# DESIGN CONSIDERATIONS FOR RESIDENTIAL BUILDINGS OF HOT-DRY CLIMATE WITH SPECIAL REFERENCE TO GULBARGA (KARNATAKA)

**A DISSERTATION**

***Submitted in partial fulfilment 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 **"DESIGN CONSIDERATIONS FOR RESIDENTIAL BUILDINGS OF HOT-DRY CLIMATE WITH SPECIAL REFERENCE TO GULBARGA (KARNATAKA)"** in partial fulfilment of the requirement for the award of the Degree of **MASTER OF ARCHITECTURE** submitted in the **Department of Architecture and Planning** of the Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during the period from **July 2001 to January 2002** under the supervision of **Prof. (Mrs.) Rita Ahuja**.

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

Place : Roorkee

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This is certified that the above statement made by the candidate is correct to the best of my knowledge.

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# ABSTRACT


This thesis examines the possibilities to provide thermal comfort in Residential Building in hot-dry climate by passive cooling system in Gulbarga (Karnataka).

In doing so, it identifies three basic areas to provide thermal comfort by passive cooling method;

(1) The construction techniques used for the building envelope. To reduce the heat transfer and provide thermal comfort and reducing the load.

(2) By identifying the parameters of climate responsive design in hot-dry climate and the application those parameters in Architectural design.

(3) Identifies the locally available method for construction its for thermal comfort, cost effectiveness and environment friendly.

The study of traditional vernacular passive design techniques, practice and analyzed through selected care studies and compared to the conventional building to understand under laying principles. Also study of modern passive cooling method used in hot-dry climate.

During these days of energy crises it is important that the building is designed in such a manner that minimum energy is needed during usage. In this context proper selection of roof and wall materials and sections. In specific climate is significant to achieve comfortable living and working condition. The requirement for designing thermally comfortable building is minimum flow of solar heat in to the building.

Fly-ash is abundantly available from Raichur thermal power plant near Gulbarga. Fly-ash as a building material for manufacturing bricks, mortar and

concrete. To solve the environmental problem and energy crises. So fly-ash is used as a building material.

Thesis arrives at the proposition that the architectural feature in the traditional domestic architecture of Gulbarga, as evident from the case studies, was the result of conscious designing and constructional practice for achieving thermal comfort.

In the end it proposes some guide lines, thump rules, to any architect/builder for designing/constructing a better climatic responsive building in hot-dry climate, Gulbarga (Karnataka).

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# INTRODUCTION

## 1.1 GENERAL

***"Nature is more than a bank of Resources to draw on it is the best model we have for all the design problems we face".***

Mains basic needs, whether he lives in a caves, a hut, or a castle, are similar. He must have food, clothing, and shelter. Shelter provides protection from extremes of climate and other sources of danger or discomfort. The basic function of nearly all buildings is to provide protection from extreme of climatic factor like heat and cold, and provide for certain fundamental human activities such as recreation, food sleep and work.

Hot-dry climates are characterised by very hot, dry air and dry ground. Day-time air temperatures many range between 27° and 49 °C. Humidity is continuously moderate to low. There is little or no cloud cover to reduce the high intensity of direct solar radiation. The clear skies do, however permit a considerable amount of heat to be re-radiated to outer space at night the dry air, low humidity and minimal rain fall discourage plant life, and the dry dusty ground reflects the strong sunlight, producing an uncomfortable ground glare local thermal wind of tern carry dust.

The hot-dry climates is roughly between the latitudes 15° and 30°, North and South of equator even extending as far as 45° on north and south of equator Gulbarga is located 17° N.

In hot-dry climate heat is the dominant problem where for the greater part of the year building serves to keep the occupants cool, rather than the warm.

In contemporary architectural thinking there are many approaches to man's physiological, as well as aesthetic, well being. To treat climate as a primary factor is justifiable only if the thermal environment proves to be one of the influential factors on the architectural expression.

Before designing and constructing new dwelling in a region it would, more often than not, be rewarding to study the style and structure of the traditional dwelling of the area, as they are the outcome of generation of experience and possess features suited for the local environment.

In constructing shelter for himself, man has always had to battle against nature. The outcome of this struggle has varied as man advanced technologically. The climate of a region basically consists of prevailing weather conditions which comprise various elements lime wind, temperature, and rainfall. All there elements should influence, both directly and indirectly, the design of building in a particular area.

In hot-dry climate physiological comfort by day depends mainly on a reduction of the intense radiation from the sun, ground and surrounding building. It is basically a problem of protection against heat.

To survive and progress, man has learned from nature has to protect himself against the weather and has used his ingenuity to turn its liabilities into Assets. From this unfolds the whole saga of the architecture as numerous and varied as there are different climates, offering their new solution not only for survival but for happy living.

Roger Bacon wrote four centuries ago "NATURE CAN ONLY BE MASTERED BY OBEYING ITS LAWS."

