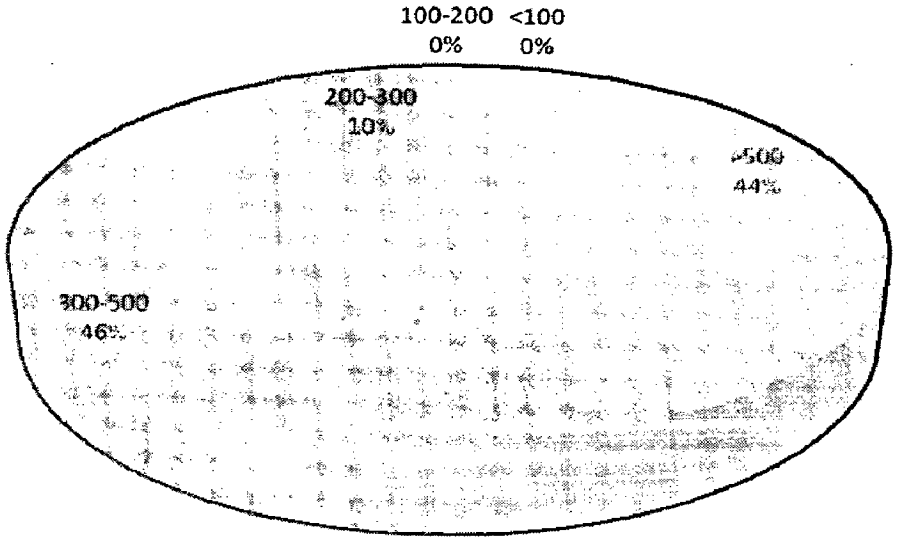


Figure 5.48-graph showing plot area of houses in Kizhakkencherry Agraharam

j) Orientation of residence

84% of the buildings have shorter walls facing east-west side and the rest 14% of residences have their shorter facing north-south direction.

k) Adequacy of the existing dwellings

Solid majority of the respondents revealed that spaces in the old structures are catering the present needs of living (fig 5.49).

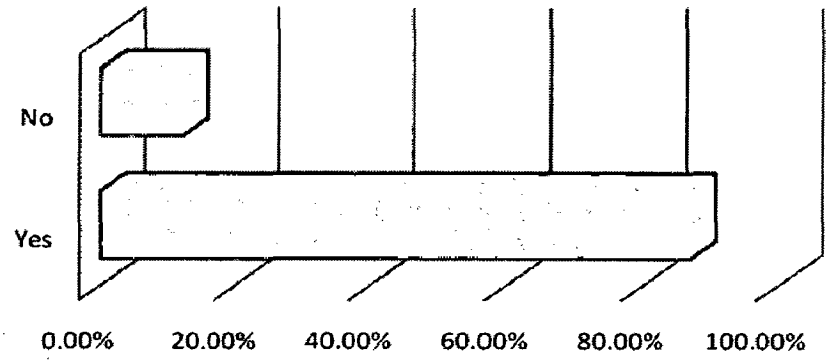


Figure 5.39-graph showing the adequacy of existing buildings

Thermal Comfort conditions in the agraharam

l) Residence cool and comfortable without fan and cooler

All respondents reported that residences are cool and comfortable without fan and cooler. More than three of every five residents stated that residences are cool and comfortable without fan and cooler for a period of 6-9 months out of it majority responded it is cool and comfortable in part of the house. These are the areas with wooden ceilings (fig 5.50).

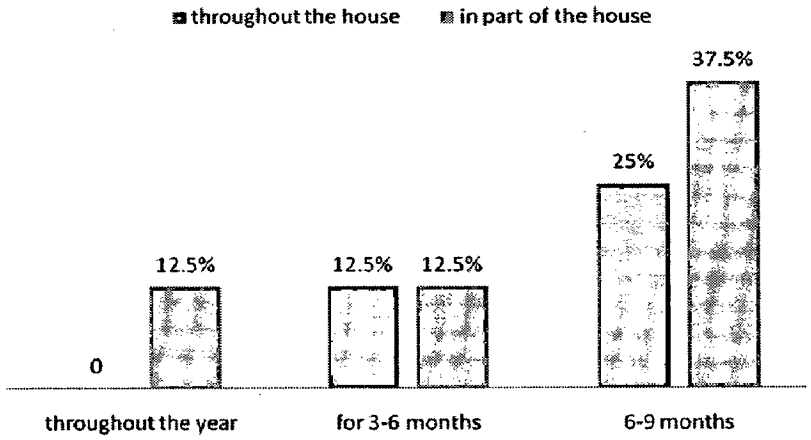


Figure 5.50-graph showing the percentage of residence cool and comfortable and its duration in Kizhakkencherry Agraharam

m) Floor cool during day time and night time

100% of the respondents stated that ground floor is cooler in the daytime. About three fourth of the respondents revealed that groundfloor itself is cooler in the night time too (fig 5.51).

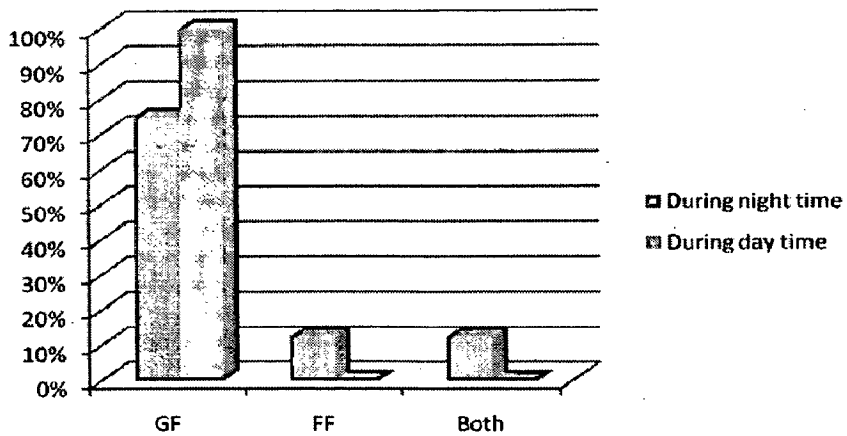


Figure 5.51-graph showing floor which is cool and comfortable during day time and night time of houses in Kizhakkencherry Agraharam

n) Average duration of use of fan/cooler

Majority of the respondents used fan/cooler throughout the year for less than 12 hours. They used fan throughout the year because of the mosquitos in the locality. One fourth of the respondents used fan/cooler for 6-9 months and next one fourth for 3-6 months, both for less than 12 hours (fig 5.52).

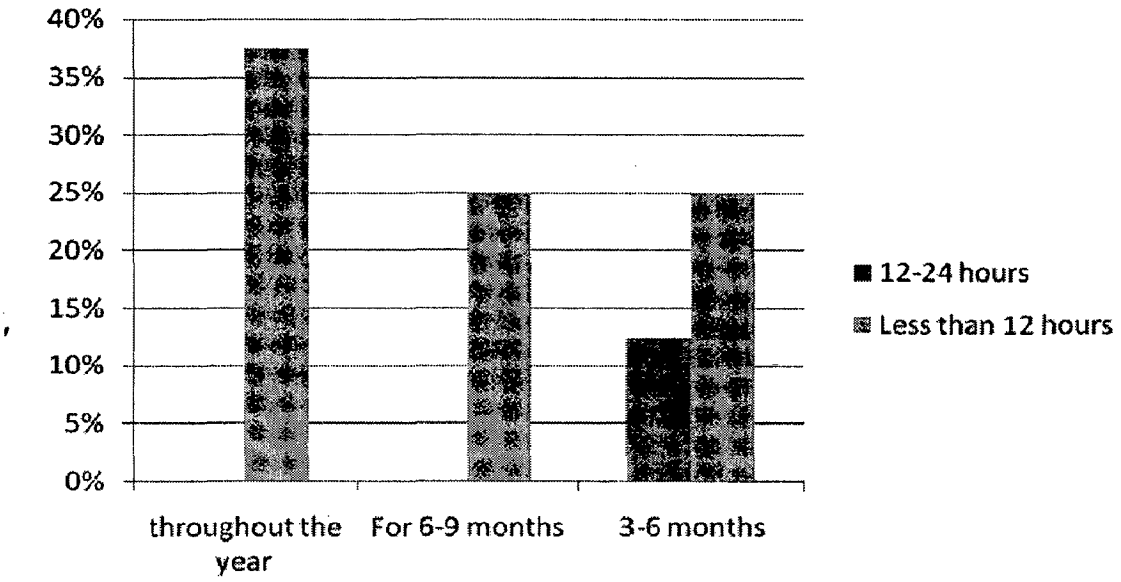


Figure 5.52-graph showing average duration of use of fan/cooler in houses of Kizhakkencherry Agraharam

o) Use of artificial light during day time

Three quarter of the residents are not using artificiall light during day time. One fourth of the residents use artificial light only in toilets or kitchen or in rooms with wooden ceiling (fig 5.53).

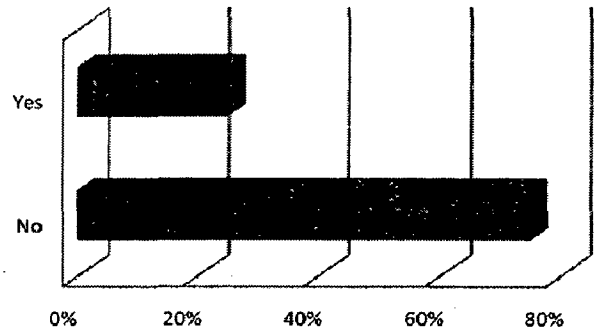


Figure 5.53-graph showing use of artificial light during daytime in houses of Kizhakkencherry Agraharam

Electricity consumption

p) Electrical appliances used by the household

Electric light and fan are the most common possessions used by all residences in the agraharam. Next common possession is TV and then Mixer/Grinder (fig 5.54).

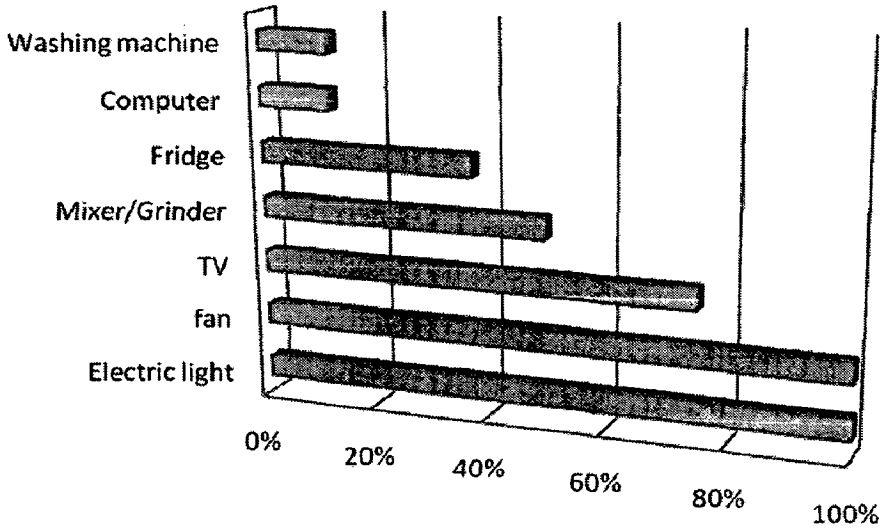


Figure 5.54-graph showing electrical appliances used by the household in Kizhakkencherry Agraharam

q) Monthly electricity consumption (in kWh)

Monthly electricity consumption of one half of the residences are 51-100 kWh. One-fourth of the houses consume 101-150 kWh of electricity in a month (fig 5.55).

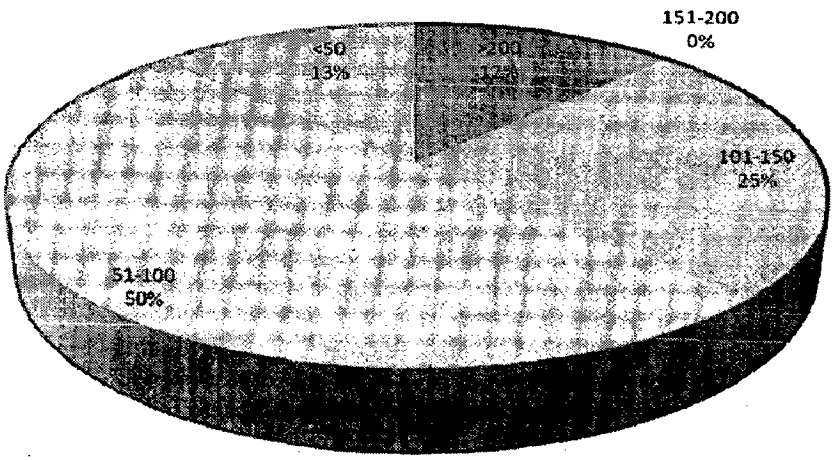


Figure 5.55-graph showing monthly electricity consumption in households of Kizhakkencherry Agraharam

Almost nine out of every ten residents in the agraharam revealed that they will not move out of agraharam even if oppourtunity arises (fig 5.56).

The total response average of the residents revealed that majority of the people live in agraharam since they own house in agraharam and rest because of its good location and environment (fig 5.56).

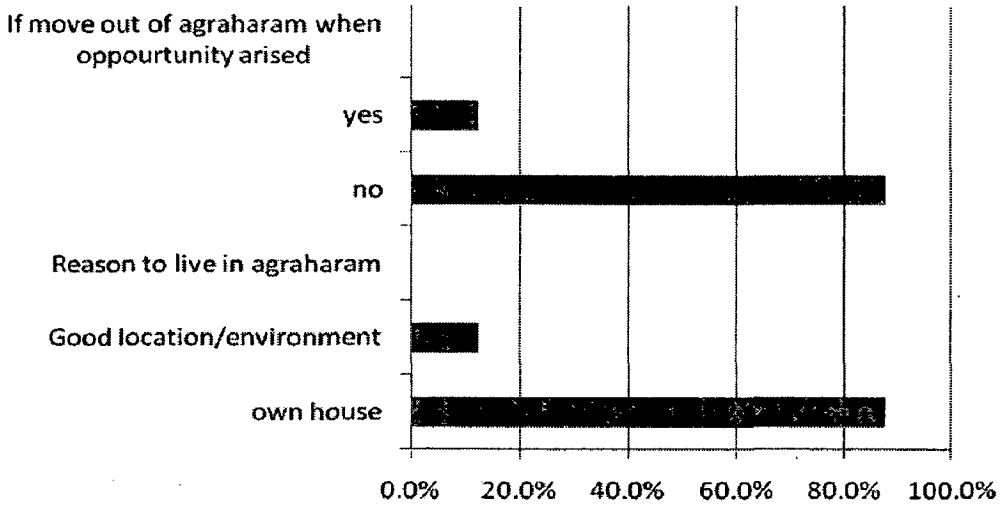


Figure 5.56-graph showing the percentage of people who like to move out of agraharam and reason to live in Kizhakkencherry Agraharam

5.7.2 Residence 1

Residence 1 comprises of two blocks and is double storeyed. An open space is provided between these two blocks.

ii. Architectural aspects

Building form and plan form

Total built up area of this residence is 209.17m² and plot area is 647.52m².The width and length of this house are 6.05m and 30.35m(including both blocks) respectively. The building is rectilinear in plan with two blocks, '*onaamkettu*' and '*randamkettu*'. Both blocks are having sloping roofs and an open space *'mittam'* in between the two blocks. *'Onaamkettu'* is double storeyed and above first floor, attic space is provided. '*Randamkettu*' is single storeyed (fig 5.57, fig 5.58, fig 5.59 & fig 5.61).

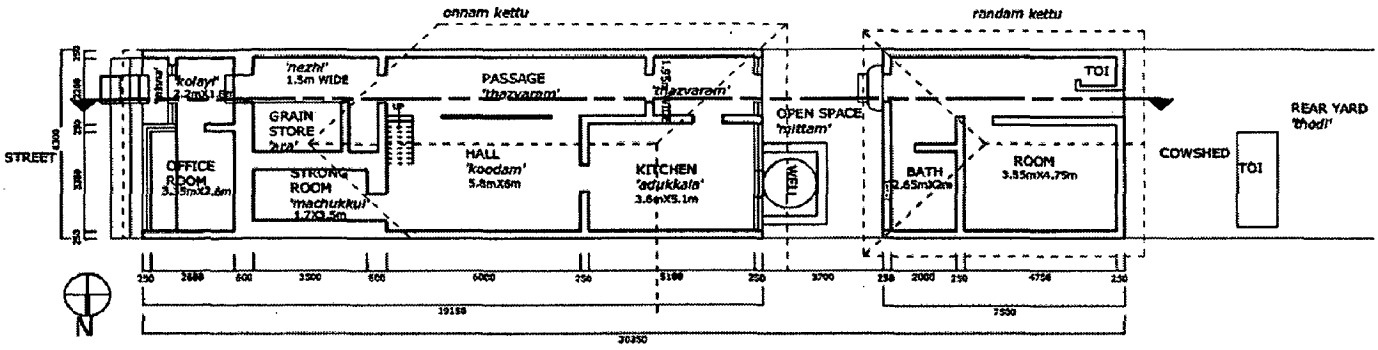


Figure 5.57 Ground floor plan of residence 1 in Kizhakkencherry Agraharam

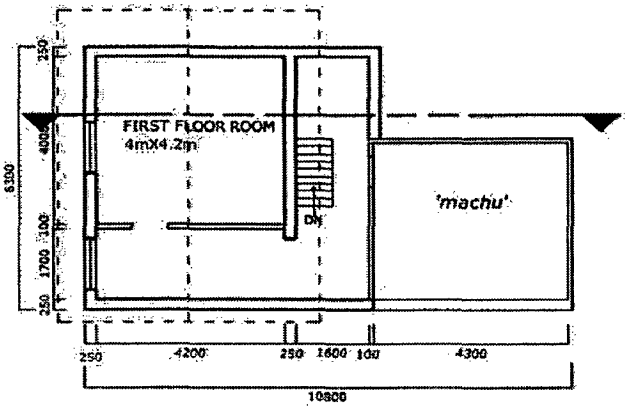


Figure 5.58 First floor plan of residence 1 in Kizhakkencherry Agraharam

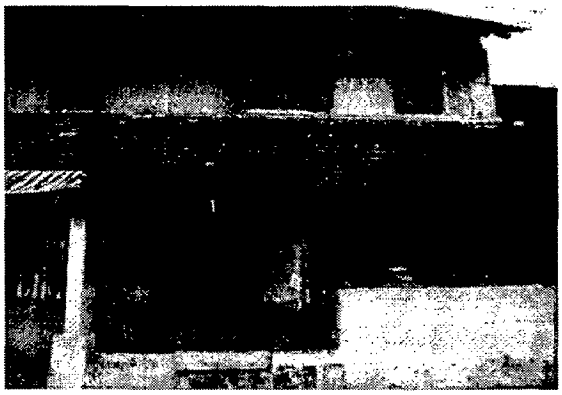


Figure 5.59 Front view of residence 1 in Kizhakkencherry Agraharam

Architectural elements

Raised plinth of 90cm is provided. Open space is provided between the two affluents of the structure. All the openings are maintained in straight alignment (fig 5.60). The entire structure is covered with sloping roof. Some parts of the building are covered by double roof. The building comprises of longitudinal and cross, load bearing walls and wooden partition wall (fig 5.61).

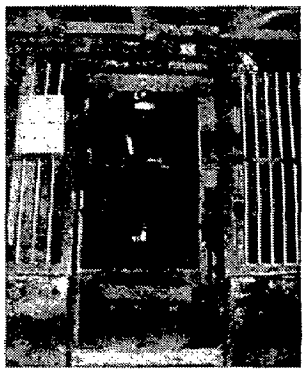


Figure 5.60-view showing openings in straight alignment

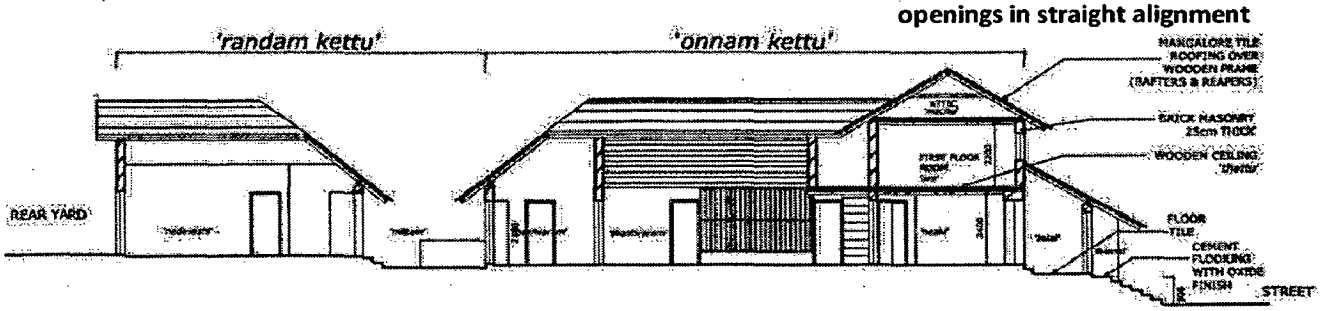


Figure 5.61- Longitudinal section of residence 1 in Kizhakkencherry Agraharam

Functionality of spaces

Room next to *thinnai* is used as an office room, which is a private space. Entry for this room is from *kolai*, which is the space next to *thinnai*. After *kolai*, a passage is provided starting adjacent to *ara*, to the kitchen. It is the main circulation space of the residence. *'Ara'* , which was used for storing grains, is used as sleeping space for one person. Next to it is the storage space for beds. A strong room type construction is done for *'machukkul'* for storing the valuables. *Koodam* is the space next to it which is a multi-functional space. It is used as living space, dining space and sleeping space at night. Next to it is the kitchen. The second block consists of bathroom, toilet and a room (fig 5.61).

iii. Construction and Materials use

The roof is of mangalore pattern tiles over wooden frame, ie. rafters and reapers. All longitudinal and cross load bearing walls are of brick masonry. Some of the partition walls are of wood. Flooring is of cement with oxide finish and terracotta tiles. The ceiling above some areas is of wood.