Man feels comfortable when body can maintain heat balance with its thermal environment without stresses unfavorable thermal discomfort which result in loss of efficiency and may even lead to breakdowns of health. Therefore, design of building for human occupation for achieving thermal comfort indoors is of great importance.

The hot dry air pulls the moisture from the ground like a suction pump, so moisture for plant growth is not available in the ground due to the lack of vegetation, the barren light coloured terrain reflects much of the radiation, thus augmenting the direct solar radiation. The total direct and reflected radiation become an important factor in human comfort and buildings design.

## 1.2 IDENTIFICATION OF THE PROBLEM

***"No Myths no Religious Miracle, no human invention begin to compare with nature".***

Mankind lived in caves before civilisation. The cave is our original cradle and very comfortable due to its cool interior.

The interior surface of the cave is dark rock, which is kept cool by water streams which are themselves cooled by evaporation to the wet bulb temperature of the air.

The mughals used to divert water streams to flow through their marble palaces for cooling their surrounding. The white marble absorbed less heat as the evaporatively cooled flowing water would carry it away. At night it would pre-cool the building mass so that is would remain cooler during the day.

Traditionally, houses in hot-dry climate have been built close together depending on each other for mutual shading and insulation. The buildings themselves have flat, vaulted and domed roofs, with walls of heavy, thermal lag materials and very small opening.

Stone or mud bricks is the favorite material for walls, and flat roof are composed of a thick layer of dried mud covered with a second impervious layer. Dumes and plasted over with mud or lime mortar.

The heat storage capacity of thick exterior walls and roofs tends to narrow the internal temperature range, bringing it to a level fairly close to the average external temperature small openings in walls are used to minimize ventilation and restrict the entry of hot, dust-laden outdoor air. This also has the result of reducing glare arising from the hot reflective surfaces outside. Buildings are compact and close. Together, so as to expose a minimum surface to radiation and hot, exterior air, while providing maximum volume for interior use.

Building tend to face inwards on sheltered courtyard, which offer not only privacy but shelter from the dust laden wind. Courtyard and roofs are used for sleeping this is partly due to the fact that the thick heat absorbing walls have, by evening, started to radiate heat into the interior thereby making the interiors warmer than the exterior at night. The most important consideration to achieves comfort conditions in buildings in hot-dry conditions is to reduce the internal day temperature.

Today building activity has increased to a large scale. Newly developed materials and techniques of construction are being employed in the construction of diverse type of building for residential, educational. Industrial commercial, and other purpose to meet aspiration of the people.

Under the crushing pressure of rising construction costs and also the influence of western architecture, the architects in this country have been planning and designing building which, most offer, are not efficient to the desirable extent from climatic comfort consideration. It may be partly because the materials and techniques are changed but is so also because the intentive and conventional approach in respect of thermal design of building.

The purpose of climatic design is to maintain, or to minimize the energy cost of maintaining thermal comfort conditions within the building interiors maintenance of thermal comfort is a problem of heat balance between the body and its surrounding.

## 1.3 THE NEED

***"Intelligence, by one definition, must be the ability to respond adaptively to the environment i.e. the ability to plan a course of action based upon information gained through the senses".***

***- John Todd Simonds***

The problem of residential building are particularly acute in developing country like India. With even growing population, the struggle to provide shelter to the teeming millions at affordable cost has surfaced as the issue of highest importance the world over.

A good physical environment in building is necessary for the well being of residents and for improving the productivity. It will increase efficiency of work and for recreation sleep by maximum utilization of natural means to obtain an acceptable Indoor environment.

## 1.4 AIMS AND OBJECTIVES

This investigation is an attempt to study how building can be designed and constructed in hot dry climate for thermal comfort.

The major objectives of this thesis is;

- To review the available data for design and its application in the design of residential building for thermal comfort in hot dry climate.
- To prepare a set of guidelines for design and construction of climatically responsive residential building in hot dry climate.
- To select the local available materials for thermal comfort in residential building in hot dry climate.

## 1.5 SCOPE

The present investigation has ample scope. Some important of there are listed below.

(1) It would pave the way for understanding the thermal comfort requirement of this particular climate and can be used as a guideline for any Architect or Engineer working in this climate.

(2) It would clearly identify and define the parameters which are highly responsible for thermal comfort condition.

(3) If the proposed guideline is implemented by the Architects or builders it would pave the way for solving the problem of thermal comfort in building in hot-dry climate.

## 1.6 LIMITATION

(1) India is a vast country which extents between 8° N to 36° N latitudes and embraces a verity of local climates. It is usually seen divided as two climatic zones, with the peninsular region as the tropical zone and the rest of the country, north of it as a temperate zone. But CBRI, Roorkee had more accurately divided India into six climatic zone for the purpose of desian of

building based on climatic and environmental consideration. "Each of these has its own special environmental and physical characteristics and each of these should be considered in planning of the building. The design criteria of thermal comfort in building would be different for different regions. According to the intensity and direction of Sun & wind, temperature , humidity etc. and the abundance and properties of locally available natural resources like soil, water, trees, building materials etc.