Analysis of building design and planning for thermal comfort objectives

a) Provision of continuous and efficient ventilation

'Mittam' or open space between *onnam kettu* and *randam kettu*, enhances ventilation throughout the building through stack effect. Doors are provided in a straight alignment, which in turn initiates continuous and efficient ventilation through tunnel effect. First floor areas have window on one wall for ventilating first floor areas. Local wind from the east is maximum utilized.

b) Protection from sun, rain and insects

Longitudinal shared side walls shades both north and south sides. Less number of openings is provided on the east and west walls and those are well shaded from sun and rain. Sloping roof with wide overhangs protect the structure from both sun and rain, and even rain drains off fast because of the slope. A small verandah and much lowered sloping roof on the east side protect the wall from direct solar radiation and precipitation. Walls near open space are also well shaded with pitched roof with wide overhangs. Raised plinth of the structure prevents dampness from entering the structure. Proper drainage is provided from kitchen and in between open space, to the exterior of the house and therefore preventing dampness entering the structure. Glass tiles are used in between

roof tiles for day lighting inside the building at the same time not allowing direct solar radiation.

c) Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings

Since the longitudinal side walls are shared and the front wall is protected by small external verandah, direct solar radiation is less through walls and thus heat gain is reduced. Minimum number of openings is provided in the east and even lesser openings on west wall and those openings are well shaded from sun, as a result heat gain through those walls are minimized. Raised plinth is provided which will cut down the heat reradiated from ground. Sloping roof with its slope and shape reduces heat gain. Wooden ceiling is provided for some spaces in ground floor and first floor. These areas remain cooler than other spaces of the structure. Double roof is provided above first floor. The air gap in between is acting as an insulating layer. This will keep the floor below cool. Terracotta tiles are used for roofing with medium heat storage capacity. These are permeable to air through the gaps between the tiles, which will help the hot air below the tiles to escape to outside. Rate of cooling in the evenings is maximised in the structure by taking maximum advantage of the evening winds from Kizhakkencherry river in the east side. Kitchen roof is in two levels, which helps the hot air to escape through it.

Activity area analysis

Thinnai is provided on the east side. This is used as outdoor space during daytime. It is well lit and shaded with lowered sloping roof and ventilated by the wind from east. Office room, used mainly at daytime, is provided in the east side, which does not require artificial light during daytime and is ventilated through the spaces between wooden battens used on the east side of the office room. *Machukkul*, which is the strong room, is well secured with thick walls and with no openings to the external wall. *Ara*, which was used for storing grains in the olden days, is used as sleeping area at present and is cool and comfortable due to the wooden ceiling above. *Koodam* which is generally used during daytime is well lit through the glass tiles in between roof tiles. It is used as dining space and is placed just next to kitchen. It is also used as sleeping space at night time. No external wall is provided for this room thus reducing heat in the room and the *machu* above makes it cool and comfortable and this also prevents heat gain from roof. Thus *koodam* is a multipurpose room in agraharams. Another sleeping space provided in this

house is an *ara* in the first floor, which is cool and comfortable due to the wooden ceiling above and ventilated through the window provided on the east exposed wall. Kitchen, *'Adukkala'* is provided towards the end of *onaamkettu*, with west wall as its external wall which helps in ventilation. It also has double level roof and particular types of roof tiles which helps the risen hot air to escape from the kitchen. Well is placed adjacent to the kitchen, which helps people working in kitchen to draw water directly from the kitchen. *'Randamkettu'* consists of a room, toilet and bath. All the rooms inside are having one side of its wall as external wall which helps daylight to enter and ventilate. No electrical lights are required during day time.

Table 5.9-Chart showing objectives of thermal comfort and normative indicators of the architectural means to achieve these objectives in residence-1 of Kizhakkencherry agraharam

Principles of building design ⇨ **Architectural means to attain principles** ⇩	*Provision of continuous and efficient ventilation*	*Protection from sun, rain and insects*	*Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings*
Building form and layout	Rectilinear plan, with two blocks and open in between blocks.	Exposed walls only on front and rear, shared side walls	
Orientation	E-W for whole agraharam, N-S for this residence-ventilation through local wind	E-W for whole agraharam	E-W for whole agraharam
Raised Plinth	90cm high, better air movement	Prevents dampness	Prevents reradiated solar radiation
Openings	Provided in straight alignment		
Shading		Sloping roof & adjacent buildings-	Sloping roofs with wide overhangs

		shared side walls	
Wide Verandahs		In the form of *thinna* in front- Prevents direct solar radiation	
Landscape		Only small plants present near rear wall, so no shading	
Roof Type		Sloping roof- easy drain off of water and shading from sun	Sloping roof-Slope and shape reduces heat gain
Wall Material			Brick masonry- locally available
Roof Material			Permeable clay tile roofing
Outdoor spaces	*Thinnai* in front		
Physical phenomena	Stack effect through open space in between and tunnel effect- through straight aligned openings		
Fly screen		absent	
Other techniques			Double roof construction, shared side walls

5.7.3 Residence 2

Residence 2 is of single block and double storeyed. It has a courtyard towards one of its edges.

ii. Architectural aspects

Building form and plan form

Total built up area of this residence is 203.83m² and plot area is 849.87m².The width and length of this house is 8m and 21.54m respectively. The building is rectilinear in plan and is double storeyed. The entire structure is covered with sloping roof. A courtyard is provided towards one edge of the rectilinear structure (fig 5.62, fig 5.63 & fig 5.64).

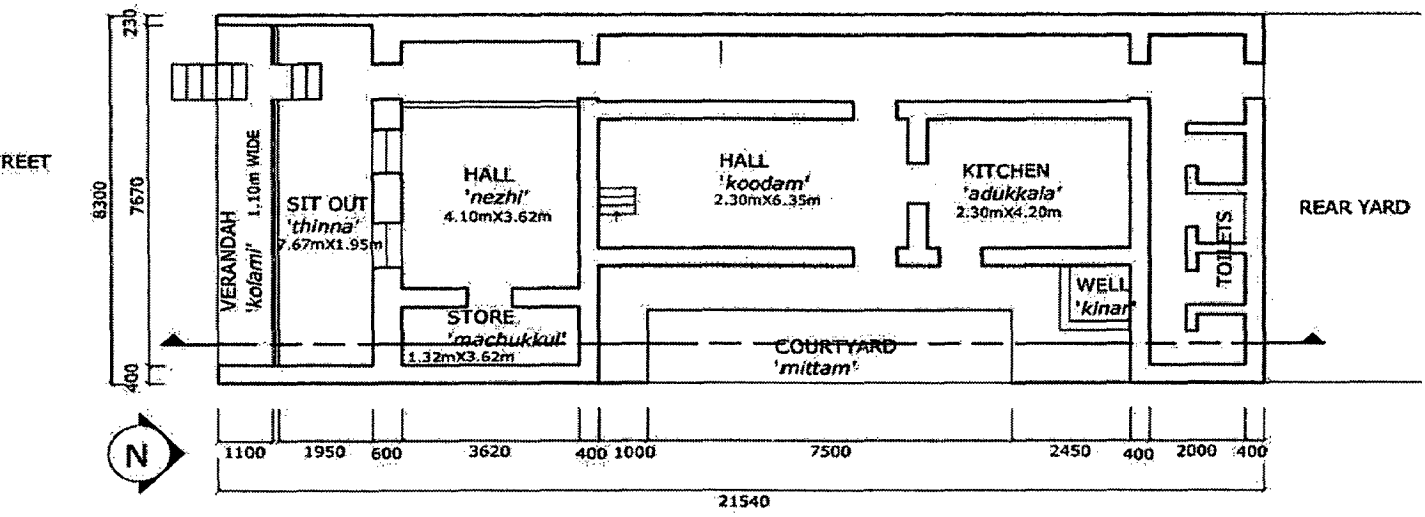


Figure 5.62 Ground floor plan of residence 2, in Kizhakkencherry Agraharam

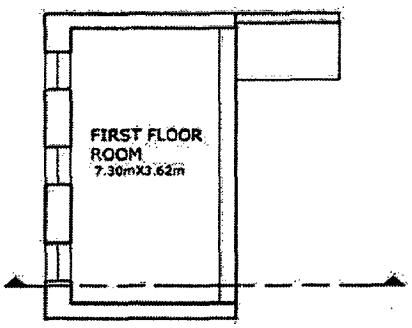


Figure 5.63 First floor plan of residence 2 in Kizhakkencherry Agraharam

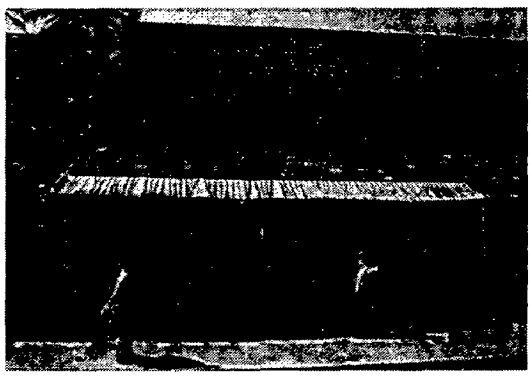


Figure 5.64 Front view of residence 2 in Kizhakkencherry Agraharam

Architectural elements

Raised plinth of 96cm is provided. An open verandah is provided in front of the residence. Doors are aligned straight, from entrance to the exit. At least two openings are provided to each habitable room. The entire structure is covered with sloping roof except the courtyard which is left open to sky. The building comprises of longitudinal and cross, load bearing walls and wooden partition wall. Rectangular courtyard is provided with dimension 1.63mX7.5m (fig 5.65).

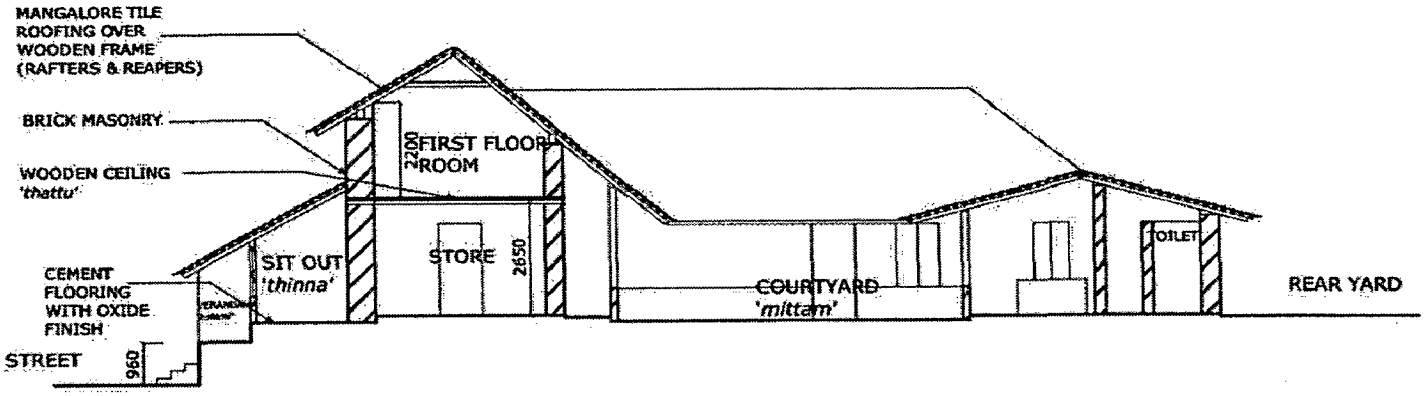


Figure 5.65-Longitudinal section of residence 2, in Kizhakkencherry Agraharam

Functionality of spaces

Next to the narrow verandah is a semi enclosed *thinnai,* the outdoor living space. *Nezhi* is the subsequent room, which is yet another living space. It is well lit through the windows. *Koodam* is next in the array. This is the space which is multi functional. Kitchen is next to it. Courtyard is adjacent to these two areas, which gives light and ventilation to the spaces. At the back, which is on the west side, is the bathroom area, which is least used. This will prevent heat entering the habitable rooms.

iii. Construction and Materials use

The roof is of mangalore pattern tiles over wooden frame, ie. rafters and reapers. All longitudinal and cross load bearing walls are of brick masonry of varying thickness. Some of the partition walls are of wood. Flooring is of cement with oxide finish. The ceiling above some areas is of wood.

Analysis of building design and planning for thermal comfort objectives

a) Provision of continuous and efficient ventilation

The courtyard, '*mittam*' near the *koodam*, enhances ventilation through courtyard effect. Doors are provided in straight alignment from first room to last room of the rectilinear structure, which in turn initiates continuous and efficient ventilation through tunnel effect. All the rooms are getting ventilation with the help of more than one opening provided for every room. First floor room is provided with three windows on the same wall, thus ensuring enough ventilation in the room. The local wind from east is maximum utilized.

b) Protection from sun, rain and insects

Mutual shading is provided to the residences, with sharing walls on north and south side. Minimum number of openings is provided on the east and west walls and those openings are well shaded from sun and are protected from rain. Sloping roof with large overhangs protects the structure from both sun and rain, and even rain drains off easily because of the slope. Verandah and semi enclosed '*thinnai*' on the east side protects the wall from direct solar radiation and precipitation. Raised plinth is provided which prevents dampness. Proper drainage is provided from the courtyard to the exterior of the house, thus preventing dampness entering the built structure. Glass tiles are used in between roof tiles for day light to enter inside the building and at the same time will not allow direct solar radiation.

c) Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings

Mutual shading is provided to the residences with sharing walls on north and south side and thus reducing heat gain. Minimum number of openings is provided in the east and west walls and those openings are well shaded from sun and thus minimising heat gain through walls. External verandah and *thinnai* in the east side protects the walls from direct solar radiation and thus reducing heat gain. Raised plinth provided reduces the entering of heat, reradiated from ground. Walls are painted white, which reflect the solar radiation falling on it and thus heat gain is reduced. Sloping roof with its slope and shape reduces heat gain. Wooden ceiling is provided for some spaces in ground floor. These areas remain cooler than other spaces of the structure. Terracotta tiles are used for roofing with medium heat storage capacity. These are permeable for air to pass through the gaps between the tiles, which will help the hot air below the tiles to escape to outside. Rate of

cooling in the evenings is maximised in the structure by taking maximum advantage of the evening winds from the east side.

Activity area analysis

Thinnai, a semi enclosed sit out is provided on the east side. This is mainly used as outdoor space during daytime. It is well lit and well shaded with the verandah provided in front of it and is ventilated through the spaces in between wooden battens provided on the east wall. *Nezhi,* drawing room, is placed next to the *thinnai.* It is also well lit by the daylight and ventilated too through the windows provided on its east wall, which is the sharing wall of semi enclosed *thinnai. Machukkul,* the strong room is well secured with thick walls and with no openings to the external wall. *Koodam* which is generally used during daytime is well lit and ventilated with the help of courtyard placed adjacent to it. Direct solar radiation falling on the *koodam* wall from the courtyard is prevented by the verandah running around the courtyard. It is also used as dining space and is placed just next to kitchen. It is also used as sleeping space at night time. *Koodam* is also having high roof which collects warm air on the top and keeps the space near floor area cool. The risen warm air will be escaped through the breathing space between the tiled roof. *Koodam* is a multipurpose room in agraharams. Another sleeping space provided in this house is an *ara* in the first floor, which is cool and comfortable due to the wooden ceiling above and ventilated through the windows provided on the east wall. Kitchen, which is chiefly used at daytime, is provided next to the *koodam.* Its north wall is towards the courtyard with opening, which helps in ventilation and daylight entering during day time. Well is placed adjacent to the kitchen, which helps people working in kitchen to draw water directly from the kitchen. Towards the end of residence are the less used spaces ie. bathrooms and toilets situated. It is having west wall as an external wall. This space placed on the west end prevents heat gain to other habitable rooms.

Table 5.10-Chart showing objectives of thermal comfort and normative indicators of the architectural means to achieve these objectives in residence-2 of Kizhakkencherry agraharam

Principles of building design ⇨ / **Architectural means to attain principles** ⇩	*Provision of continuous and efficient ventilation*	*Protection from sun, rain and insects*	*Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings*
Building form and layout	Rectilinear plan, with a courtyard towards the edge	Exposed walls only on front and rear, shared side walls	
Orientation	E-W for whole agraharam, N-S for this residence-ventilation through local wind	E-W for whole agraharam	E-W for whole agraharam
Raised Plinth	96cm high, better air movement	Prevents dampness	Prevents reradiated solar radiation
Openings	Provided in straight alignment		
Shading		Sloping roof & adjacent buildings-shared side walls	Sloping roofs with wide overhangs
Wide Verandahs		Small verandah in front of *thinnai*	
Landscape		Tall trees shade rear wall	Shading by tall trees reduces solar heating
Roof Type		Sloping roof- easy drain off of water and shading from	Sloping roof-Slope and shape reduces heat gain

		sun	
Wall Material			Brick masonry of varying thickness-locally available
Roof Material			Permeable clay tile roofing
Outdoor spaces	*Thinnai* or semi enclosed sit-out in front		
Physical phenomena	Courtyard effect & tunnel effect		
Fly screen		absent	
Other techniques			Shared side walls

5.7.4 Comparison of thermal performance of traditional agraharam and modern building of same locality

Temperature difference of outside and inside of traditional row house without courtyard in Kizhakkencherry agraharam was found to be 5°C, for traditional row house with courtyard was 8°C and that of modern concrete house near by was just 1°C (table 5.11). This makes it clear that traditional row houses are cooler and more comfortable than modern RCC houses. Among traditional row houses, row house with courtyard is cooler than row house without courtyard.

Table 5.11-chart showing comparison of thermal performance of traditional agraharams and modern building of same locality in Kizhakkencherry agraharam

Residence	Residence 1-Traditional row house (without courtyard)	Residence 2-Traditional row house (with courtyard)	Modern house (detached)
Time & Date	2.45pm, 26-01-2010	2.45pm, 26-01-2010	4.45pm, 26-01-2010
Outside	36°C	36°C	32°C

temperature			
Inside temperature	31°C	28°C	31°C
Temperature difference	5°C	8°C	1°C

5.8 VADAKKENCHERRY GRAMAM (ROW HOUSING-3)

Location- Vadakkencherry (30km from Palakkad)

District- Palakkad (Central Kerala- midland)

The total population of this agraharam is about 130. There are 32 row houses in a single street of this agraharam. Net dwelling density of this agraharam is 17 dwelling units per hectare and gross dwelling density is 14 dwelling units per hectare.

Figure 5.66- View of Vadakkencherry agraharam from east

Figure 5.67-Site layout of Vadakkencherry agraharam

i. Planning aspects

This agraharam consists of two streets with row houses facing each other, with one temple for each street. One street is running in east-west and another in north-west direction (For the study only one street, which is running in east-west direction, is taken). This type of settlement growth is mainly seen near water body. Here in this case it is the two ponds (one temple pond and other pond) on the north side of the settlement (fig 5.66 & fig5.67).

5.8.1 Household and visual survey responses

Analysis of the surveyed data of residences in Vadakkencherry Agraharam shows the following results.

Household data

a) Earning population

The total response average reveals that about 64% of the population are non-earning. And in the population 64% are females and 36% are males (fig 5.68).

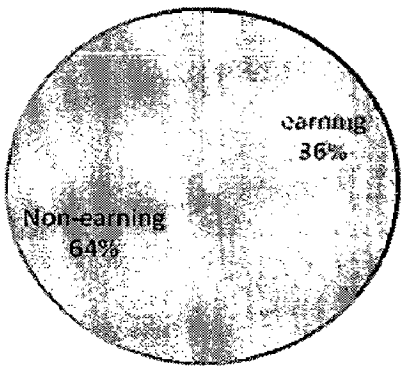


Figure 5.68-Graph showing earning population in Vadakkencherry Agraharam

b) Occupation of Head of Household

Majority of the head of households are retired people. Next to it is private service and Govt. Employed (fig 5.69).

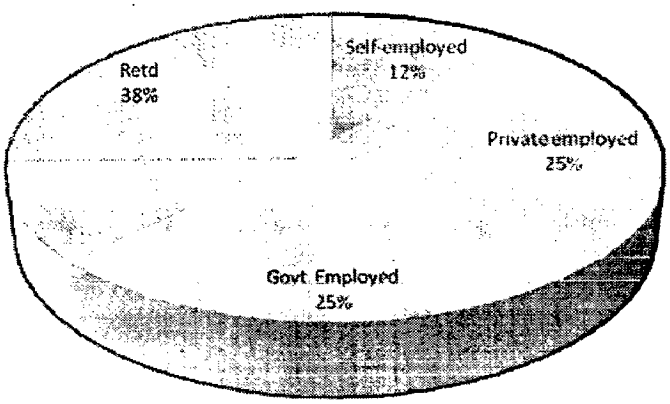


Figure 5.69-Graph showing occupation of head of household in Vadakkencherry Agraharam

c) Total income of household

Majority of houeholds ie.38% houses in the agraharam are having total monthly income of Rs. 5,001-10,000 (fig 5.70).

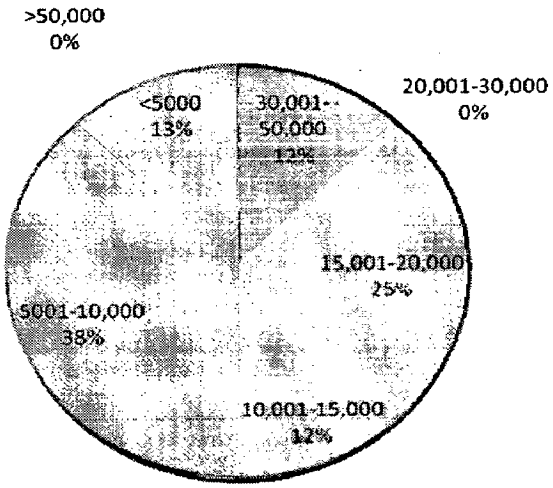


Figure 5.70-graph showing total income of household in Vadakkencherry Agraharam

Particulars of residence

d) Tenure

Solid majority of houses in this agraharam are owned(fig 5.71) .

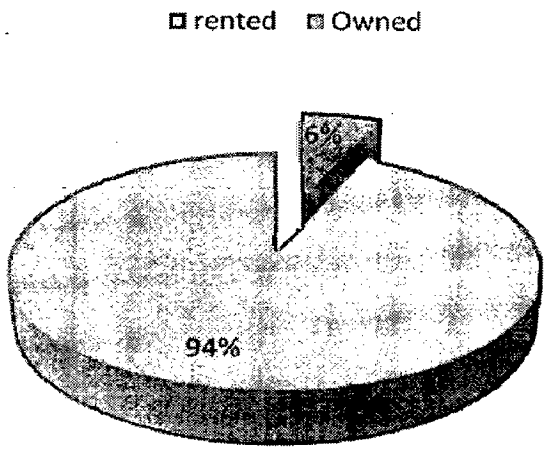


Figure 5.71-graph showing tenure of house in Vadakkencherry Agraharam

e) Type of Residence

From the visual survey it was revealed that majority of houses in this agraharam are double-storeyed (fig 5.72).