The present investigation confirms to Gulbarga in Karnataka state. Since some homogeneous characteristic are found here which differ from other hot-dry climate. The recommendations may be implemented in the rest of hot-dry climate by taking into consideration the relevant parameters of that data.

(2) So the investigator concentrates more on the way to provide thermal comfort in the building by natural means.

(3) The present investigation focuses only on residential buildings because of the limited time frame available. But the recommendation may be effectively implemented on to other types of buildings.

## 1.7 METHODOLOGY

(1) At the outset, the investigation would analyse the climatological data's and other related literature to infer the thermal comfort needs for hot-dry climate.

(2) Further the primary survey is conducted through case studies by selecting some Traditional and Conventional buildings of this regions to understand the traditional passive techniques which are applied and material used.

(3) The next stage would be to evaluate both these data's and come out with influences which forms the base along with modern techniques in these

fields to prepare a set of policy guideline for designing and constructing a thermally comfortable buildings in hot-dry climate.

(4) Analysis of the building in context of

- Space planning and form
- Environmental control in terms of lighting, ventilation and thermal comfort
- Material and construction techniques
- Special building elements
- Landscape elements

# LITERATURE REVIEW

***"If a central purpose of planning is to create for any person or group of person an environment suited to their needs, the climate must be a very first consideration".***

The building is usually by farther biggest single enterprise in any country, and its decision on planning, design and methods of construction often require accurate information on weather and climate. Over the centuries traditional building techniques were carefully developed in relation to the climatic impacts. Modern architecture and technology have broken with this understanding of the significance of climate. The attempts to correct the shortcomings by engineering techniques haveled to excessive energy demands by air-conditioning. In evaluating the built environment in terms of its effect on man, a choice of criteria must be made. The general procedure is based on the fact that a building is a physical object, acting in the first place as a transformer of outdoor climate to indoor climate. Therefore its efficiency could be evaluated with respect to human thermal comfort the cost involved for improving the indoor environment to satisfy thermal comfort requirements. Human thermal comfort is one of the important objective of air-conditioning technology. Thermal comfort is defined as the condition of mind which expresses satisfaction to the thermal environment. Fanger reported that the reason for creating thermal comfort is to satisfy man's desire to feel thermally comfortable in line with his desire for comfort in other conditions. The primary requirement for thermal comfort is thermal balance between the body and the environment; i.e.

when all the excess heat produced is dissipated to the environment without stressing the thermo-regulatory system of the human body, such as high rate of sweating due to sever heat and shivering due to the sever cold. This ensures the core temperature of the body is kept within the comfort range i.e. 36.5-37.5°C., despite the wide temperature fluctuations in the external environment. The trend over the years is that the architect would do the design and the mechanical engineer would define the mechanical installations required.

## 2.1 HEAT TRANSFER CONCEPTS

Conduction heat transfer usually occurs in solids. In this case the vibrations of the molecules, representing temperature, are transferred to nearby molecules, and thus the temperature in increased. One typical example of conduction is to hold a spoon in a hot cup of coffee. Soon the handle of the spoon becomes hot due to conduction through the metal. Convection heat transfer occurs in fluids. In this process, the fluid is first heated through contact with a hot surface, then the fluid moves to a different location. When this flow is due to the natural buoyancy (i.e., hot air rises), then the process is referred to as natural or free convection. A hot air balloon follows these principles. If the fluid motion in caused by a pump of fan, then the process is referred to as forced convection .the home furnace would be an example of this process.

Radiant heat transfer occurs due to electromagnetic radiation. All objects give off energy due to their temperature above absolute zero, which occurs at 460oF below zero. To prove this, close your eyes and hold your hand a few inches away from your cheek. You will feel a sensation of warmth, even through there is no contact between your cheek and your hand. This is radiant heat transfer. Also consider when you are outside on a cold, sunny winter day. When the sun ducks behind a cloud, you suddenly feel cold. That is also radiant heat transfer. Walk past a west facing brick wall shortly after sunset: you can feel the heat "radiating" off the wall (interally). Finally, consider standing in front of a large picture window on a cold night. someone closes the curtains, and you suddenly feel warmer. Radiant heat transfer again. It is all around us, but since you can't see it or touch it, it is seldom considered. Except in our profession.