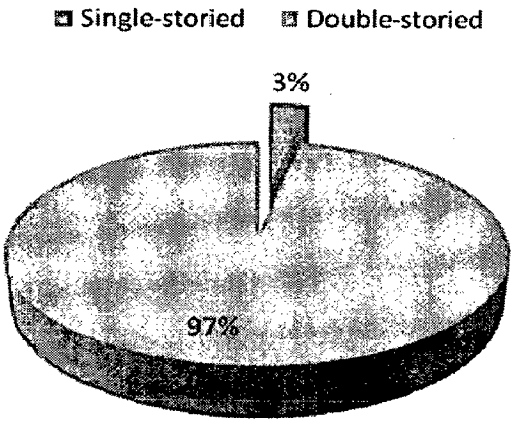


Figure 5.72-graph showing type of residence in Vadakkencherry Agraharam

f) Building materials

Flooring Material

About nine of ten houses in agraharam have wood-cement floor (fig 5.73).

Wall Masonry

Almost nine of ten houses in the agraharam have wall masonry as brick (fig 5.73).

Roofing Material

From the visual survey it was reavealed that majority of houses are having tiled roofs (fig 5.73).

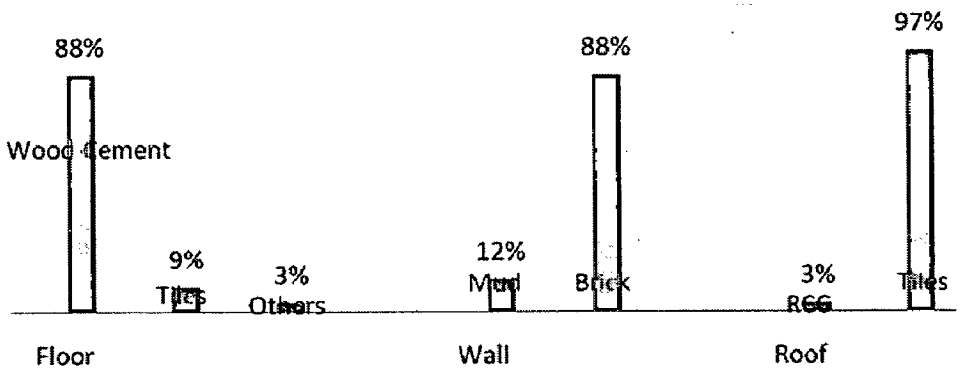


Figure 5.73-graph showing building materials used in house of Vadakkencherry Agraharam

g) Number of habitable rooms in residences

From the total response average it was found that one half of the houses are having 4 habitable rooms (fig 5.74).

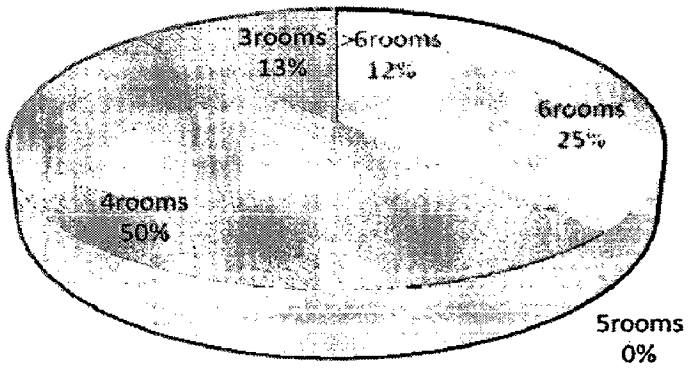


Figure 5.74-graph showing number of habitable rooms in houses of Vadakkencherry Agraharam

h) Floor area (in sqm)

From the visual survey it was observed that about half of the residences are having floor area of 151-200 sqm (fig 5.75).

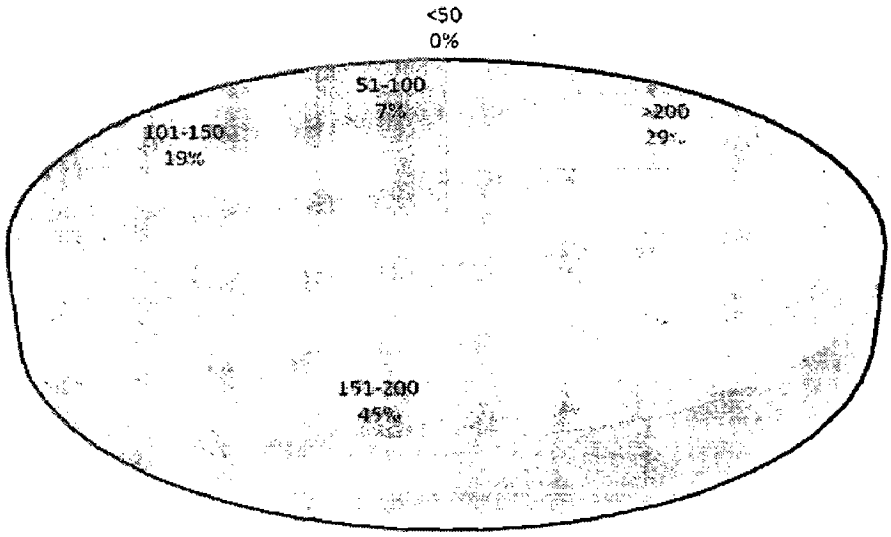


Figure 5.75-graph showing floor area of houses in Vadakkencherry Agraharam

i) Plot area (in sqm)

Visual survey revealed that one half of the plots in the agraharam are having area of 300-500sqm and 42% plots are having area more than 500sqm. From it is clear than more than 9 out of ten plots are having area of more than 300sqm (fig 5.76).

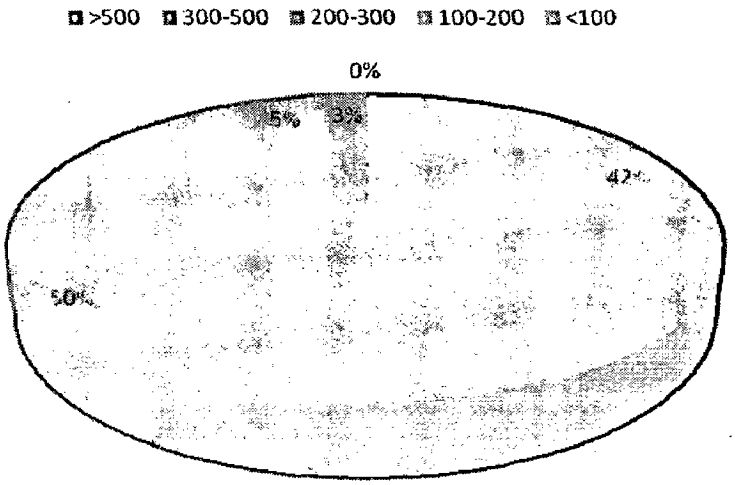


Figure 5.76-graph showing plot area of houses in Vadakkencherry Agraharam

j) Orientation of residence

About one out of ten houses are oriented in E-W axis and the majority of the houses are having its shorter walls facing N-S direction.

k) Adequacy of the existing dwellings

Largest part of responses specified that spaces or areas in the old structures are catering the present needs of living (fig 5.77).

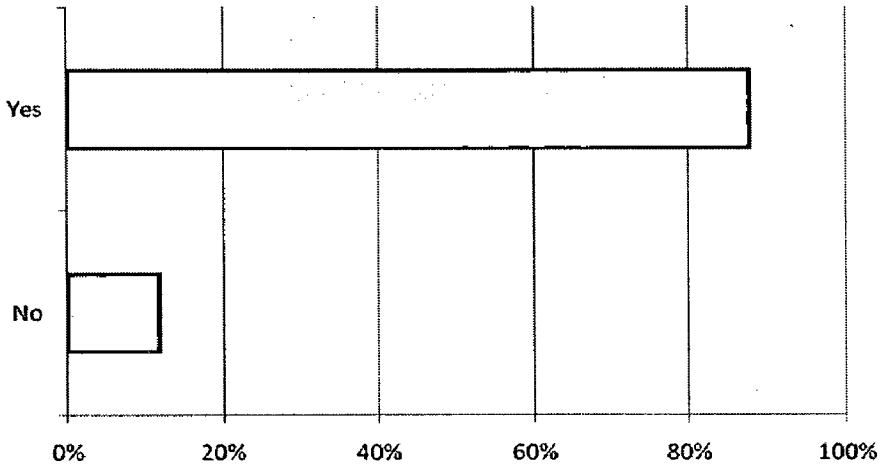


Figure 5.77-graph showing adequacy of existing buildings in Vadakkencherry Agraharam

Thermal Comfort conditions in the agraharam

l) Residence cool and comfortable without fan and cooler

Every respondents revealed that residences are cool and comfortable without fan and cooler. Majority of the residents stated that it is cool in part of house. In that, one half respondend that it is cool for a period of 3-6 months and one third respondend that it is cool for a period of 6-9 months (fig 5.78).

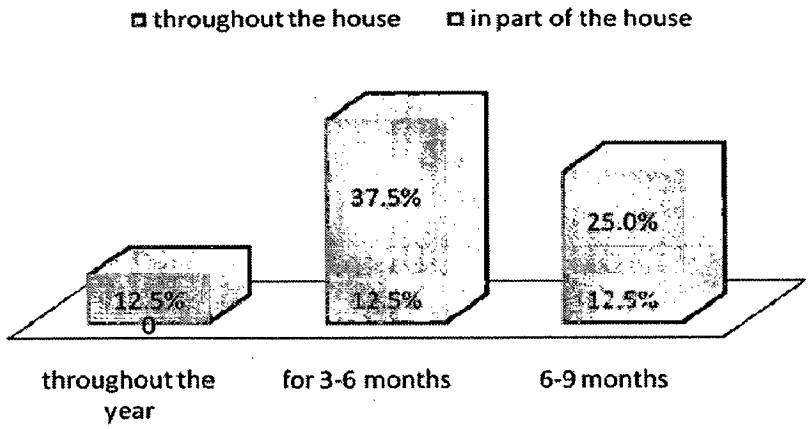


Figure 5.78-graph showing the percentage of residence cool and comfortable and its duration in Vadakkencherry Agraharam

m) Floor cool during day time and night time

100% of the respondents stated that ground floor is cooler during day time and three quarter of respondents expressed that ground floor itself is cooler during night time (fig 5.79).

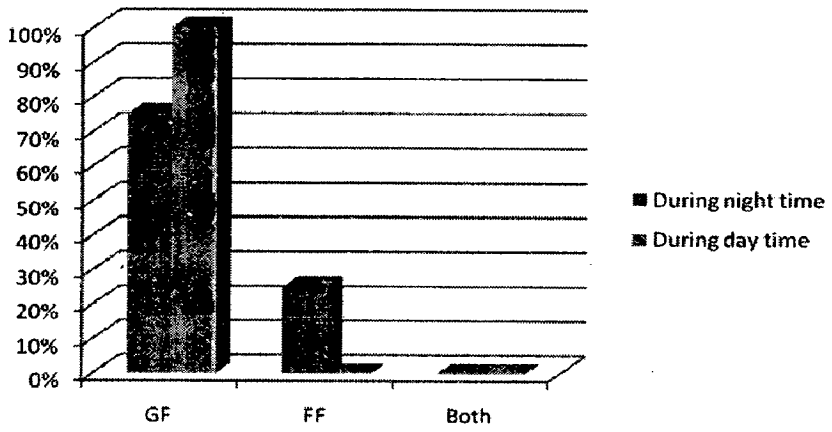


Figure 5.79-graph showing floor which is cool and comfortable during day time and night time of houses in Vadakkencherry Agraharam

n) Average duration of use of fan/cooler

About two third of the respondents specified that they use fan/cooler for less than 12 hours throughout the year. Mosquitoes are the main reason for using fan/cooler throughout the year (fig 5.80).

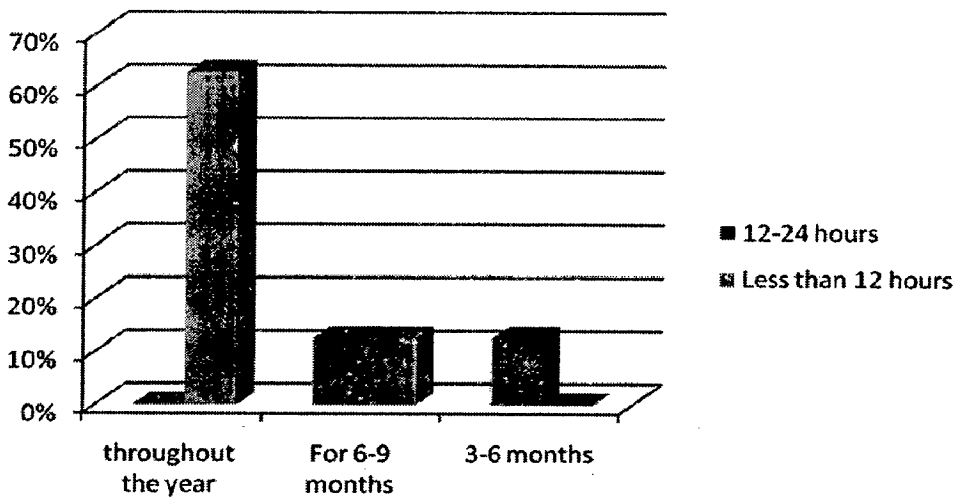


Figure 5.80-graph showing average duration of use of fan/cooler in houses of Vadakkencherry Agraharam

o) Use of artificial light during day time

One-half of the residences did not use artificial light during day time and rest half used in part of house during daytime. It was mainly used in toilets and rooms with ceiling (fig 5.81).

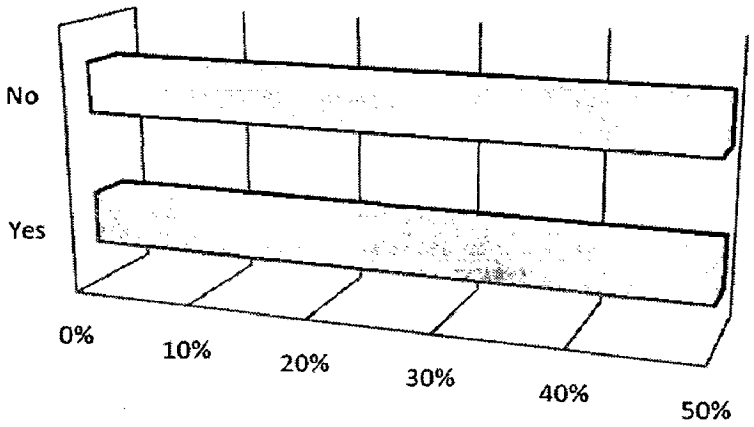


Figure 5.81-graph showing use of artificial light during daytime in houses of Vadakkencherry Agraharam

Electricity consumption

p) Electrical appliances used by the household

The total response average revealed that all the houses are having electrical appliances like electric light and fan. Next common possession by the residents was TV, and then mixer/grinder and Fridge (fig 5.82).

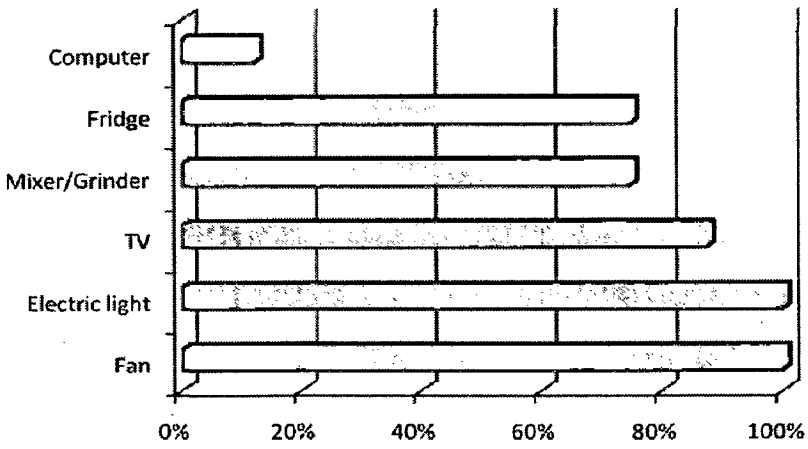


Figure 5.82-graph showing electrical appliances used by the household in Vadakkencherry Agraharam

q) Monthly electricity consumption (in kWh)

Half of the residences used 51-100 kWh of electricity in a month. One fourth of the houses consumed a monthly electricity of 101-150 kWh (fig 5.83).

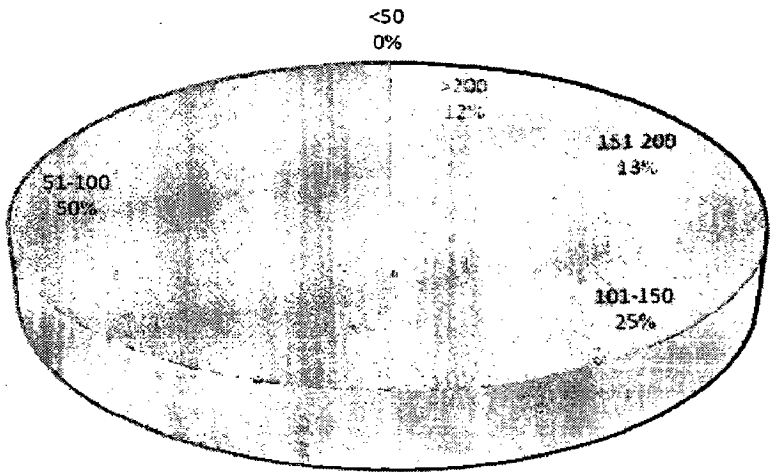


Figure 5.83-graph showing monthly electricity consumption in households of Vadakkencherry Agraharam

100% of the respondents stated that they will not move out of agraharam even if opportunity arises (fig 5.58).

Majority of the people stayed in agraharam because they own house and rest because of the good location/environment (fig 5.84).

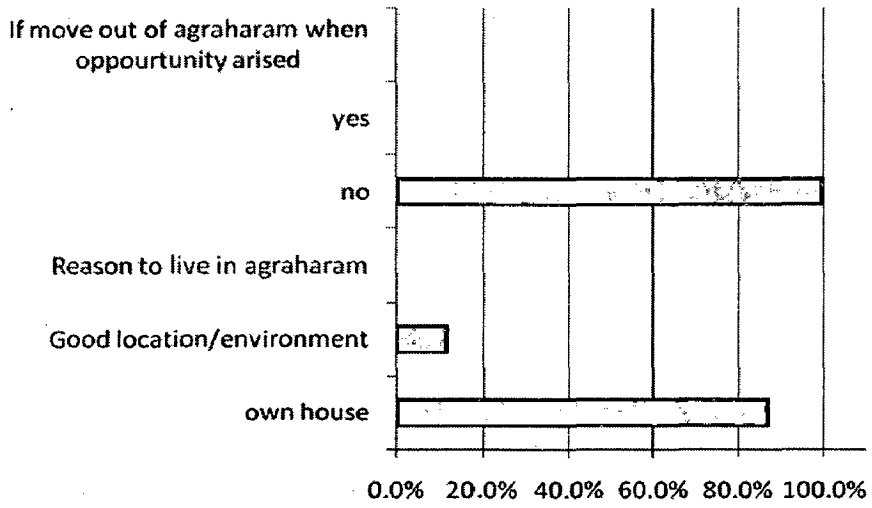


Figure 5.84-graph showing the percentage of people who like to move out of agraharam and reason to live in Vadakkencherry Agraharam

5.8.2 Residence 1

Residence-1 is double storeyed with an attic space above first floor. It is in one block and has a courtyard.

ii. Architectural aspects

Building form and plan form

Total built up area of this residence is 204.05m² and plot area is 473.41m².The width and length of this house is 6.15m and 22.85m respectively. The building is rectilinear in plan and double storeyed. The entire structure is covered with sloping roof. A courtyard is also provided in the structure (fig 5.85, fig 5.86 & fig 5.87)

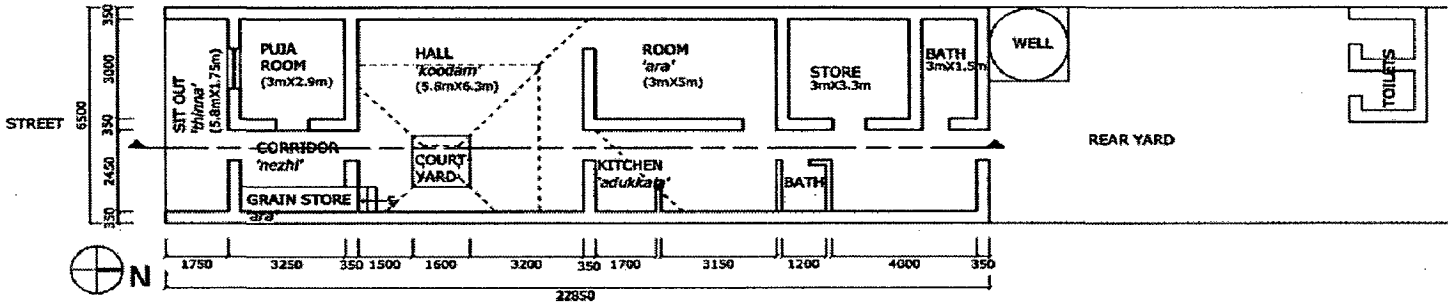


Figure 5.85- Ground floor plan of residence 1, in Vadakkencherry agraharam

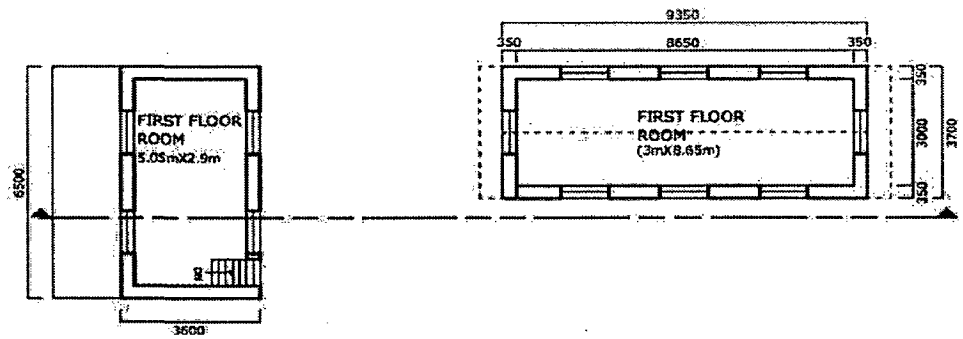


Figure 5.86- First floor plan of residence 1, in Vadakkencherry agraharam

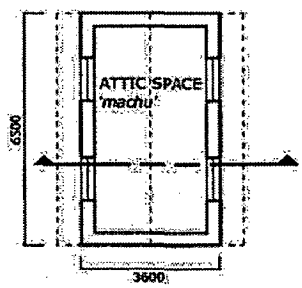


Figure 5.87- Attic plan of residence 1, in Vadakkencherry agraharam

Architectural elements

Raised plinth of 60cm is provided for this residence. Openings in this residence are provided in straight alignment. A sunken courtyard of size 1.55mX1.6m is provided which is sunk by 60cm. The entire structure is covered by sloping roof (fig 5.88).

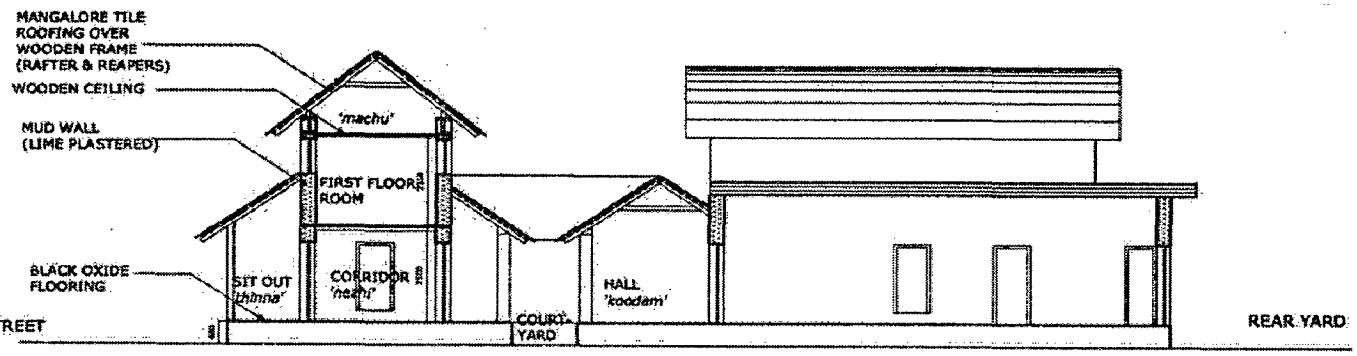


Figure 5.88- Longitudinal section of residence 1, in Vadakkencherry agraharam

Functionality of spaces

Semi public area, an open verandah or *thinnai* is provided in front which is used as an outdoor living space. Storage space is provided next to the *thinnai*. Hall or *koodam* with courtyard is the next in space which is habitable. This space is a multifunctional space, which is used for dining, living and sleeping. Next to it is the kitchen space, which has to be near *koodam*. Other rooms and toilets are next in the order. Well is provided next to the bath room, for easy accessibility of water (fig 5.88).

iii. Construction and Materials use

The roof is of mangalore pattern tiles over wooden frame, ie. rafters and reapers. The wall masonry is of mud with lime plastering. The ceiling above some areas is of wood.

Analysis of building design and planning for thermal comfort objectives

a) Provision of continuous and efficient ventilation

Courtyard in the '*koodam*' initiates ventilation through courtyard effect. Doors are provided in straight alignment from front to back as a result ventilation is ensured with tunnel effect. First floor rooms are with openings on opposite sides for cross ventilation. So first floor is more comfortable and used to sleep at night.

b) Protection from sun, rain and insects

Glass tiles are used in between roof tiles for adequate day light. Sloping roof is provided which makes it easy for rain water to drain off. Wide overhangs are provided for the roofs, which protects the wall from rain & sun. External verandahs are also provided which protects the walls from sun & rain. Proper drainage provided from the courtyard to the exterior of the house and raised plinth prevents dampness.

c) Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings

Inner verandahs around the courtyards and external verandah or *thinnai* in the front part protects the walls from direct solar radiation. Raised plinth is provided which reduces heat radiating from ground. Openings are only on north and south walls, which reduces direct heat gain. West side is shaded by the adjacent residential unit through out the agraharam. Sloping roof with its slope and shape reduces heat gain. Double roof(tiled roof above and wooden ceiling below) is provided above first floor. This reduces temperature in the space below. Wooden ceiling is provided for some spaces in ground floor and first floor.

Activity area analysis

'Thinnai', used during day time as an outdoor living space is provided on the south side which is an open space, which is shaded and has better ventilation by means of local winds. Courtyard is provided in *koodam,* which is mostly used during day time, helps in providing diffused daylight. Ventilation is also enhanced in that area with the help of courtyard effect. Kitchen is sunlit with the help of glass tiles. Well is provided adjacent to the bath room for easy water supply. Sleeping areas, in ground floor and first floor, are mostly provided with wooden ceiling, which makes it cooler and more comfortable to sleep in. In first floor windows are provided on opposite sides for cross ventilation. *Koodam* is also used for sleeping.

Table 5.12-Chart showing objectives of thermal comfort and normative indicators of the architectural means to achieve these objectives in residence-1 of Vadakkencherry agraharam

Principles of building design ⇨ / **Architectural means to attain principles** ⇩	*Provision of continuous and efficient ventilation*	*Protection from sun, rain and insects*	*Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings*
Building form and layout	Rectilinear plan, with a courtyard	Exposed walls only on front and rear, shared side walls	
Orientation	N-S for whole agraharam, E-W for this residence-ventilation through local wind	N-S for whole agraharam-protection from sun	N-S for whole agraharam-less heat gain
Raised Plinth	60cm high, better air movement	Prevents dampness	Prevents reradiated solar radiation
Openings	Provided in straight alignment		
Shading		Sloping roof & adjacent buildings-shared side walls	Sloping roofs with wide overhangs
Wide Verandahs		1.75m wide verandah in the form of *thinnai*	
Landscape		Tall trees shade rear wall	Shading by tall trees reduces solar heating
Roof Type		Sloping roof- easy drain off of water	Sloping roof-Slope and shape reduces

		and shading from sun	heat gain
Wall Material			Brick masonry of varying thickness-locally available
Roof Material			Permeable clay tile roofing
Outdoor spaces	*Thinnai* or sit-out in front		
Physical phenomena	Courtyard effect & tunnel effect		
Fly screen		absent	
Other techniques			Double roof construction & Shared side walls

5.8.3 Residence 2

Residence-2 is in one block and double storeyed.

ii. Architectural aspects

Building form and plan form

Total built up area of this residence is 125.6m² and plot area is 364.23 m². The width and length of this house are 4.6m and 23.8m respectively. The building is rectilinear in plan. It is double storeyed. The entire structure is covered with sloping roof (fig 5.89, fig 5.90, fig 5.91 & fig 5.92).

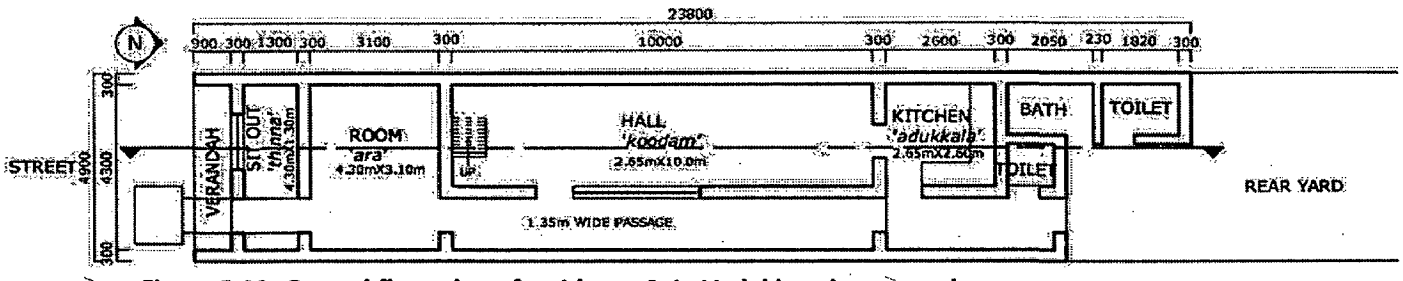


Figure 5.89- Ground floor plan of residence 2, in Vadakkencherry agraharam

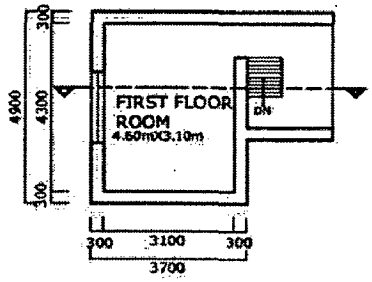


Figure 5.90- First floor plan of residence 2, in Vadakkencherry agraharam

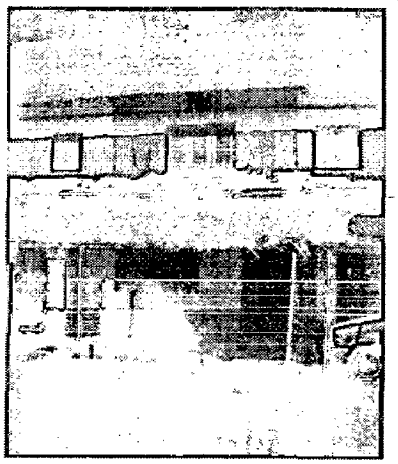


Figure 5.91- Front view of residence 2, in Vadakkencherry agraharam

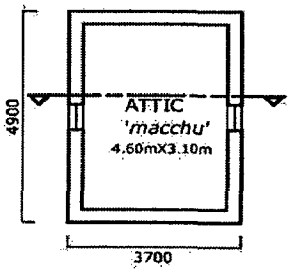


Figure 5.92- Attic plan of residence 2, in Vadakkencherry agraharam

Architectural elements

A narrow verandah is provided in front of the residence. The whole structure is covered with sloping roof. Openings are provided in straight alignment (fig 5.93).

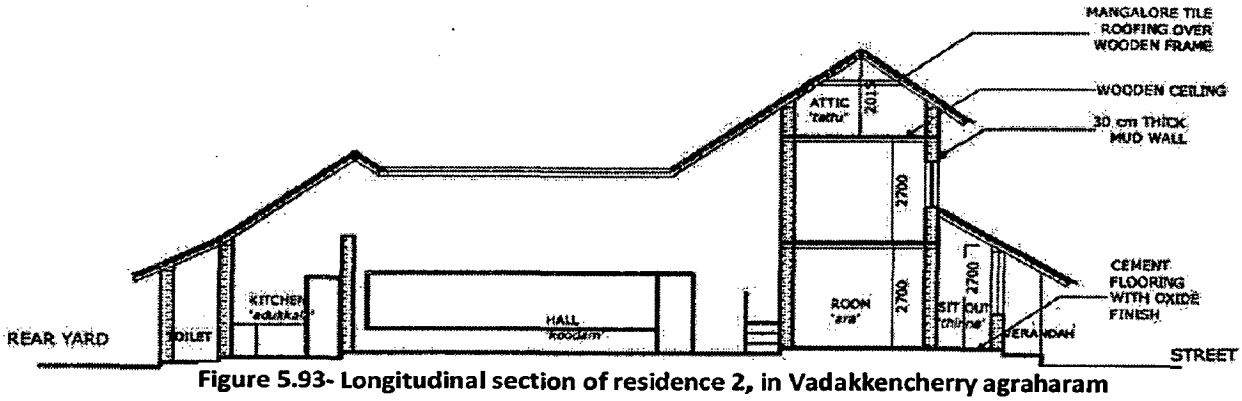


Figure 5.93- Longitudinal section of residence 2, in Vadakkencherry agraharam

Functionality of spaces

Thinnai or semi enclosed sit out is provided next to verandah which is used as an outdoor living space. *Ara* next to *thinnai* is presently used a living space. A long passage runs adjacent to *koodam*, kitchen and toilet. *Koodam* is mainly used as sleeping space. Kitchen

is provided next to *koodam*. Toilets are provided at the end of the rectilinear building (fig 5.93).

iii. Construction and Materials use

The roof is of mangalore pattern tiles over wooden frame, ie. rafters and reapers. The wall masonry is of mud with lime plastering. The flooring is of cement with oxide finish. The ceiling above some areas is of wood.

Analysis of building design and planning for thermal comfort objectives

a) Provision of continuous and efficient ventilation

From front to back, doors are provided in straight alignment which in turn causes tunnel effect and hence ensures continuous ventilation. Window provided on the single wall of the first floor room also helps in ventilation in that room.

b) Protection from sun, rain and insects

Glass tiles are used in between roof tiles for day light. Sloping roof with steep slope and wide overhangs, and a temporary porch in front, protects the front facade from sun and rain. The steep slope of the roof allows easy drain off of precipitation. External verandah and semi enclosed *'thinnai'* protects the walls from rain and direct solar radiation.

c) Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings

East and west walls are sharing, so these are mutually shaded and so no windows on these sides, which in turn reduce major part of direct heat gain. Minimum number of openings provided on north and south walls, which will again reduce heat gain of the structure. Sloping roof with its slope and shape receives less amount of direct solar radiation. Double roof is provided above the first floor, which leaves air gap between roof and the ceiling. This air gap will not allow heat gain of roof to enter the habitable area. Wooden ceiling is provided for some spaces in ground floor and first floor. Rest of the spaces have high roofs, which in turn collects warmer air towards the top of the room and thus keeping the surface near the floor cool.

Activity area analysis

'Thinnai', used during day time is provided on the south side, next to verandah, which is a semi enclosed space and thus providing sufficient diffused daylight and ventilation by means of local winds. *Ara,* which is now used as living space and formerly a store for grains, requires artificial daylight, because no windows and wooden ceiling is provided above this area. Another room is provided in first floor with wooden ceiling above, which will be cool and comfortable throughout the day and can be used for sleeping. *Koodam* in this residence is now used as sleeping area, which was formerly meant as a hall. This room had a courtyard adjacent to it for daylight and ventilation, before splitting the house into two. Kitchen gets daylight through glass tiles provided above.

Table 5.13-Chart showing objectives of thermal comfort and normative indicators of the architectural means to achieve these objectives in residence-2 of Vadakkencherry agraharam

Principles of building design ⇨ **Architectural means to attain principles** ⇩	*Provision of continuous and efficient ventilation*	*Protection from sun, rain and insects*	*Minimizing solar heating of the buildings and maximizing rate of cooling in the evenings*
Building form and layout	Rectilinear plan, with rooms arranged one behind the other	Exposed walls only on front and rear, shared side walls	
Raised Plinth	absent		
Orientation	N-S for whole agraharam, E-W for this residence-ventilation through local wind	N-S for whole agraharam-protection from sun	N-S for whole agraharam-less heat gain
Openings	Provided in straight alignment		
Shading		Sloping roof, adjacent buildings	Sloping roofs with

		and temporary porch in front	wide overhangs
Wide Verandahs		small verandah in front of *thinnai*	
Landscape		Vegetation far from rear wall, so no shading	
Roof Type		Sloping roof- easy drain off of water and shading from sun	Sloping roof-Slope and shape reduces heat gain
Wall Material			Mud wall
Roof Material			Permeable clay tile roofing
Outdoor spaces	*Thinnai* or semi enclosed sit-out in front		
Physical phenomena	Tunnel effect		
Fly screen		absent	
Other techniques			Double roof construction & Shared side walls

5.8.4 Comparison of thermal performance of traditional agraharam and modern building of same locality

Temperature difference of outside and inside in a traditional row house in vadakkencherry agraharam is found to be 3°C but that of modern detached concrete house was just 1°C, almost at the same time (table 5.14). This makes it clear that traditional row house is cooler and more comfortable than modern RCC house.

Table 5.14-chart showing comparison of thermal performance of traditional agraharams and modern building of same locality in Vadakkencherry agraharam

Residence	Residence 2- Traditional row house	Modern house (detached)
Time & Date	4pm, 26-01-2010	4.45pm, 26-01-2010
Outside temperature	33°C	32°C
Inside temperature	30°C	31°C
Temperature difference	3°C	1°C

5.9 COMPARISON OF CASE STUDY AGRAHARAMS

The three agraharams which have been studied are compared in table 5.15, in terms of architectural means used to attain the design objectives for warm humid climate.

Table 5.15-Chart showing comparison of case study agraharams

Architectural means for attaining design objectives	**Kalpathy Agraharam**		**Kizhakkencherry Agraharam**		**Vadakkencherry Agraharam**	
	Res 1	**Res 2**	**Res 1**	**Res 2**	**Res 1**	**Res 2**
Building form and layout	rectilinear plan -double storeyed courtyard & open space	rectilinear plan -single storeyed	rectilinear plan -double storeyed -open space	rectilinear plan -double storeyed courtyard	rectilinear plan -double storeyed courtyard	rectilinear plan -double storeyed
Orientation	Agraharam as a whole N-S		Agraharam as a whole E-W		Agraharam as a whole N-S	
	E-W	E-W	N-S	N-S	E-W	E-W
Raised Plinth	60cm	absent	90cm	90cm	60cm	absent

Openings	Straight alignment	Straight alignment	Straight alignment	Straight alignment	Straight alignment	Straight alignment
Shading	Roof & verandah	Roof & verandah	Roof & verandah	Roof, verandah, vegetation	Roof & verandah	Roof & verandah
Wide Verandahs	In the form of *thinnai* in front	In the form of *thinnai* in front	In the form of *thinnai* in front	Narrow verandah in front	In the form of *thinnai* in front	Narrow verandah in front
Landscape	Only in the backyard of all buildings		Only in the backyard of all buildings		Only in the backyard of all buildings	
Roof Type	Sloping	Sloping	Sloping	Sloping	Sloping	Sloping
Wall Material	Brick	Brick	Brick	Brick	Mud	Mud
Roof Material	Mangalore pattern tile over wooden frame & wooden ceiling over some areas	Mangalore pattern tile over wooden frame & clay tile ceiling over some areas	Mangalore pattern tile over wooden frame & wooden ceiling over some areas	Mangalore pattern tile over wooden frame & wooden ceiling over some areas	Mangalore pattern tile over wooden frame & wooden ceiling over some areas	Mangalore pattern tile over wooden frame & wooden ceiling over some areas
Outdoor spaces	Semi enclosed *thinnai*	Semi enclosed *thinnai*	*Thinnai*	Semi enclosed *thinnai*	Open *thinnai*	Semi enclosed *thinnai*
Physical phenomena	Tunnel effect through street for whole agraharam		Tunnel effect through street for whole agraharam		Tunnel effect through street for whole agraharam	
	Courtyard effect & tunnel effect	Tunnel effect	Stack effect & tunnel effect	Courtyard effect & tunnel effect	Courtyard effect & tunnel effect	Tunnel effect
Fly screen	absent	absent	absent	absent	absent	absent
Other	Shared	Double roof &	Double roof &	Shared	Double roof &	Double roof &

techniques	wall	shared wall	shared wall	wall	shared wall	shared wall

Most of the architectural means provided are almost similar in all the three agraharams. The main differences are in the orientation and the density of houses in agraharam. Owing to these differences, the thermal comfort objective attained in each agraharam is also different.

Best ventilation is obtained in the case of New Kalpathy agraharam as the wind direction in this case is in the same direction of the street running between the row houses (in the other two agraharams, wind direction is perpendicular to the street). This causes tunnel effect through the street, which in turn initiates efficient ventilation in each dwelling unit.

In the case of protection from sun, New Kalpathy agraharam and Vadakkencherry agraharam are better protected than Kizhakkencherry agraharam as the former two agraharams are oriented in N-S as a whole, which prevents it from direct solar radiation, and latter oriented in E-W direction. Protection from rain is same in the case of all the three agraharams, as the same architectural elements are used in all cases for the protection from rain. There is no protection given for prevention of insects in any of these agraharams.

The solar heat gain is less in New Kalpathy agraharam and Vadakkencherry agraharam because of its N-S orientation. But when compared between these two agraharama, the solar heat gain is least for houses in Kalpathy agraharam as the width of houses in this agraharam are lesser than the width of houses in Vadakkencherry agraharam. The rate of cooling in the evening is found to be better in New Kalpathy agraharam, with the help of local winds, than other two agraharams.

Overall, New Kalpathy agraharam is the most climate responsive agraharam among the three agraharams studied. This agraharam is also accommodating more families than other agraharams, when compared in terms of net or gross density of these agraharams. Net density of New Kalpathy agraharam is 56 dwelling units/ha, of Kizhakkencherry agraharam is 17 dwelling units/ha and that of Vadakkencherry agraharam is 17 dwelling units/ha. Altogether New Kalpathy agraharam is most climate responsive and most densest among all.

CHAPTER 6
INFERENCES AND GUIDELINES

6.1 PREAMBLE

Inferences from analysis of survey data, from visual and questionnaire survey of buildings in study area are discussed here. From the inferences useful site planning and architectural design guidelines are derived for urban housing in tropical climatic conditions of Kerala. These guidelines help to attain thermal comfort objectives in the buildings.

6.2 INFERENCES

6.2.1 General inferences from both courtyard and row housing

1. Vernacular buildings (both courtyard and row houses) with their less usage of energy are more energy efficient compared to new buildings. Because of its planning, which allows adequate daylight and ventilation, energy usage or electricity required is quite less compared to modern RCC building.

2. From temperature analysis it was found that vernacular buildings are cooler and more comfortable than modern RCC buildings.

3. For vernacular construction heat gain through conduction and radiation is almost nil. Heat gain is mainly through convection.

4. All the openings are placed in straight alignment for continuous ventilation.

5. Since vernacular buildings are using locally available materials for its construction, it causes less impact to the environment.

6. All together vernacular buildings are resource conserving and example for 'green' architecture, to a large extent.

6.2.2 Inferences from comparison of courtyard planning and row housing

1. Row houses are cooler and more comfortable with less heat gain than detached courtyard houses. Row houses are having almost zero heat gain through walls, in case of N-S orientation. Only heat gain is from roof and it is also negligible when double roof construction is used for the residence.