## 2.2 THERMAL COMFORT PARAMETERS

There are eight basic parameters that affect thermal comfort, plus a ninth that deals with indoor air quality. Half are under the control of the design team; the rest are controlled by the occupant. Temperature is the basic control parameter for most buildings. All residences have a thermostat to control the temperature of the air in the space. Humidity is the second parameter we can control. This is generally referred to as the relative humidity, although there are other terms such as wet bulb and dew point to define the amount of moisture in the air. Air movement is the third aspect that we can control. The volume and condition of the air being moved, as well as where and how it is injected into the room are determined by the designer. The last design parameter is the mean radiant temperature (MRT) of the space. This is the average temperature of the walls, floor and ceiling—those surfaces which the occupant has radiant transfer with. If these surfaces are cold in winter (as in uninstalled walls or large glass areas), the occupant will feel cold, even though the room air temperature is higher than normal. There are four parameters controlled by other. The activity level (measured in METs) of the occupants affects their comfort. People moving around quickly, like waiters in a restaurant, prefer a lower temperature than sedentary people (like diners). The clothing level (measured in clo) also affect comfort. Stores in winter cater to the customer, who is usually wearing a winter coat. Thus the people who work there must wear a sweater to keep warm.

## 2.3 WHAT IS THERMAL COMFORT?

Man has always striven to create a thermally comfortable environment. This is reflected in building traditions around the world-from ancient history to present day. Today, creating a thermally comfortable environment is still one of the most important parameters to be considered when designing buildings. But what exactly is thermal comfort? It is defined in the ISO 7730 standard as being "That condition of mind which expresses satisfaction with the thermal environment". A definition which is not easily converted into physical parameters.

The complexity of evaluating thermal comfort is illustrated by the drawing. Both persons illustrated are likely to be thermally comfortable, even though they are in completely different thermal environments. This reminds us that thermal comfort is a matter of many physical parameters, and not just one, as for example the air temperature.

Thermal environments are considered together with other factors such as air quality, light and noise level, when we evaluated our working environment. If we do not feel the everyday working environment is satisfactory, our working performance will inevitably suffer. Thus, thermal comfort also has an impact on our work efficiency.

## 2.4 HOW IS BODY TEMPERATURE REGULATED ?

Man has a very effective temperature regulatory system, which ensures tha the body's core temperature is kept at approximately 37°C.

When the body becomes too warm, two processes are initiated first the blood vessels vasodilate, increasing the blood flow through the skin and subsequently one beings to sweat. Sweating is an effective cooling tool, because the energy required for the sweat to evaporate is taken from the skin. Only a few tenths of a degrees increase in the core body temperature can stimulate a sweat production which quadruples the body's heat loss.

If the body is getting too cold, the first reaction is for the blood vessels to vasoconstrict, reducing the blood flow through the skin. The second reaction is to increases the internal heat production by stimulating the muscles, which causes shivering. This system is also very effective, and it can increase the body's heat production dramatically.

The control system which regulates the body temperature is complex, and is not yet fully understood. The two most important set of sensors for the control system are however known. They are located in the skin and in the hypothalamus. The hypothalamus-sensor is a heat sensor which starts the body's cooling function when the body's core temperature exceeds 37°C. The skin-sensors are cold sensors which start the body's defence against cooling down when the skin temperature falls below 34°C.

In the hot and cold sensors output signals at the same time, our brain will inhibit one or both of the body's defence reactions.

**Hot-Dry Climate**

Where the annual rainfall is less, mostly hot and dry condition prevails. In this geographical zone, roughly between the latitude 15° and 25°N North and South of the equator. The highest temperature occurs. There are the sunniest parts on the earth Perhaps the only regions where there is to much of sun.

The characteristic topographical features of this climatic zone are ;

- Strong sunlight reflected the dry light coloured ground,

- Frequent dust storms,
- Little rainfall,

The dwelling the regions are;

- Thick walls,
- Small window openings ,
- Built out of inert materials,
- Mud as the binding materials,
- Flat roofs (peoples sleeps on roof or in varandas),
- Houses are planned facing inwards on to a patio,
- Courtyard planning,
- Blank wall facing street.

## 2.5 HOT-DRY CLIMATE AND TRADITIONAL BUILDINGS

Although buildings have many functions and purpose. It is uncontroversial to say that one of the roles of a building is to provide shelter from the natural elements only in a very few parts of the world is the climate such that people could survive with no shelter an all and even if survival were possible. It would not be comfortable.

Shelter as primitive as those above are usually associated with nomadic people. Permanent settlements allow more substantial shelter to be developed. Often reflecting cultural as well as climatic requirements. A further important factor is the availability of building materials.

In old buildings are richly constructed with massive walls and roof with height ceiling and the traditional dwellings of the poor built with mud, stone and thatch constituted shelter which offered adequate indoor thermal comfort. In olden days, in hot dry climate the planning concept is minimize the outside openings and courtyard planning the openings are opened inside the courtyard. Now building, bye laws are changed. It is required to provide a set back from all sides of the building. All the openings are provided in external wall. It causes the faster transfer of heat from outside environment to inside environment of the building.