2. In warm humid climate, controlled and continuous ventilation is required. Row houses with courtyards have this type of ventilation than detached houses.

3. Protection of the building from rain is also better in row houses than courtyard houses as only front and rear walls are exposed and roofs provided are sloping.

6.2.3 Inferences from courtyard planning

i. Planning Aspects

Site planning

1. Buildings should be planned in the site at a location where enough set backs are provided around the building, which allows prevailing wind to pass through the building.

2. Landscaping around the structure should also not deviate the prevailing wind entering the structure. For that small plants are only allowed to plant near the prevailing wind direction.

3. Tall trees can be planted on the west side of the building to give shade from west sun.

Form & Layout

1. Square building plans are the best, since they will allow wind to enter building from any direction.

2. Rectangular plan is the next best option.

3. Double storied courtyard houses are better than single storied courtyard houses, where the ground floor will be comfortable than first floor because heat gain is mainly through roof. First floor will also be comfortable if double roof is there above first floor.

Orientation

1. In case of square plan, the building should be oriented to the cardinal directions and not in angular.

2. The rectangular building can be oriented in N-S direction for less heat gain.

3. A balanced orientation can be adopted for both ventilation and reduction of heat gain.

Plan concept

1. Courtyard planning – All the spaces are arranged around the courtyard. One or two courtyards can be given with in a building according the area of the building. As the number of courtyards increasing ventilation also increases.

ii. Architectural Design Aspects

Plan form and building form

1. Square building plans are the best, since they will allow wind to enter building from any direction.

2. Rectangular plan is the next option, which should be oriented in N-S direction.

Spatial quality & arrangement of spaces

1. Habitable room or other rooms, where it is used for long period of the daytime, should be oriented and planned in such a way that least heat gain is there or direct sun's radiation is prevented.

2. Hall or living area, dining area etc. should be located or arranged where diffused sunlight is available, ie. with sufficient daylight but at the same time well shaded. The position should also be such that adequate ventilation is also provided. It can generally be provided on the east side, south-east side etc. Courtyard can be provided adjacent to the hall, for both sufficient ventilation and daylight.

3. No habitable rooms should be located on the west side. Only spaces like store, bathrooms, toilets etc. can be provided on the west side.

4. Sleeping area should be located in a position where good ventilation is available. According to the general prevailing wind direction of Kerala, ie. from south west to north east, sleeping areas can be provided on the south-west side. At the same time it should not be on the extreme west or if so, the west side should be well shaded or insulated. Windows should be provided on opposite sides for cross-ventilation or at least one on the external wall and one on the wall towards the

courtyard. Sleeping areas can also be provided on first floor for better air movement.

5. Kitchen should not be located on the west side, since it is another space which is continuously used during daytime. According to the general prevailing wind direction, it can be located on the north-east side, which in turn helps the hot air from kitchen to escape to the outside rather than spreading inside the residence. Well should also be located adjacent to the kitchen.

Architectural elements

1. Raised plinth should be provided because of intense rainfall and so to prevent dampness.

2. Verandah should be provided all around the building to prevent the walls from direct solar radiation. Verandah on the east side can be used as outdoor living space in the afternoon time. Verandah on the west side should be the widest of all to protect from the west sun's intense radiation.

3. Courtyard should be provided on the centre of the house for maximum utilization. If the courtyard is in rectangular shape, then it can be oriented in E-W orientation, so that direct sun's radiation enters the building for less time. Courtyard should be sunken, so that cool air will remain inside the courtyard. Verandah should also be provided all around the courtyard.

4. Openings, ie. doors and windows, should be provided opposite to each or in straight alignment for inducing ventilation.

5. Sloping roof, with wide overhangs, is the best in this type of climate for reduced heat gain and easy water drain off.

6. Fly screen, which was not used in the vernacular buildings, should be additionally provided due to insects in this type of climate.

Functionality of spaces

1. Multifunctional spaces can be provided for saving space. Living or dining space can be used for sleeping at night. Separate sleeping areas can be provided additionally for privacy.

iii. Building Construction & material use

1. Locally available materials should be used, which are climate responsive.
2. Walls can be thicker with locally available material like laterite or other insulating materials. Wall section can also be made with air gap between two skins of walls and further it can be filled with insulating material. Walls exposed to east and mainly west should be more insulating.
3. Double roof construction can be used for allowing the space below cool and comfortable. The material used for ceiling should be wood or any other insulating material. The air gap in between the roof and ceiling should be ventilated to remove the hot air, or roof material should be permeable for the hot air to escape.
4. Roofing material can be tile, or any other material with medium heat storage. If tile is used, it will allow air to pass through the gap in between the tiles. Skylights should be provided in between for sufficient day lighting. In case of tiled roof, glass tiles can be provided in between.

6.2.4 Inferences from row housing

i. Planning Aspects

Site planning

1. Row houses can be provided on one side or on both sides of the street.
2. The number of houses in a continuous row can vary according to situation and need.
3. Instead of a long and continuous row, breaks in the form of lane can be provided.
4. Row houses provided on both sides of the street cause shading of opposite buildings and will shade the street too.
5. Backyards provided for every house gives individual private space for the buildings.
6. If shorter walls are facing E-W direction, tall trees can be planted on the west side of the building which give shade from west sun.

Form & Layout

1. Rooms are arranged one after the other, with opening in straight alignment for better ventilation.
2. Spaces are provided in such a way that, public spaces like street comes at first, next to it is the semi public or transition space like verandah or semi enclosed *thinnai*, and then private areas of the residence.
3. Double storied agraharam houses are observed more comfortable than single storied.
4. Row houses can be provided with and without courtyard. Row houses with courtyards are cooler and more comfortable.

Orientation

1. Best orientation for row housing is N-S as a whole for the row houses ie. shorter walls of individual row houses facing North-South.
2. East- West is the second best option since the east and west walls will be shorter, with less openings. Further walls and openings should be well shaded with the help of large overhangs of the sloping roof.

Plan concept

1. The rooms are arranged one after the other in row houses and with or without courtyard.

ii. Architectural Design Aspects

Plan form

1. Row houses were found to be of rectilinear plan.
2. Row houses can be provided with or without courtyard.

Size &proportion

1. The width of row houses varies from 3m to 10m. The proportion even goes up to 1:10.

Spatial quality & arrangement of spaces

1. Since the row houses are with rooms arranged one behind the other, the rooms which need light and ventilation have to be placed in the front and back of the house, or open to the courtyard.

2. The front verandah can be used as outdoor living space, which gets adequate daylight and ventilation. This space can be open or semi enclosed, which will provide light and ventilation to the adjacent rooms.

3. Sleeping spaces should be provided in a place where it is cool and comfortable, so that it can be a space with false ceiling above or it can be on first floor where double roof is used above it. In sleeping areas are provided on first floor then openings can be placed opposite to each other, to increase natural ventilation.

4. Other habitable areas like hall can be provided in a space, where adequate daylight is obtained. Rooms in the middle of the single storied building can have skylight in the form of glass tiles. Courtyard inside the hall is also another option to provide good daylight and ventilation. This hall space can also be used for sleeping at night.

5. If house is oriented in E-W longer axis and if west is towards the back of the residence, then rooms which is less used like, toilets, bathrooms or stores should be oriented on the west side.

6. Kitchen should be located towards the back of the residence, with one wall as the exterior wall for ventilation. If it is not possible, then roof should be provided in two levels for hot air to escape or tiles of particular features like with tiles with openings has to be provided on the roof. No habitable room should be placed above the kitchen.

Architectural elements

1. Raised plinth should be provided because of intense rainfall and so to prevent dampness. Ventilation is also better in this case. Raised plinth also reduces reradiated solar radiation from entering the structure.

2. Verandah should be provided in front of shorter walls to prevent the walls from direct solar radiation. If the building is oriented with shorter walls facing E-W direction, then verandah on the east side can be used as outdoor living space in the afternoon, for buildings on west side of the street. Verandah on the west side should be wider than that at the east to protect the wall from the west sun.

3. Courtyard can be provided on the centre of the house for maximum utilization. If the courtyard is in rectangular shape, then it can be oriented in E-W orientation, such that direct sun's radiation enters the building for less time than oriented in the opposite direction. Courtyard should be sunken as cool air remains in the courtyard. Verandah should also be provided all around the courtyard.

4. Openings, ie. doors and windows, should be provided in straight alignment from front to back of the structure. If courtyard is there, openings from adjacent rooms should be towards courtyard area, for better ventilation and daylight.

5. Sloping roof, with wide overhangs, is the best in this type of climate for reduced heat gain and easy water drain off.

6. Fly screen, which was absent in the vernacular buildings, has to be used in new buildings.

Functionality of spaces

1. Multifunctional spaces will be very useful in row houses for saving space. Living or dining space can be used for social functions and sleeping at night. Separate sleeping areas can be provided additionally for privacy.

iii. Building Construction & material use

1. Locally available materials can be used as they are responsive to climate.

2. Shorter walls which are exposed to direct solar radiation may be with insulation. The long shared side walls can be ordinary, but it should provide sound privacy.

For this purpose of sound insulation, wall with insulation or cavity wall can be used.

3. Rooms with wooden ceilings or clay tile ceiling or with double roof are found to be more cool and comfortable through out the year.

4. Tile roofing is a good option, because of its medium heat storage capacity. If tile is used, it will allow air to pass through the gap in between the tiles. Skylights should be provided in between for sufficient day light or glass tiles can be provided in between.

6.3 PLANNING AND ARCHITECTURAL GUIDELINES

Guidelines are derived from the appropriate inferences, from courtyard planning and row housing, which are applicable in the modern context for urban housing.

i. Planning Aspects

Site planning

1. Adequate setbacks should be provided around the buildings for natural light and ventilation.

2. Buildings should be planned in clusters or row, with sharing walls (fig 6.1).

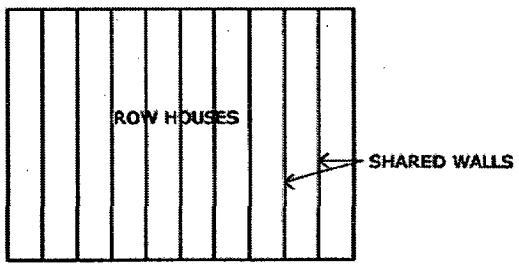


Figure 6.1-Row houses with shared wall

3. Row houses can be provided on one side (fig 6.2) or on both sides of the street (fig 6.3).

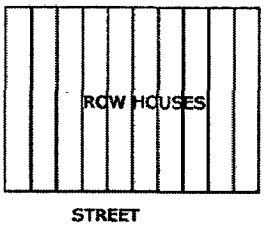


Figure 6.2-Row houses on one side of street

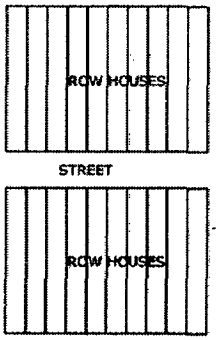


Figure 6.3-Row houses on both sides of street

4. Instead of a long and continuous row, breaks in the form of lane should be provided (fig 6.4).

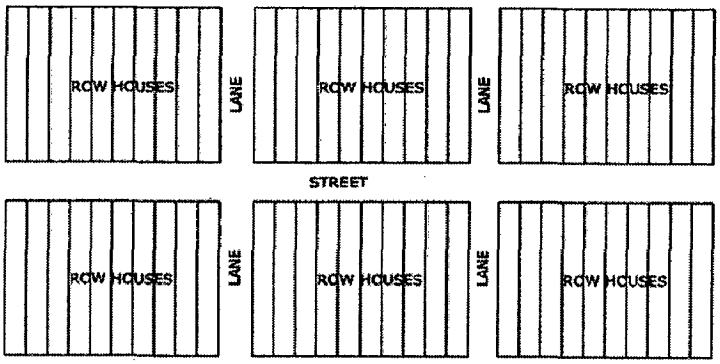


Figure 6.4-Breaks for continuous row houses in the form of lanes

5. Service lane or roads should be provided through the back of row houses.

6. Landscape should be used for shading the external walls, especially on the west side of the building (fig 6.5).

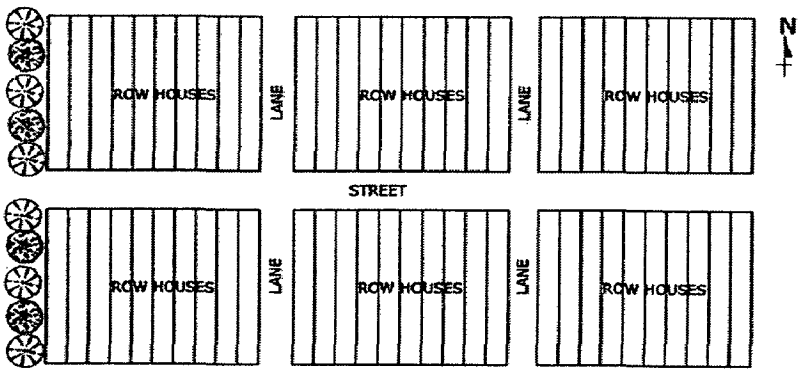


Figure 6.5-Landscape in the west side of row housing for shading purpose

7. Backyard or front yard should be provided for individual buildings in row houses for private use (fig 6.6).

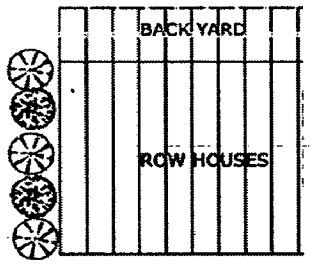


Figure 6.6-Backyard is provided for row houses as a private space

8. Parking facility in the form of garages should be provided in a common covered area adjacent to the row houses, for the entire row (fig 6.7).

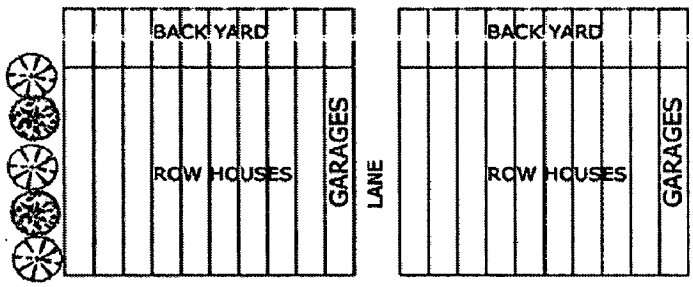


Figure 6.7-Common garages provided for all households in a row housing block

9. Open space or community space should be provided as common space for the community living there (fig 6.8).

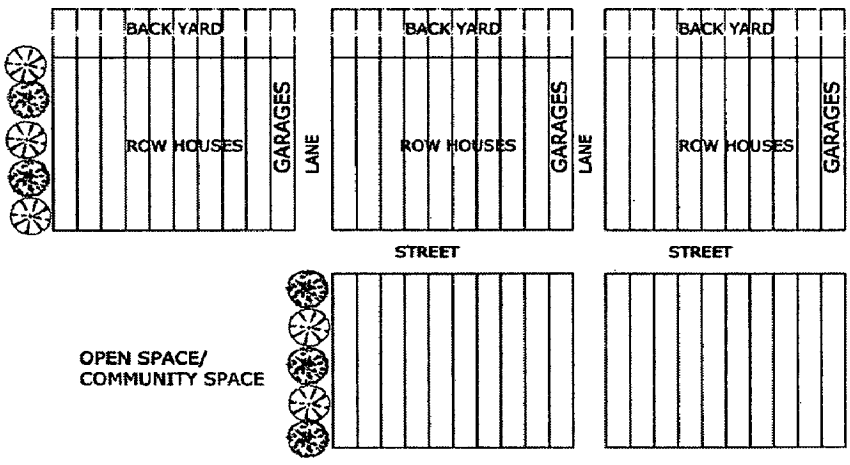


Figure 6.8-Common open space provided for row housing community

Form & Layout

1. Row houses should be planned in staggered manner, for increasing ventilation (fig 6.9).

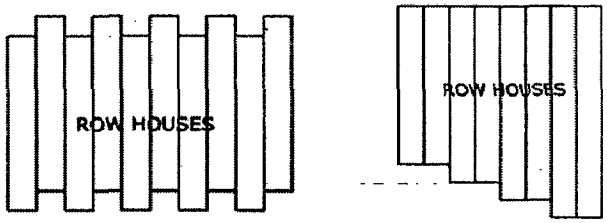


Figure 6.13-Staggered arrangements in row houses for increase in ventilation

2. Multi-storeyed buildings should be planned instead of single-storied, with different households at different levels (fig 6.10).

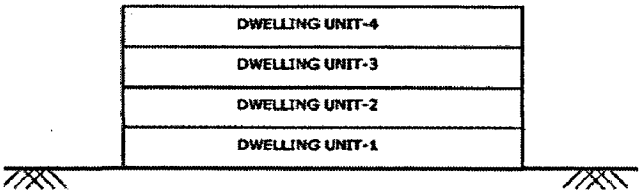


Figure 6.14-Multistoreyed row house with different dwelling units on each floor

3. Multi-storeyed buildings may also be staggered in different levels (fig 6.11).

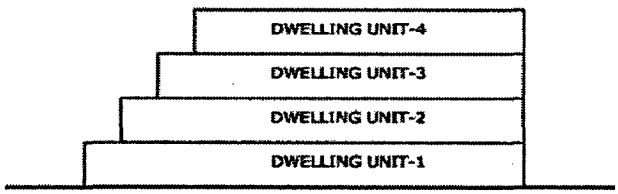


Figure 6.15-Multi-storeyed row house with staggered floors

Orientation

1. Shorter walls facing N-S is the best option, if possible (fig 6.12).

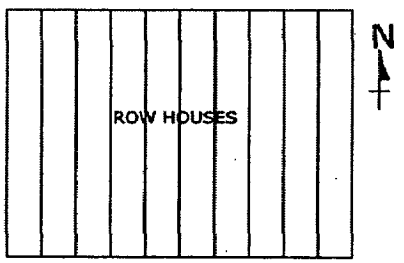


Figure 6.16-Row houses in N-S orientation

2. A balanced orientation should be provided which increases ventilation and reduces heat gain.

3. Open space/ community space provided common for the entire row houses, should be located in the south west side, as the prevailing wind, ie. from south west to north east should reach the row houses, without any hindrance.

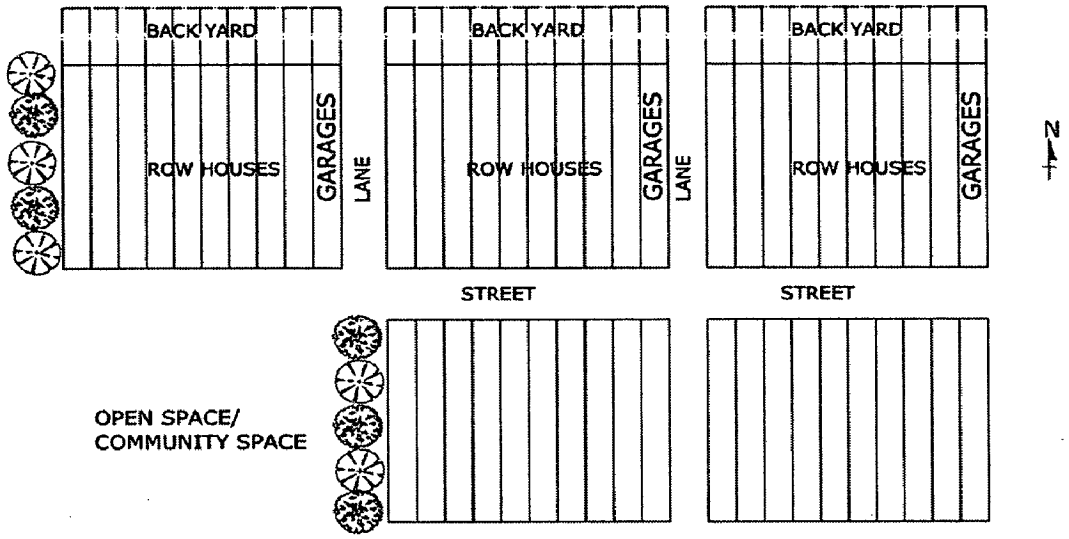


Figure 6.17-Open space/community space on south-west side of row housing community

Plan concept

1. Courtyard planning- One or more courtyards should be provided with in the buildings with habitable rooms oriented adjacent to the courtyard. Courtyard may also be landscaped. Courtyards can be provided as individual (fig 6.15) or combined for two dwelling units (fig 6.14).

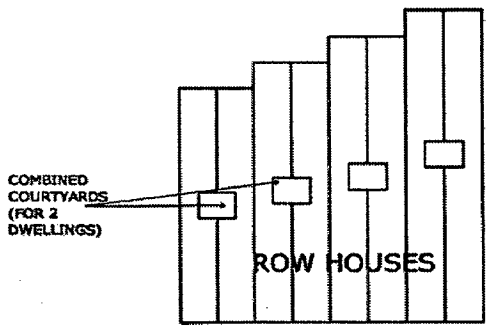


Figure 6.14-Row houses with combined courtyards

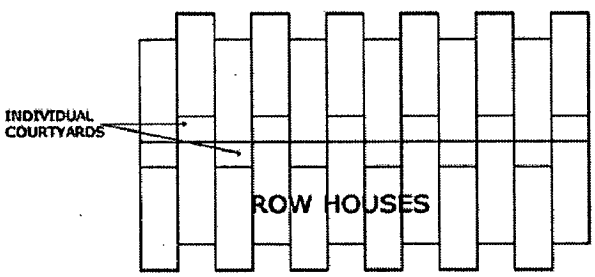


Figure 6.15 -Row houses with individual courtyards

ii. Architectural Design Aspects

Plan form

1. Each dwelling unit in row housing should be planned in rectilinear plan (fig 6.15).
2. Courtyards should be provided inside row or clustered housing (fig 6.14, fig 6.15).

Spatial quality & arrangement of spaces

1. Semi public spaces or outdoor living spaces, provided in front should be open (fig 6.16) or semi enclosed (fig 6.17), which helps to provide light and ventilation to adjacent rooms.

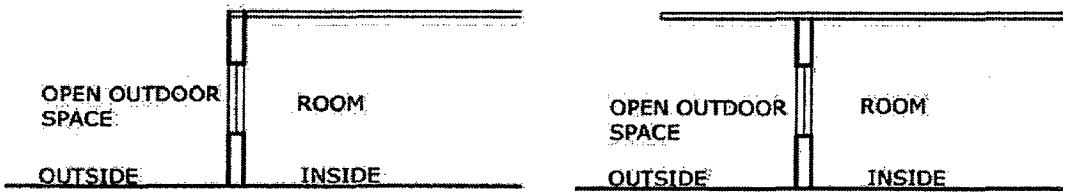


Figure 6.16 Open outdoor spaces with windows

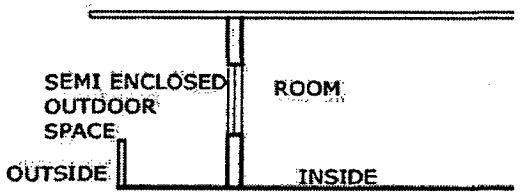


Figure 6.17 Semi enclosed outdoor spaces with windows

2. Rooms should be arranged one after the other (fig 6.18).

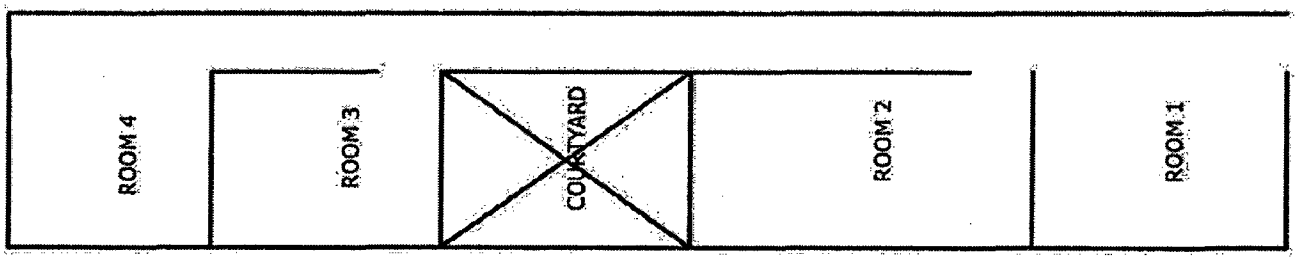


Figure 6.18 Rooms arranged one after other

3. Private spaces or habitable rooms should not be oriented towards the external walls, with direct solar radiation (fig 6.20). It should be in between and should have walls with openings towards the courtyard, for daylight and ventilation(fig 6.19). Thus bed rooms and halls can be oriented in this manner.

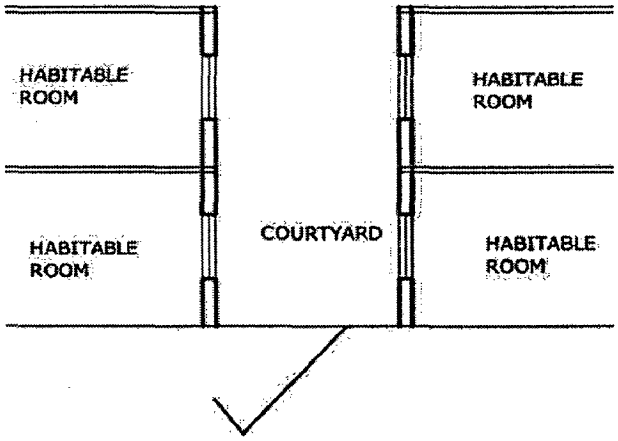


Figure 6.19 Habitable rooms oriented towards courtyard

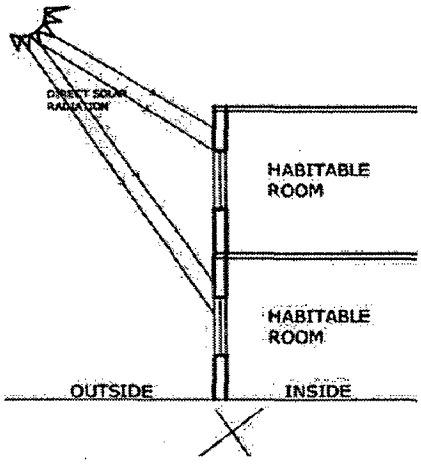


Figure 6.20-Habitable rooms should not be oriented towards external wall

4. Kitchen should be arranged towards the end, with one wall as external wall or wall towards courtyard (fig 6.21). If it is not possible, then duct should be provided. Kitchen should not be oriented in prevailing wind direction.

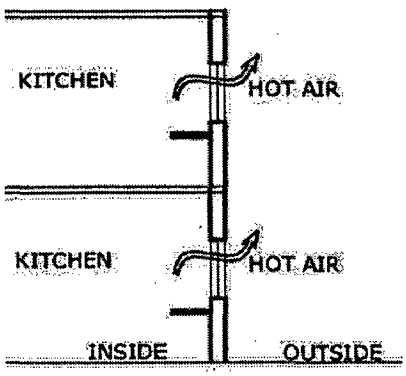


Figure 6.21-Kitchen arranged towards external wall

5. Toilets and storage spaces should be placed towards western external walls (fig 6.22). Toilets provided in between should be ventilated by ducts (fig 6.23).

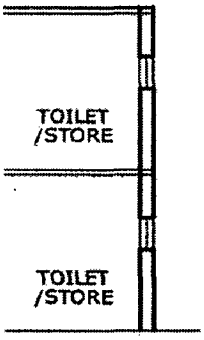


Figure 6.22-Toilet placed towards west external wall

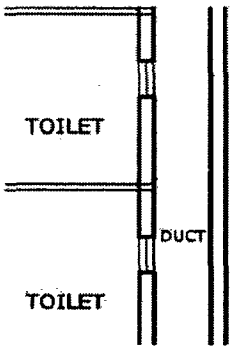


Figure 6.23-Duct for inner toilets

Architectural elements

1. Raised plinth of minimum 60 cm should be provided in the ground floor (fig 6.24).

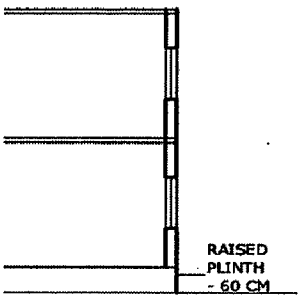


Figure 6.24-Raised platform of 60cm for ground floor

2. Open or semi enclosed verandah should be provided in ground floor and balcony/terraces in upper storeys (fig 6.25). These areas have to be provided on the edges facing shorter walls.

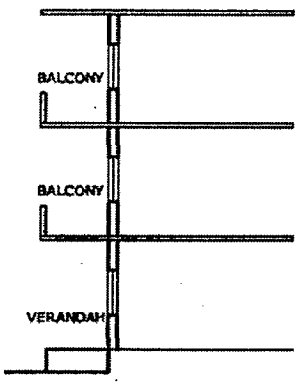


Figure 6.25-Semi-outdoor spaces in the form of verandah and balconies

3. Openings should be placed in straight alignment (fig 6.26).

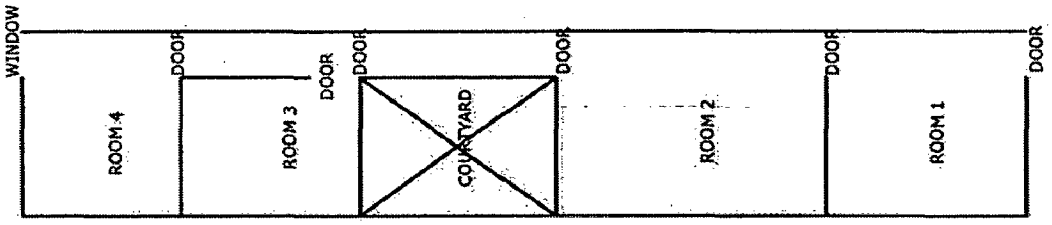


Figure 6.26-Openings arranged in straight alignment

4. Proper shading should be provided for walls in each storey. Shading can be given with the help of balcony on each floor (fig 6.25).

5. Sunken courtyards, which are a better option, should be provided (fig 6.27).

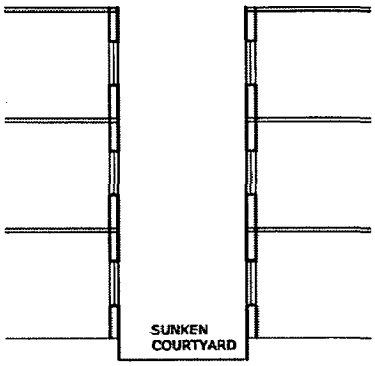


Figure 6.27-Sunken courtyard

6. Fins or screen walls should be provided to external walls, for directing wind towards inside, of those buildings, which are not oriented according to wind direction of that place (fig 6.28).

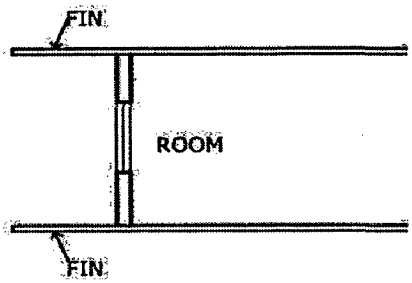


Figure 6.28-Fins for directing wind

7. Fly screens should be provided on all external doors and windows (fig 6.29 & fig 6.30).

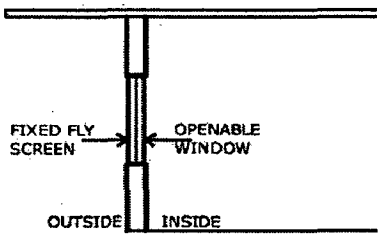


Figure 6.29-Fixed fly screen towards outside

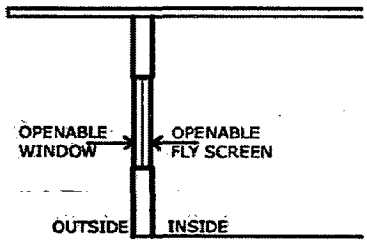


Figure 6.30-Openable fly screen towards inside

8. Sloping roofs with wide overhangs should be provided, with proper drainage (fig 6.31).

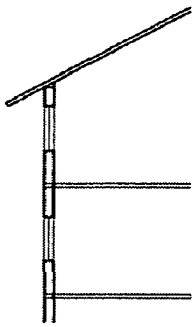


Figure 6.31-Sloping roof with wide overhang

Functionality of spaces

1. Use multifunctional or multipurpose spaces wherever possible in the building for saving floor area.
2. Hall can be used for both living and dining. It can also be used for sleeping.
3. Additional bed rooms should be provided for privacy.

iii. Building Construction & material use

1. Use locally available materials
2. Building materials used should be of minimum heat storage capacity.
3. Roof should be double roof or double layered. Inner layer should be insulating and outer layer reflecting and in between space should be ventilated (fig 6.32).

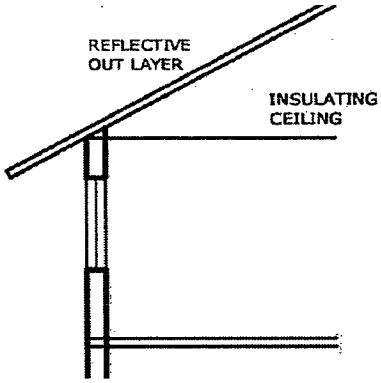


Figure 6.32-Double roof with inner insulative layer and outer reflective layer

4. External walls should be insulated or double layered walls with air gap or air gap filled with insulating materials (fig 6.33).

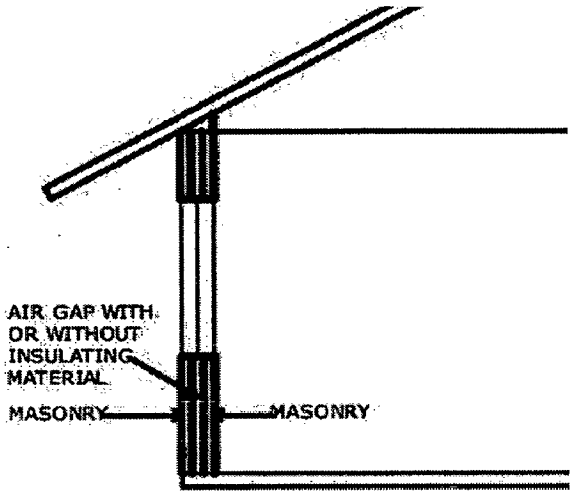


Figure 6.33-Cavity wall

5. Light coloured external paints should be used for reflecting solar radiation.

CHAPTER 7
APPLICATION OF GUIDELINES

7.1 PREAMBLE

The framed guidelines are applied on buildings of low rise (up to 4 storeys) and medium density (gross density of 75-120 dwellings/ha and net density of 120-180 dwellings/ha) in the modern context, at the site planning level.

7.2 APPLICATION OF GUIDELINES

In order to apply the guidelines, the general prevailing wind direction of Kerala is taken ie from south west to north east.

Application of guidelines in Site planning level

Different types of arrangements of individual dwelling units or buildings in row housing are given below (fig 7.1, fig 7.2 & fig 7.3). All the arrangements are staggered type for maximum utilization of prevailing wind, which is from south west. These houses can be oriented both N-S and E-W, but individual row houses oriented in N-S longer axis is more climate responsive. Courtyards are also provided in all arrangements. The dwelling units on the edges of these arrangements are without courtyard, in combined courtyard option arrangement, as these are getting more advantage of ventilation from the exposed side wall. For all the options garages are provided on one edge or both. Staircases are provided in between two dwelling units, which are common for both. Advantage of backyard will be given in all cases, for individual units of row housing. All the row house arrangements are of four floors, which is walkable, ie. without lift. These arrangements can have two types of arrangements in building form, ie. with same size of dwelling units in every floors and other with smaller dwelling units towards upper floors. The staggered arrangement in building form will provide more open private space for individual units. Third option (fig 7.3) is more useful in trapezoidal shaped sites. In first and second option, there are a total of 40 dwelling units, in 4 floors. In the case of third option, there are 24 dwelling units, in four floors.

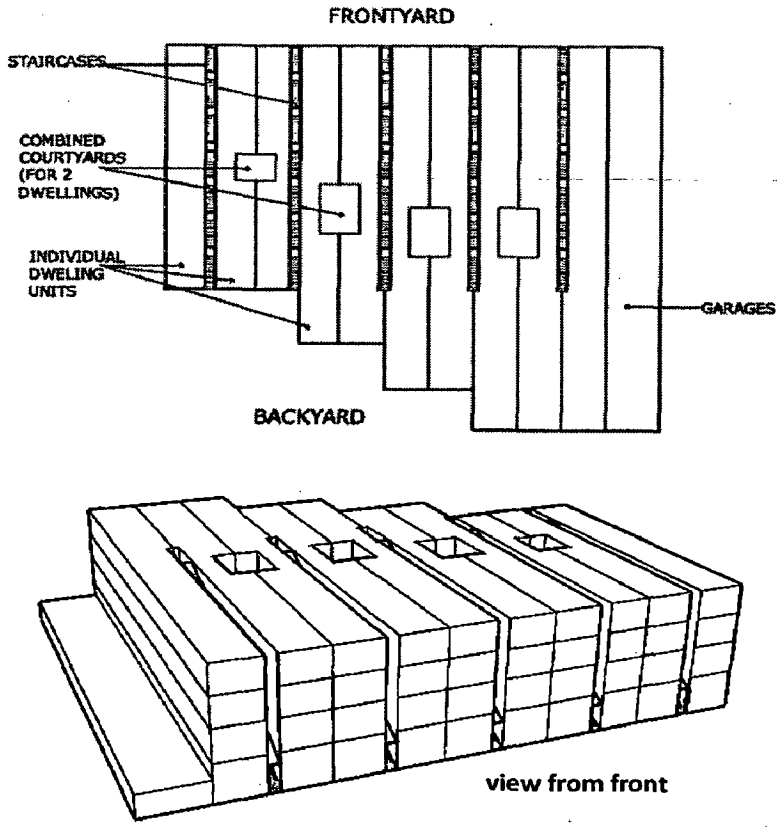


Figure 7.1- Plan &3d view of Option-1

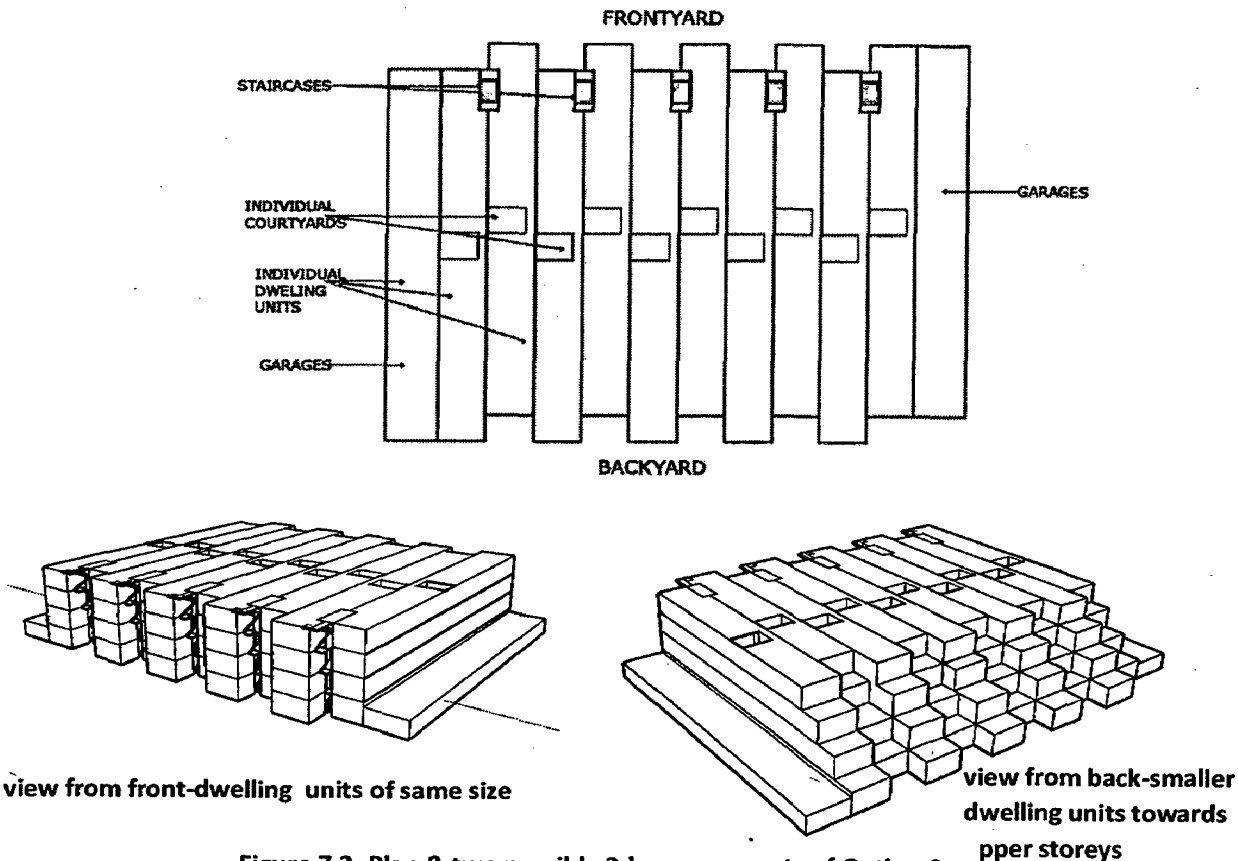


Figure 7.2- Plan & two possible 3d arrangements of Option-2

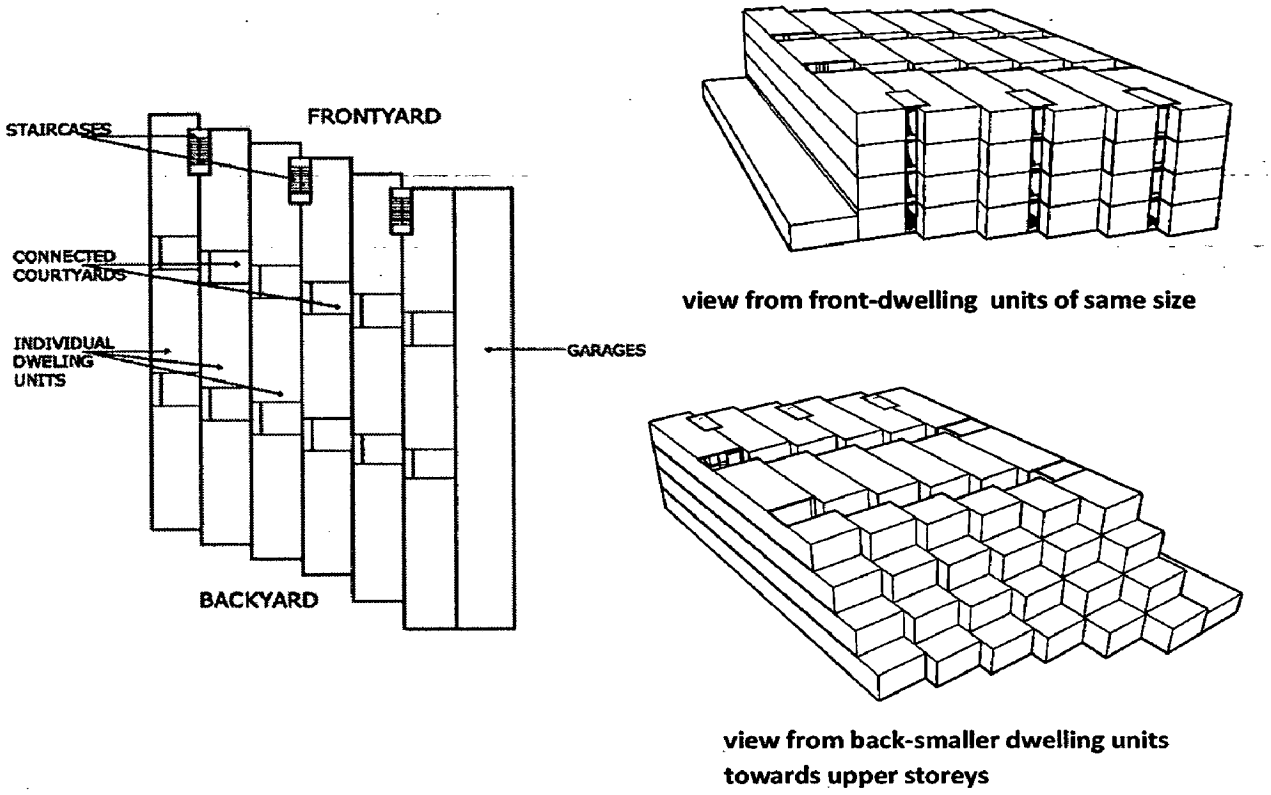


Figure 7.3- Plan & two possible 3d arrangements of Option-3

Different types of arrangements of the above options in the planning layout, in different shaped sites are given in following figures. All the buildings provided are of 4 floors and the density obtained by each arrangement is given below the respective planning layouts. Increased density can be attained by reducing the width of individual dwelling units and length. With different size and shape of site, the number of dwellings can be changed accordingly and arranged in the site. In all the arrangements, south west corner is provided with open space as the prevailing wind is from that direction. All the blocks are arranged in such a way to get maximum advantage of prevailing wind. Trees, with less dense foliage which will allow the wind to pass through, are planted on the west to give shade to the building from intense west sun. Trees are required only on the west edge of the western most blocks since other buildings towards the east side will be shaded by the adjacent west buildings. Third option is more suitable for trapezoidal shaped sites or sites with irregular shapes. It is also possible to do the planning layout with the combination of these options in the same site.