## 2.6 HEAT EXCHANGE BETWEEN BUILDING AND ENVIRONMENT

The modifying effect of the envelope materials on the indoor temperature and energy consumption for heating and cooling results from its effect on the heat exchange between the building and its environment. This heat exchange takes place through the envelope by different physical modes. Its rate depends on the thermal properties of the envelope materials, mainly their thermal transmission. Different standard procedures are applied in calculating the heat loss than in calculating the heat gain of a building because of the different effects of orientation, windows' shading, and the color of the various surfaces on the calculations of heat loss and of heat gain.

The heat exchange between building and its environment take place by the process of conduction, convection and radiation.

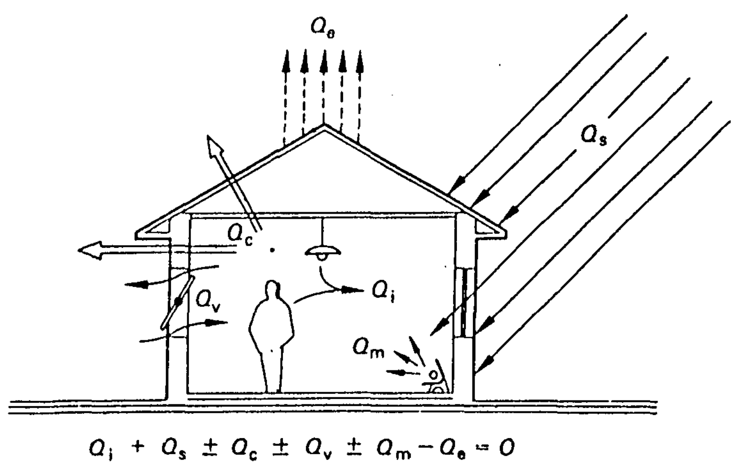



**Fig. 2.1 : Heat exchange of buildings and its environment**

## 2.7 BIOCLIMATIC CHART

A bioclimatic chart on which the comfort zone is defined in terms of DBT and R.H. but subsequently it is shown by additional lines, how this comfort zone is pushed up by the presence of air movement and how is lowered by radiation.

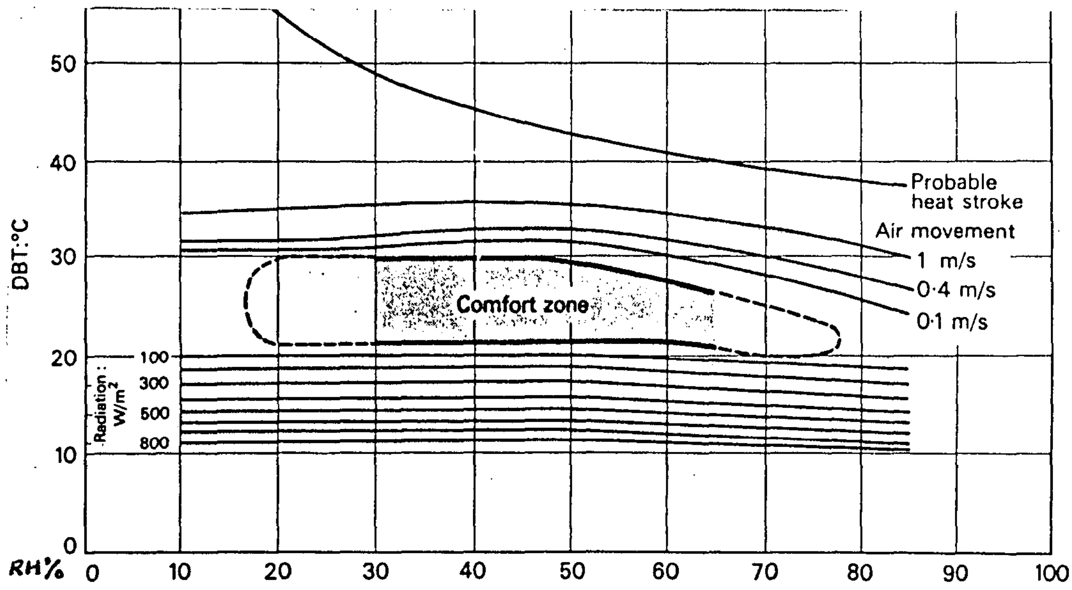



**Fig. 2.2 : Bioclimatic Chart showing comfort zone**

## 2.8 VIEWS OF SELECTED ARCHITECTS

Several architect of this date are deeply influenced by the architectural heritage and they are producing. Contemporary with the primitive aspects a few c' them can be listed below.

Charles Correa

B.V. Doshi

Uttam C. Jain

Laurie Baker

Raj Rawal

**CHARLES CORREA**

He uses sunlight and wind as tangible raw material for his design that are closely attained on the environment and local conditions as he has done in Bharat

Bhawan in Bhopal. He designs according to climatic requirements of a particular place. For north India he provides open terraces but covered balconies due to high humidity. In Mumbai as done in Kanchanganga apartments. He tries to take maximum advantage of wind direction and protect main areas from direct sun by providing verandahs on East and West faces just as in Kanchanganga apartments. According to him "there are some phenomenon which are perennially. Fascinating among them are the subtle variation of light, and the modulations of the ambient air which we sense as we step out from within on enclosed room into a varandah and thence perhaps into an open to sky courtyard, which itself may be qualified by an over heated pergola, plants, or by the spreading branches of tree.

**BALKRISHANA V. DOSHI**

He creates design based on climate, considering flow of breeze, orientation of sun and micro climate. In the Institute of Indology in Ahmedabad he has not used Mechanical ventilation and has lit it by natural means through slots around the edges.

In his residence in Ahmedabad he has used 'Jharokas' for forced ventilation. He tries his best to provide cross ventilation and take advantage of existing land scope element as done in school of Architecture and planning, Ahmedabad. Element have been used to cast deep shadows on the exposed surface as done in 'Sangath' in Ahmedabad copying the elements of historical buildings.

**UTTAM C. JAIN**

He has tried to induce ventilation due to shaft effect as done in Jodhpur university complex.

**LAURIE BAKER**

He stresses on the use of techniques for construction based on local climate and local building materials his construction. Technique such as brick screen wall slopping tiled roof, over hanging eaves, brick, jali in place of glass of windows and corbetted openings in place of lintel above the openings. The best example which he has designed is the Centre for Development Studies, Trivandrum.

**RAJ REWAL**

He is said to be a climate conscious designer. His concern for climate and comfort has found its physical manifestation in the cluster and pergola. The best example for such a work is Asiad village, Mumbai. The interlocking space, shaded courts, narrow connecting paths, terraces shaded with pergola, use a jalis, shading devices etc.

# STUDY AREA PROFILE OF GULBARGA

## 3.1 GEOGRAPHICAL ASPECT

**Location**

| | | |
|---|---|---|
| Place | - | Gulbarga |
| Latitude North | - | $17^0$ 21' |
| Longitude East | - | $76^0$ 51' |
| Mean Sea Level in m | - | 458 |

**General Boundaries**

It is bounded on the north by Bidar District of Karnataka state and Osmanabad District of Maharashtra, on the East by Medak and Mahabubnagar District of Andhra Pradesh, on the south by Raichur District and on the west by Bijapur District of Karnataka state and Sholapur District of Maharastra state. The river Krishna forms the natural boundary between Gulbarga and Raichur Districts and river Bhima forms the natural boundary between Bijapur and Gulbarga District.

**Area and Population**

The total area of the District is 6, 271.2 sq. miles or 16,242.4 sq. km. In area it occupies the second place among the districts of Karnataka state. The population according to the 1991 census was 25.82 lakhs. In population it stands seventh.

In density, it is the fourteenth with a population of 160 per sq. km.

## 3.2 CLIMATIC PARAMETERS

The Climate of the district is generally dry and healthy. The Gulbarga district enjoys only two seasons, Summer and winter with only a merge rainfall of about 30 inches. The district enjoys a bright sunlight almost throughout the year. This bright sunlight, excessive heat, scanty rainfall and a abundance of stone has affected a great deal of the Domestic Architecture.

### 3.2.1 TEMPERATURE

Hot during summer, cool during winter and warm humid during monsoon season.

* December is the coldest month with the mean daily max temperature at 29.7°c and the mean daily min at 14.8°c.
* From the middle of the February, temperature rises rather rapidly till May, which is the hottest month. The mean daily max. temp. during the month is 40.6°c and the mean daily min. temp is 25.9°c. The day temp. Sometimes go up to 45°c in the hot season. The dry heat is sometimes very tiring.
* When the S-W monsoon advances into the District by about the first week of June, temperatures decrease appreciably and the weather becomes milder.
* After October, both day and night temperatures decrease gradually, the drop in the night temperatures being more rapid.

**TABLE 3.1 : NORMAL OF TEMPERATURE**

| Sl. No. | Months | Mean Daily Max. Temperature | Mean Daily Min. Temperature |
|---|---|---|---|
| | | °C | °C |
| 1. | January | 30.4 | 16.0 |
| 2. | February | 33.4 | 18.5 |
| 3. | March | 36.8 | 21.7 |
| 4. | April | 39.1 | 25.0 |
| **5.** | **May** | **40.2** | **26.3** |
| 6. | June | 35.0 | 23.8 |
| 7. | July | 31.4 | 22.5 |
| 8. | August | 31.2 | 22.2 |
| 9. | September | 31.1 | 21.9 |
| 10. | October | 31.9 | 21.0 |
| 11. | November | 30.4 | 17.5 |
| 12. | December | 29.5 | 15.1 |