Different arrangements in planning layout of option 1

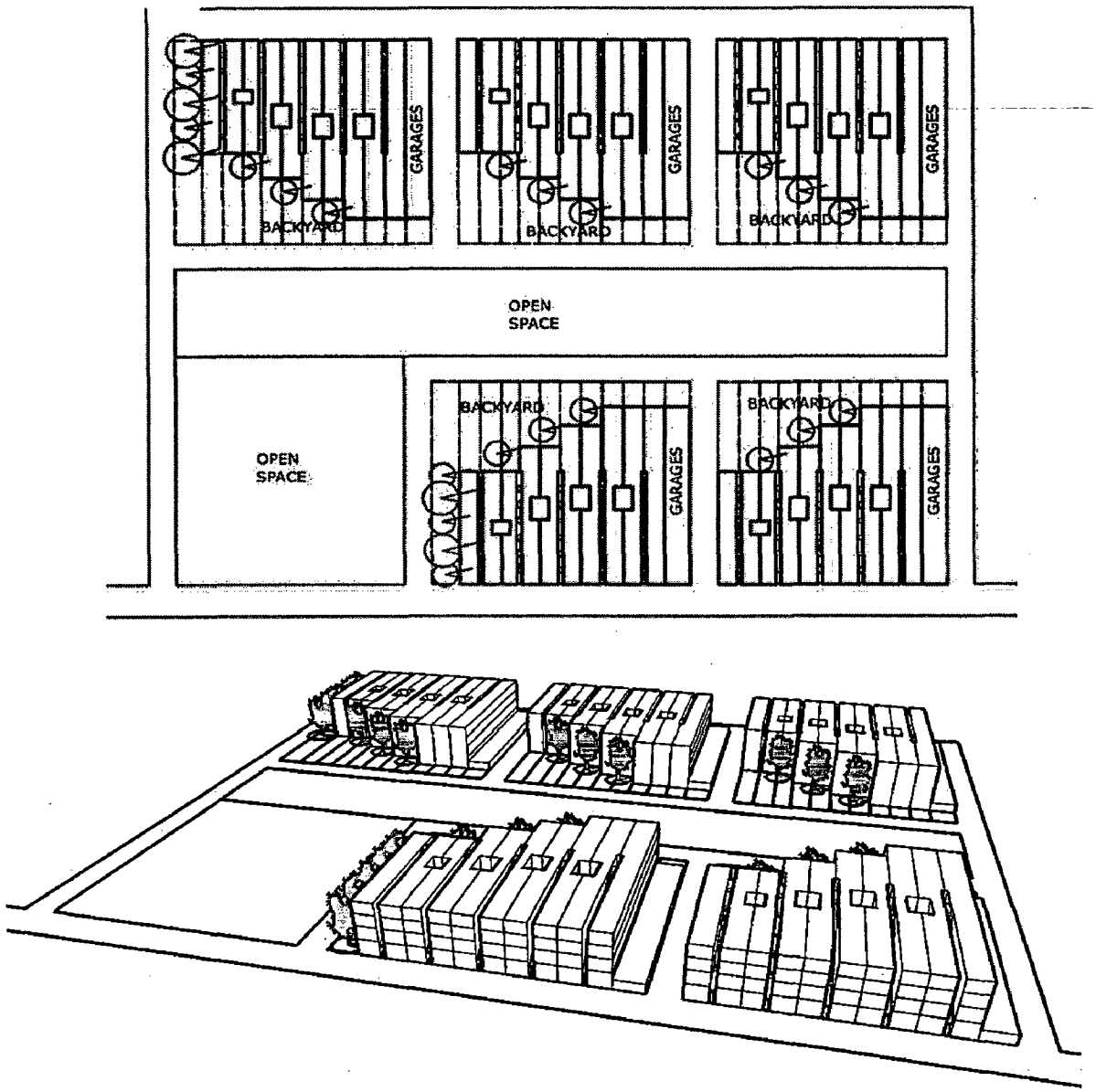


Figure 7.4- Site plan option and view in rectangular site of Option-1

Number of houses- 200 **Gross area**- 2.61 ha **Gross density**- 77 dwelling units/ha

Net area- 1.36 ha **Net density**- 147 dwelling units/ha

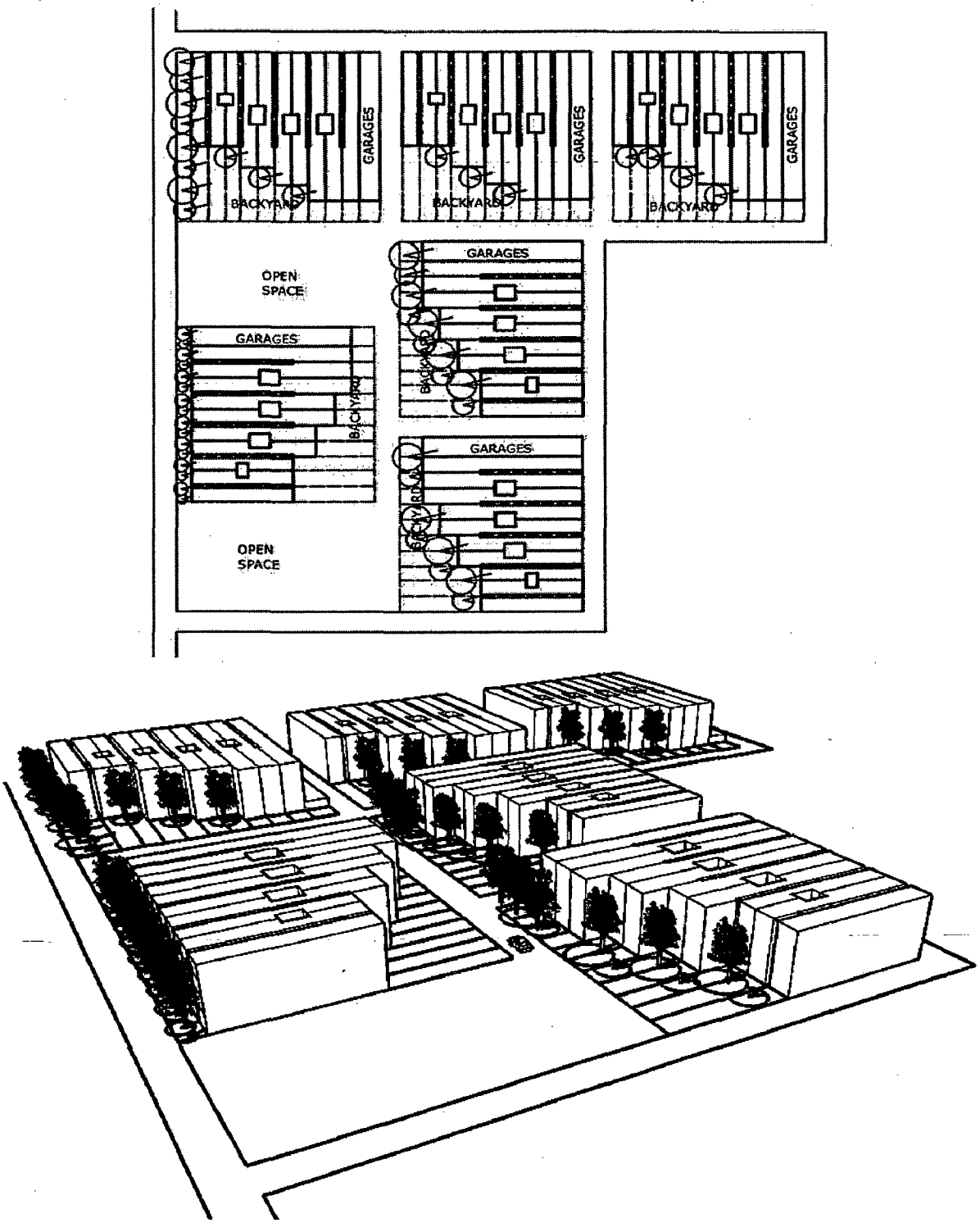
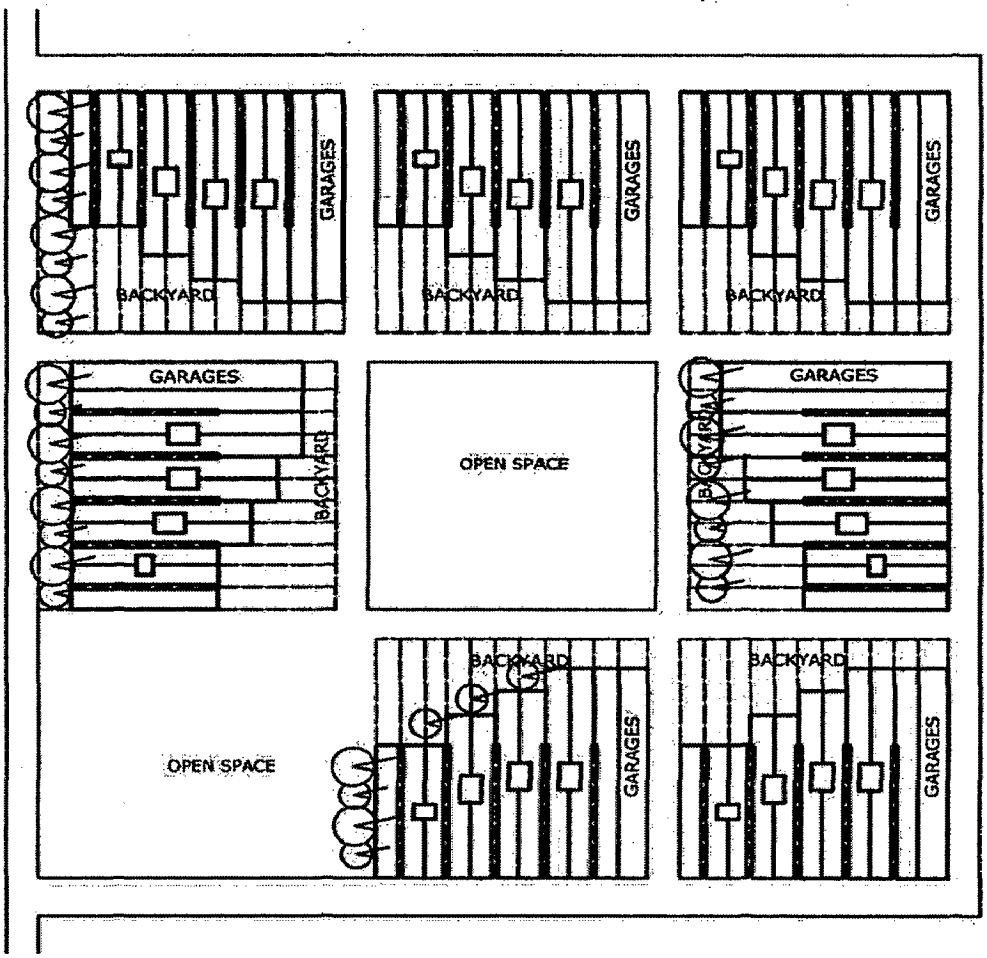


Figure 7.5- Site plan option and view in L-shaped site of Option-1

Number of houses- 240 **Gross area-** 2.41 ha **Gross density-** 100 dwelling units/ha

Net area- 1.5 ha **Net density-** 160 dwelling units/ha



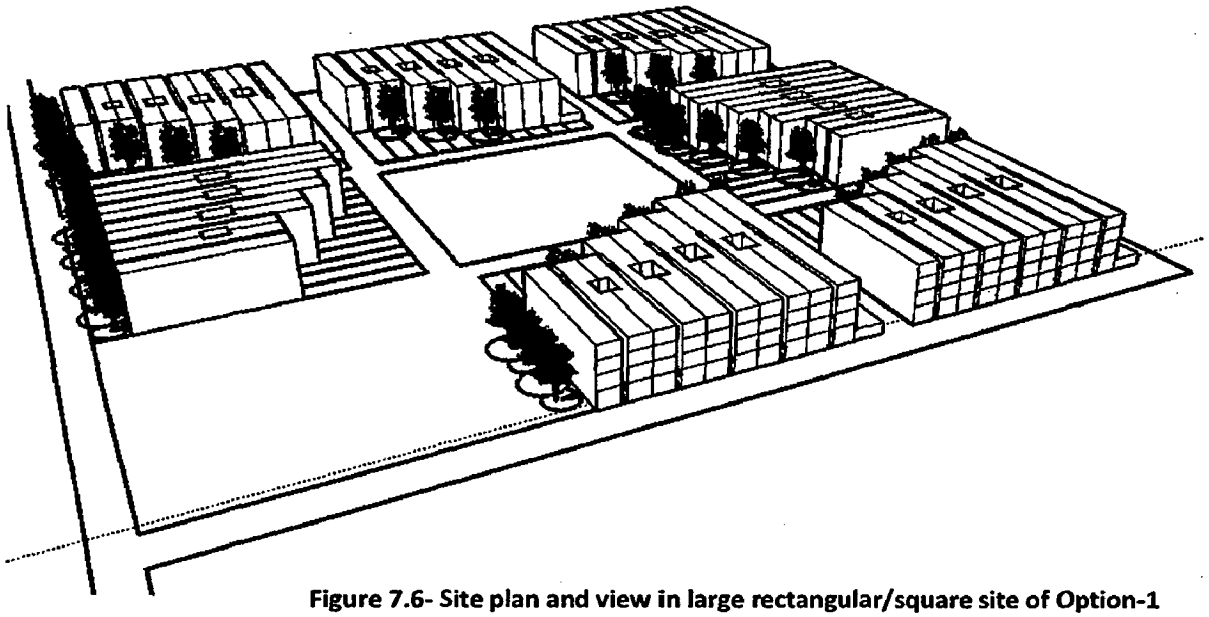
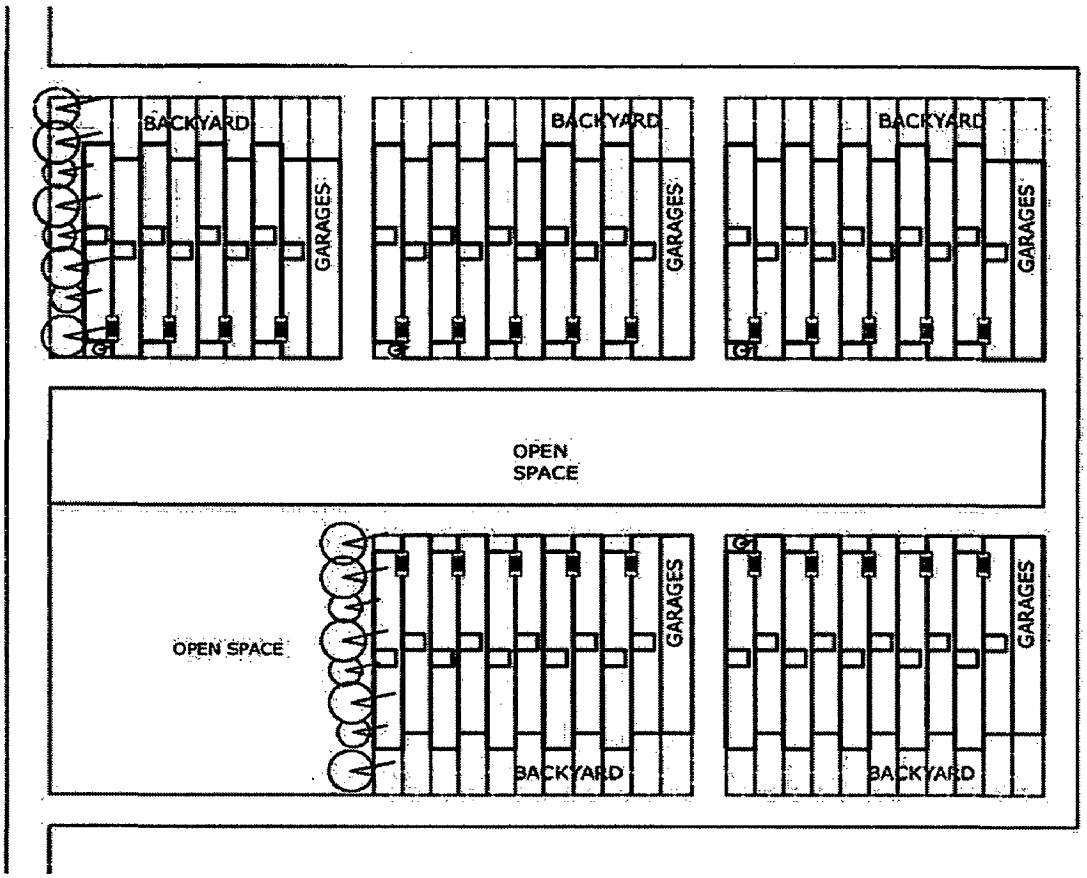


Figure 7.6- Site plan and view in large rectangular/square site of Option-1

Number of houses- 280 **Gross area**- 3.13 ha **Gross density**- 90 dwelling units/ha

Net area- 1.76 ha **Net density**- 159 dwelling units/ha

Different arrangements in planning layout of option 2



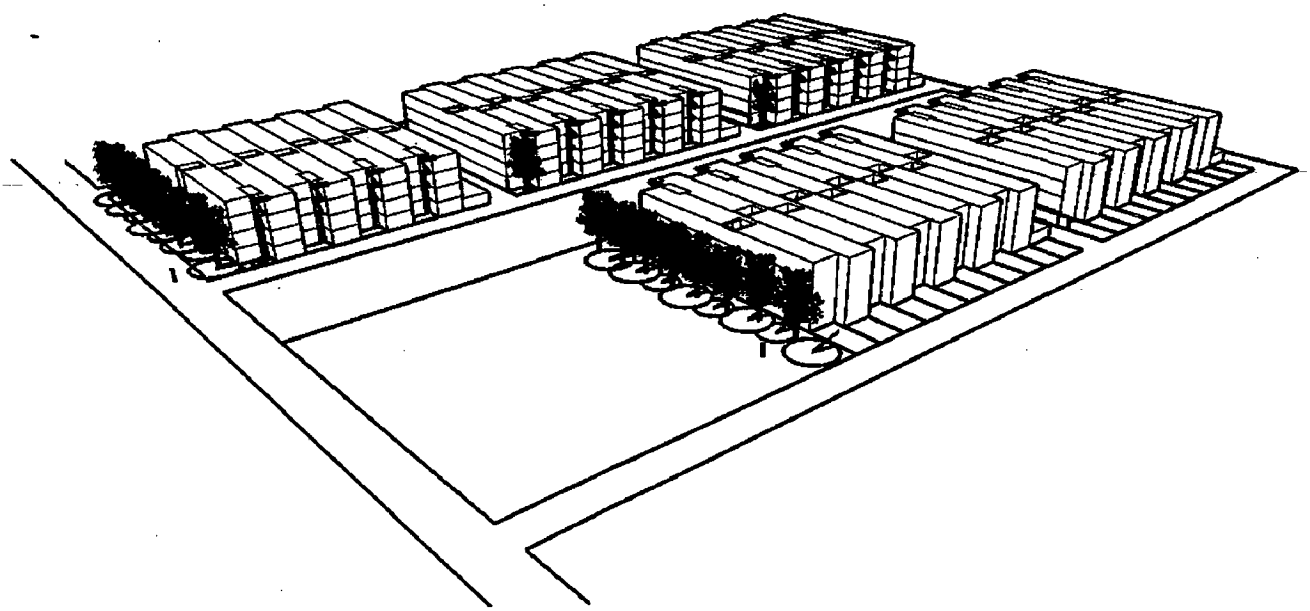
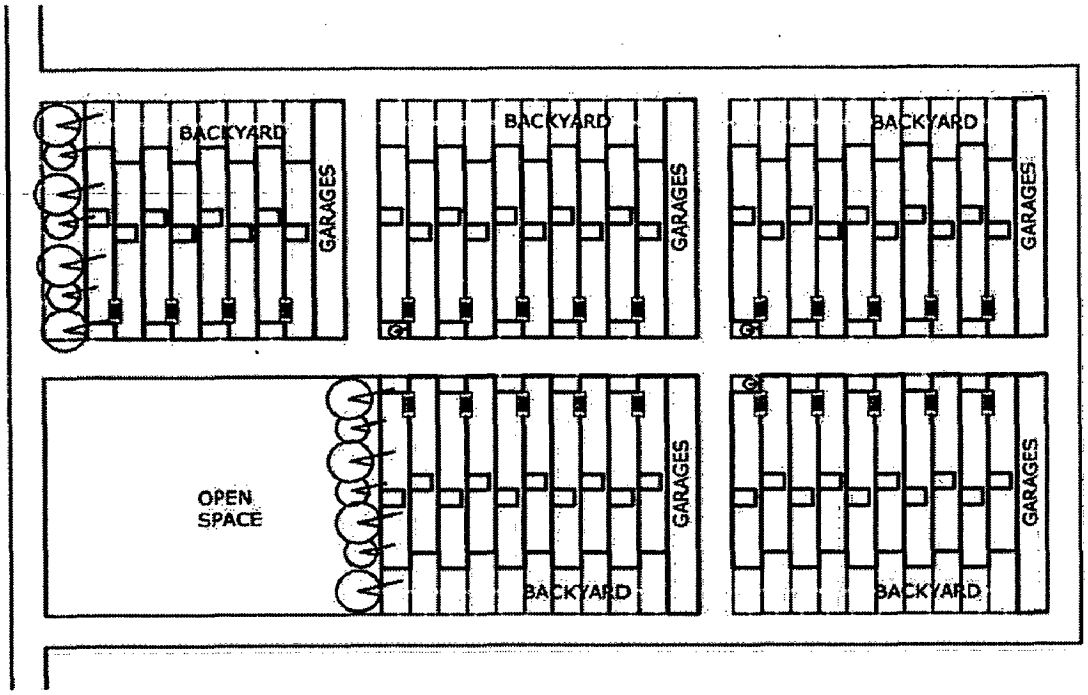