| Mean Monthly Maximum Temperature $^0C$ | | | | Mean Monthly Minimum Temperature $^0C$ | | | | Mean Highest of the Month $^0C$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan. | May | Aug. | Nov. | Jan. | May | Aug. | Nov. | Jan. | May | Aug. | Nov. |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 30.7 | 40.8 | 31.5 | 30.7 | 15.5 | 25.9 | 21.9 | 17.3 | 33.2 | 43.3 | 34.9 | 33.1 |

| A. Mean Lowest of the Month $^0C$ | | | | Maximum ever recorded $^0C$ | Minimum ever recorded $^0C$ |
|---|---|---|---|---|---|
| Jan. | May | Aug. | Nov. | | |
| 13 | 14 | 15 | 16 | 17 | 18 |
| 11.5 | 22.3 | 20.2 | 12.6 | 45.0 | 6.7 |

### 3.2.2 HUMIDITY

The period from December to May is the driest part of the year when the relative humidity in the mornings is between 40 and 60 percent, and in the afternoons about 20 to 30 percent. Humidity increases by about 20 to 30 percent during the South-West monsoon months.

**TABLE 3.2 : RELATIVE HUMIDITY**

| Sl. No. | Months | Relative Humidity | |
|---|---|---|---|
| | | 0830 hrs. IST | 1730 hrs. IST |
| 1. | January | 54 | 27 |
| 2. | February | 43 | 24 |
| 3. | March | 36 | 20 |
| 4. | April | 41 | 22 |
| 5. | May | 47 | 26 |
| 6. | June | 71 | 47 |
| 7. | July | 81 | 62 |
| 8. | August | 81 | 59 |
| 9. | September | 80 | 61 |
| 10. | October | 48 | 48 |
| 11. | November | 57 | 35 |
| 12. | December | 56 | 31 |

### 3.2.3 SKY CONDITION

Skies are moderately to heavily clouded in the S-W monsoon period. Cloudiness decreases during the post-monsoon season. During the rest of the year, the skies are generally clear or lightly clouded.

### 3.2.4 RAINFALL/PRECIPITATION

The average annual rainfall in the District is 776.5 mm. The rainfall increases from the South -West towards the North-East. The rain fall in the South-West monsoon season constitutes about 80 percent of the annual rainfall. September is the rainiest month. The District gets some rain during the latter part of the summer and post-monsoon months mostly as thunder showers.

The variation in the rainfall from year to year is large. In the 50 year period from 1901 to 1950, the highest annual rainfall amounting to 200 percent of the normal was received in 1903; 1920 was the year with the lowest rainfall which was 51 percent of the normal.

On an average, there are 47 rainy days in a year in the District.

**TABLE 3.3 : NORMAL RAIN FALL IN mm (1901 To 1990)**

| District | Jan. | Feb. | March | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Gulbarga | 6.3 | 6.2 | 9.3 | 19.0 | 35.6 | 107.7 | 146.0 | 136.5 | 198.6 | 69.8 | 26.1 | 5.3 |

| B. C. | Mean Monthly Total Rainfall (m.m.) | | | Mean Annual Total Rainfall (m.m.) | Heaviest Rainfall within 24 hours (m.m.) |
|---|---|---|---|---|---|
| Jan. | May | Aug. | Nov. | | |
| 1 | 2 | 3 | 4 | 5 | 6 |
| 5.3 | 28.5 | 128.8 | 27.9 | 746.0 | 147.0 |

### 3.2.5 WIND

Winds are generally light to moderate with some increase in force in the latter half of summer and the monsoon season. Winds are from directions between

South-West and North–West in the monsoon season. In the post-monsoon season, they are North – Eastrly or Esterly. In the cold seasons, winds blow mainly from directions between North-East and South – East in the summer season, winds are variable in direction, but by May, winds from directions between West and North predominate.

**TABLE 3.4 : MEAN WIND SPEED IN KM/HR**

| ***Months*** | **Jan.** | **Feb.** | **March** | **Apr.** | **May** | **June** | **July** | **Aug.** | **Sept.** | **Oct.** | **Nov.** | **Dec.** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wind speed | 9.1 | 9.9 | 10.4 | 11.7 | 16.8 | 19.2 | 20.3 | 17.5 | 13.0 | 11.2 | 11.3 | 9.8 |

| **Mean No. of days with wind > 4/8** | | **Wind Direction** | | | | | | | | **Mean Monthly wind speed km.hr.** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Morning** | | | | **Evening** | | | | | | | |
| ***Mor*** | **Eve.** | **Jan.** | **May** | **Aug.** | **Nov.** | **Jan.** | **May** | **Aug.** | **Nov.** | **Jan.** | **May** | **Aug.** | **Nov.** |
| 115 | 149/2 | E/C | NW/W | W/NW | E/NE | E/SE | NW/N | W/NW | NE/W | 7.56 | 13.36 | 14.65 | 9.50 |

## 3.3 GEOLOGICAL ASPECT

The Geology of Gulbarga has been recorded by Bruce Foote and is to be found forming part of the monograph published as Memoir XII of the Geological Survey of India.