Figure 7.7- Site plan option-1 and view in rectangular site of Option -2

Number of houses- 192 **Gross area-** 2.53 ha **Gross density-** 76 dwelling units/ha

Net area- 1.32 ha **Net density-** 145 dwelling units/ha



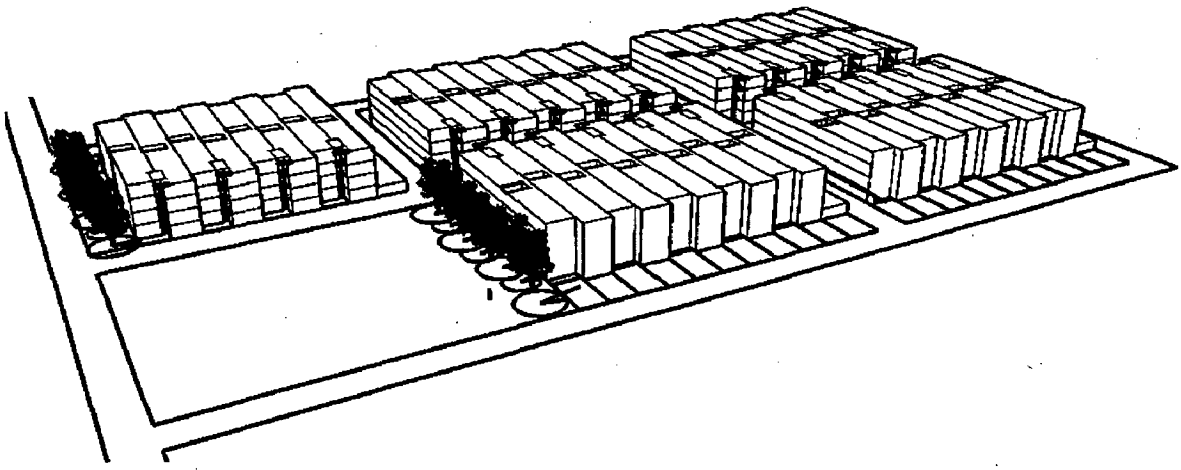


Figure 7.8- Site plan option-2 and view in rectangular site of Option-2

Number of houses- 192 **Gross area-** 1.93 ha **Gross density-** 100 dwelling units/ha

Net area- 1.22 ha **Net density-** 157 dwelling units/ha

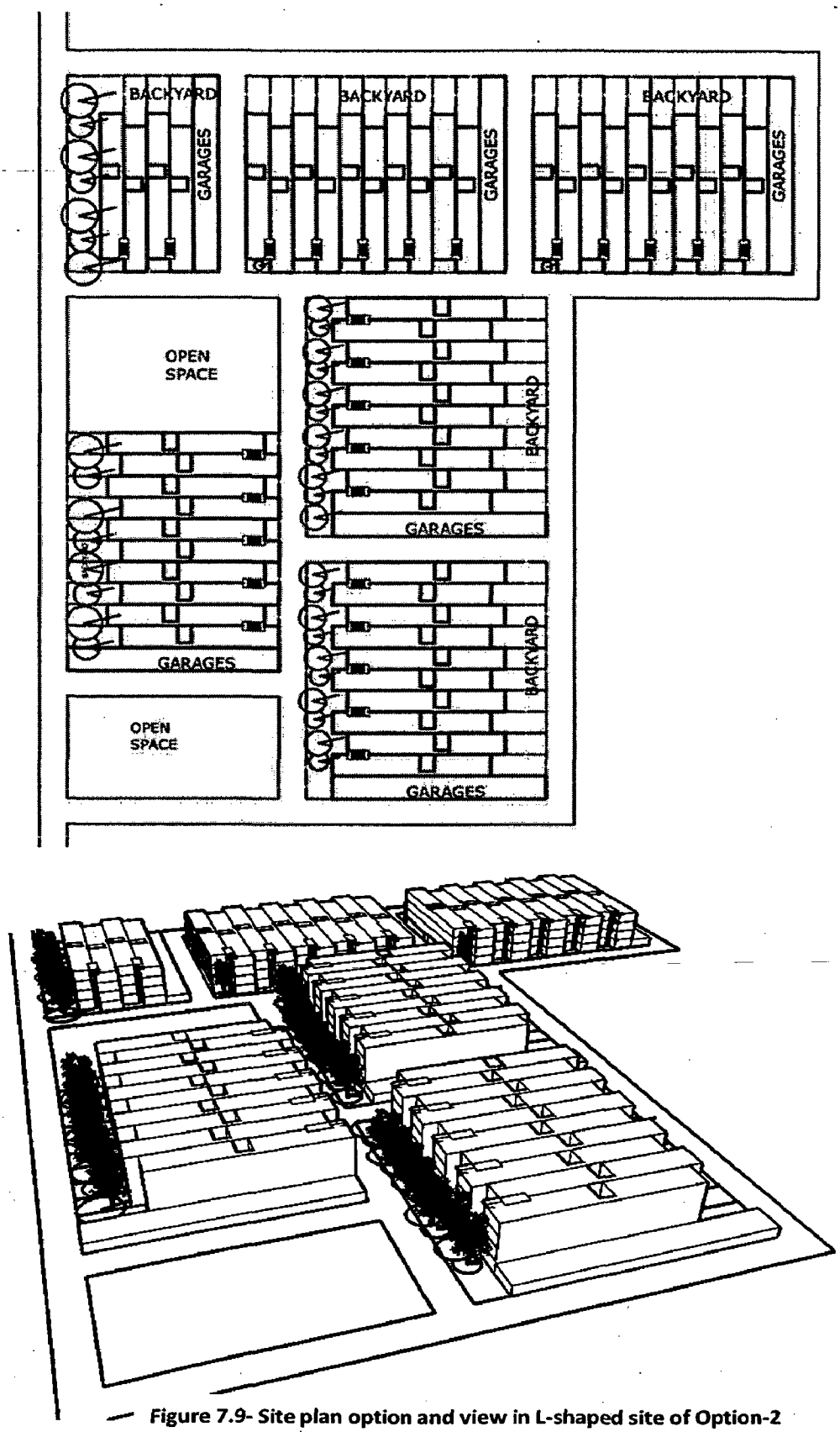
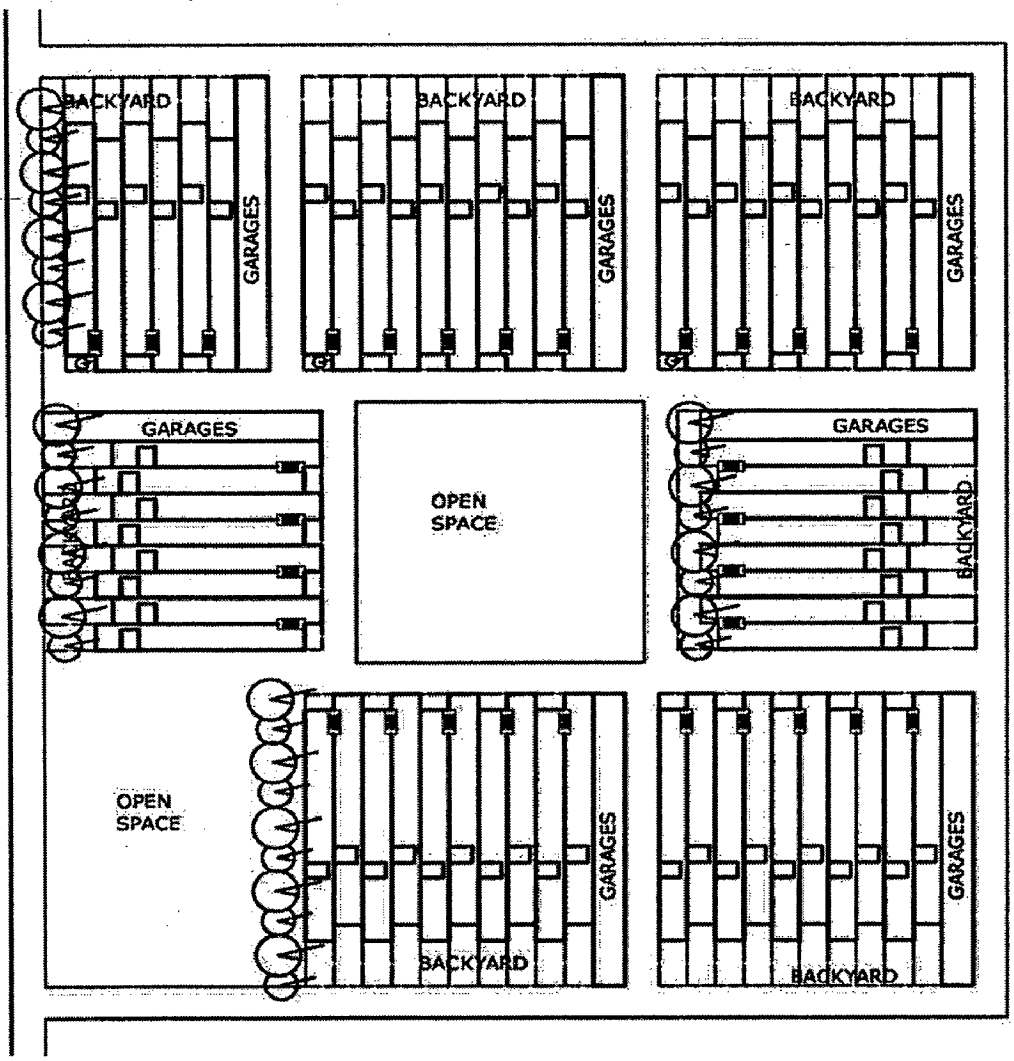


Figure 7.9- Site plan option and view in L-shaped site of Option-2

Number of houses- 216 **Gross area-** 2.38 ha **Gross density-** 91 dwelling units/ha

Net area- 1.48 ha **Net density-** 146 dwelling units/ha



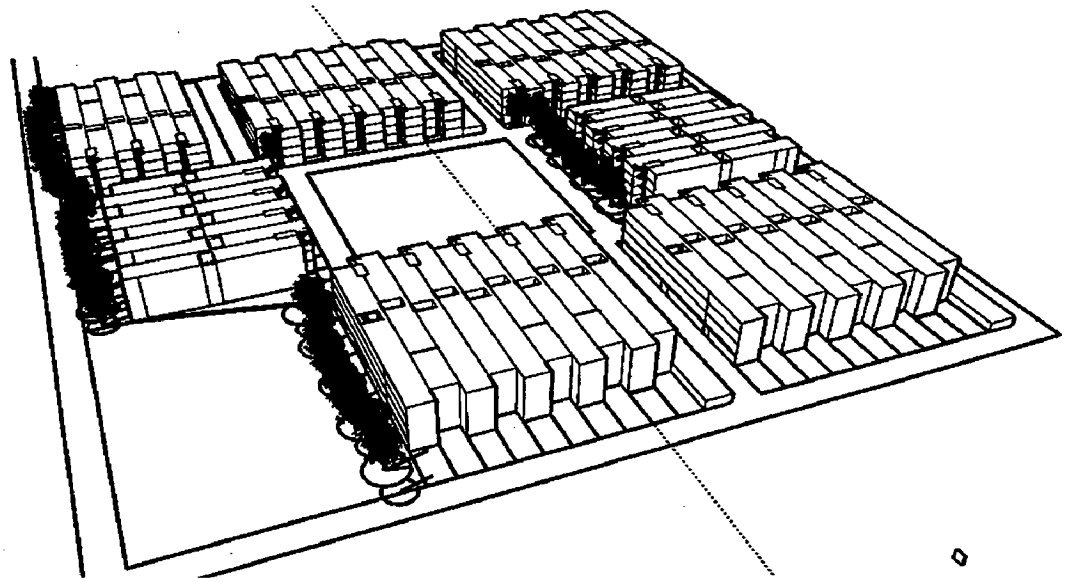


Figure 7.10- Site plan option and view in large rectangular/square site of Option-2

Number of houses- 248 **Gross area-** 3.24 ha **Gross density-** 77 dwelling units/ha

Net area- 1.91 ha **Net density-** 130 dwelling units/ha

Planning layout of option 3

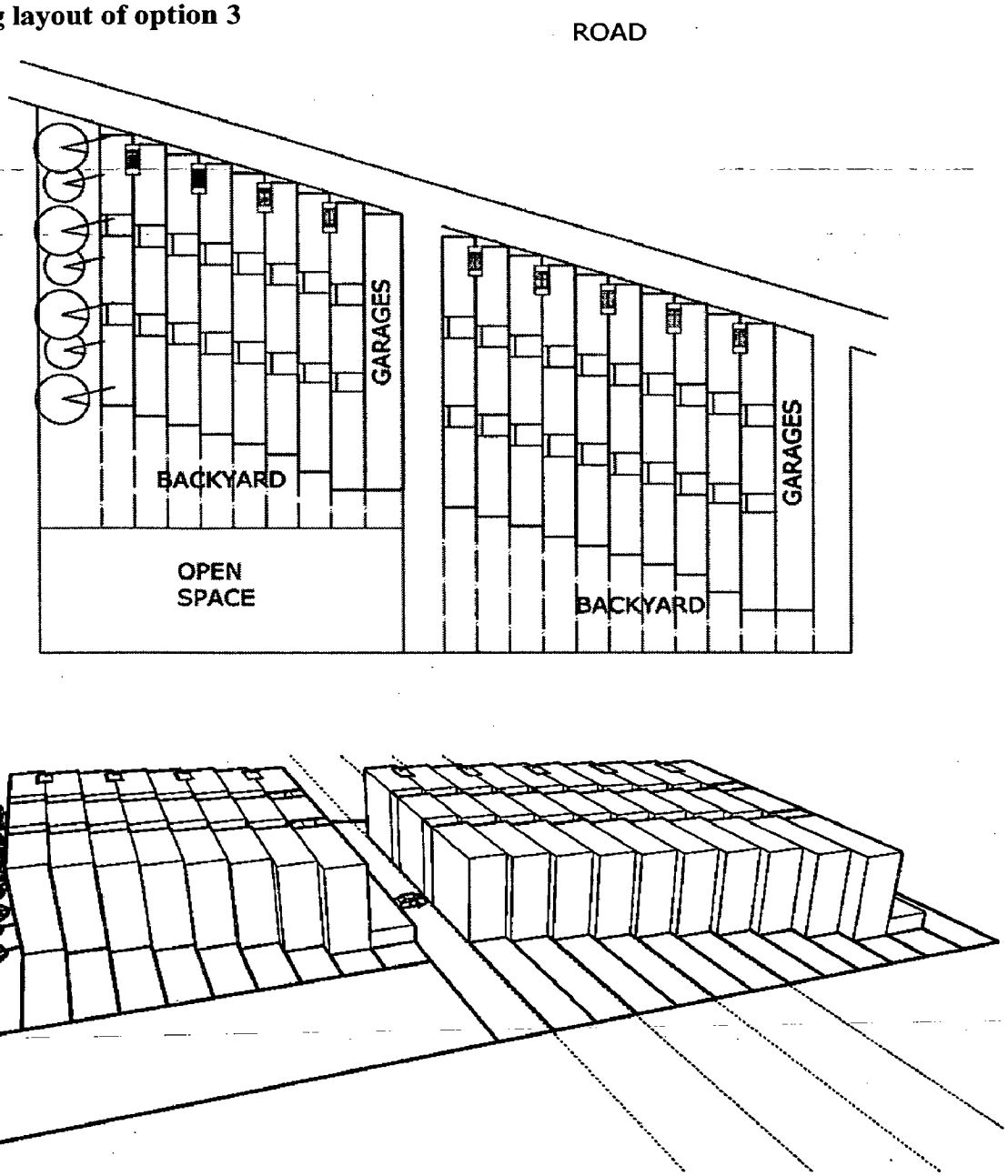


Figure 7.11- Site plan option and view in irregular site in trapezoidal shape of Option-2

Number of houses- 72 **Gross area-** 0.80 ha **Gross density-** 90 dwelling units/ha

Net area- 0.56 ha **Net density-** 128 dwelling units/ha

In all the cases, four storeyed structures are arranged in the site layouts. A maximum of ten buildings were arranged in a row and after that the continuity is broken by providing lanes in between. Different planning layout options obtained different densities, ie Net density between 125 and 165 and gross density between 75 and 105. Thus in all the options medium density is

obtained by providing four storeyed buildings, backyards for individual buildings and open space/community space common for the entire community.

CHAPTER 8

CONCLUSION & SCOPE FOR FUTURE RESEARCH

8.1 PREAMBLE

Conclusions are drawn from the various preliminary studies and analysis from the literature review, literature based case studies and live case studies from the study area, analysing the case studies. Scope for future research based on this dissertation is also discussed.

8.2 CONCLUSION

From the entire study it was found that vernacular buildings have evolved their planning and design aspects over a long period of time and hence are more climate responsive than modern buildings. This makes taking lessons from vernacular architecture, in the modern context a necessity. It could also be seen that vernacular buildings are energy conserving and 'green'. Row houses were found out to be the best option in terms of climate responsiveness, as the solar heat gain of row houses is less compared to courtyard houses and it also has efficient ventilation. Row houses with courtyards are cooler and more comfortable.

Row houses are an appropriate solution in the modern context. In modern context, row houses of 4 storeys or those that have height up to 15m can be provided to attain both climate responsiveness and medium density. In the modern context, the advantages of vernacular row houses like backyards may be incorporated with the present spaces. Row houses can also be used in different regions as it is suitable for most of the climate types. Even building byelaws should provide for such changes to be made effective.

8.3 SCOPE FOR FUTURE RESEARCH

As the guidelines framed out of this dissertation was limited to low rise, up to 4 storeys and medium density residential development of urban housing, further research may be done on high density and medium rise residential development in Kerala.

It is also recommended to conduct similar studies in vernacular residential buildings in other zones of Kerala, like highlands and also in different parts of the country having

different climatic conditions. The results and findings obtained from the research can be applied to the modern residential buildings to make it climate responsive.

Research can also be done for other typologies of vernacular buildings in Kerala.

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ANNEXURES

ANNEXURE-I

User Response Questionnaire

1. Household Data

a. Total number or persons in the household: Male [ ] Female [ ]

b. Number of members: earning [ ] non-earning [ ]

c. Occupation

Head of Household	Other earning members of the household		
1	2	3	4

d. Total monthly income of the household: (in rupees)

[ ] above 50,000 [ ] between 30,000 and 50,000

[ ] between 20,000 and 30,000 [ ] between 15,000 and 20,000

[ ] between 10,000 and 15,000 [ ] between 5,000 and 10,000

[ ] below 5,000

2. Particulars of your residence: (Tick off whichever statement is applicable)

a. Tenure: [ ] Owned [ ] Rented [ ] Others.....

b. Type: [ ] Single-storied [ ] Double-storied

c. Floor [ ] wood-cement [ ] Madras terrace [ ] R.C.C[ ] Others.....

d. Wall [ ] Laterite [ ] Stone [ ] Mud [ ] Brick [ ]
Others.....

e. Roof [ ] Tin sheet [ ] Tile [ ] R.C.C [ ] Others.....

f. Number of habitable rooms: (room excluding toilet, kitchen, store)

[ ] One [ ] Two [ ] Three [ ] Four [ ] Five [ ] Six [ ] More

g. Floor Area:	[ ] More than	[ ] Between	[ ] Between	[ ] Between	[ ] Less than
(sq.m)	200	150-200	100-150	50-100	50
h. Plot Area	[ ] More than	[ ] Between	[ ] Between	[ ] Between	[ ] Less than
(sq.m)	500	300-500	200-300	100-200	100

i. Orientation of residence.....

3. Do you feel the spaces or areas in the old structure are catering the present needs of living?

[ ] Yes,.....

[ ] No,.....

4. Do you find your residence cool and comfortable to live in, without using fan, cooler

[ ] Yes, [ ] throughout the year [ ] throughout the house

[ ] for six to nine months [ ] in part of the house

[ ] for three to six months

[ ] No,

5. Do you ever use artificial light during day time?

[ ] Yes, [ ] in toilet [ ] in store [ ] in kitchen [ ] other rooms.....

[ ] throughout the year [ ] For six to nine months [ ] For three to six months

[ ] No,

6. What is the average monthly electricity consumption in your household?

[ ] By light meter .....units [ ] By power meter .....units

7. What cooking appliances does your household use normally?

[ ] Electric oven/ Hot plate [ ] Gas stove

[ ] Kerosene Stove [ ] Charcoal oven

[ ] Firewood Chula [ ] Others

(Specify).....

8. What (other) electric appliances do you use regularly? (Specify number)

[ ] Electric light ..... [ ] Fan

[ ] Radio ..... [ ] Tape/ Cassette recorder

[ ] Record Player ..... [ ] Fridge

[ ] Television ..... [ ] Electric iron

[ ] Geyser ..... [ ] Mixer/Grinder

[ ] Others(specify) .....

.....

9. For what average duration do you use electric fan or cooler in your house?

(Tick off the appropriate statements from both columns).

In a year	In a day
[ ] Throughout the year	[ ] All 24 hours
[ ] For six to nine months	[ ] From 12 to 24 hours
[ ] For three to six months	[ ] For less than 12 hours

10. Which floor do you feel is more thermally comfortable?

a. During daytime

[ ] Ground floor

[ ] First floor

[ ] both

b. During night time

[ ] Ground floor

[ ] First floor

[ ] both

11. Why do you live in agraharam?

[ ] Own house [ ] Cheaper rent [ ] Good location/environment [ ] Others

12. Would you like to move out of agraharam if opportunity arises?

[ ] Yes [ ] No

13. What according to you are the benefits/ positive aspects of living in agraharam?

14. What according to you are the drawbacks/ negative aspects of living in agraharam?