The Northern portion of the District is covered entirely by the Deccan trap, while spreads of Limestone and Shale belonging to the Bhima series are seen in the middle of the District. The archaen rocks, composed of the peninsular gneisses are confined to the Southern and Eastern parts of the District.

## 3.4 URBAN HOUSING

Houses in the town do not differ very largely from the rural pattern except that many of them are better built and have more accommodation. These houses have spacious room a verandah and a separate block for the kitchen and bathroom and same of them have an upper story also. Modern-type concrete-roofed houses are becoming common. New concepts of house-building are slowly gaining ground an in Gulbarga town itself there are a few structures conforming in style to what may be called the modern cottage house.

The house furnitures are like chairs, sofas, tables, bedstands, stools, benches, selves, tea-poys, mirrors, chest of drawers etc. have become almost indispensable items of furniture in a modern house.

## 3.5 MATERIALS AND CONSTRUCTION TECHNIQUES

### Materials

Stone, lime, timber and granite are the chief building materials used in all traditional buildings of Gulbarga District. The black trap stone and granite in almost any size is abundant in the surroundings. This is perhaps the cheapest building material available there.

In modern buildings the materials used are brick, sand, cement, steel, R.C.C. for lintel, beam, column, and slab is the common material for construction. The thickness of wall varies with from 10 cm, 20 cm, and 30 cm.

### Construction Techniques

Traditional Architecture is not Architect designed, but is customarily owner built or community built utilising locally available resources, local talent and local construction techniques. The proper use of materials, interesting pattern, delicate carving of wood, proper dressing of stones, smooth finish and inter locking joints are highlighted in all these Traditional buildings.

# KARNATAKA

The state of Karnataka came into existence in its present form and boundaries on I[st] November 1956. Initially it was called as Mysore state. The language spoken in Karnataka [mother tongue] is Kannada.

**LOCATION:** Karnatak is on the western side of India, having a long coast line on the Arabian sea with Goa & Maharashtra states as its northern boundaries, As on the East, Kerala & Tamil Nadu on its southern boundaries. It stretches between 145° & 19$^0$ North latitudes & 74° & 78° east longitudes.

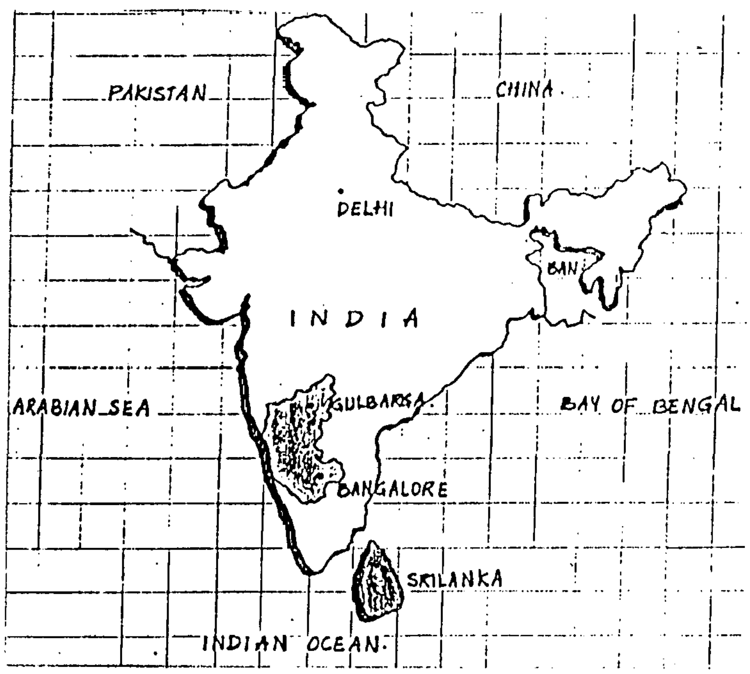



**Fig. 3.1 : Location of Karnataka**

**AREA:** It has an area about 1,19,791, 58 kms.

**CLIMATE:** As a major part of the Karnataka is above sea level, there is hot-dry extremes of climate.

**GEOLOGICAL:** A major portion of Karnataka is within the Deccan plateau which is a stated to be the oldest land mass of India. Rock, granite, limestone & slate are the chief building materials available.

# GULBARAGA

Gulbaraga is so named to imply a leaf with flower, since 'Gul' means flower & 'Burg' means 'Leaf' in the persian Language. Gulbaraga is also know as Kalburgi which means a 'Stoney land' or a' Heap of stones' in Kannada language.

**LOCATION:** Gulbarga district is situated in The Northern part of Karnataka state. It lies between longitude 70° 04' & 77° 42' & Latitude 16° 12' & 17° 46'.

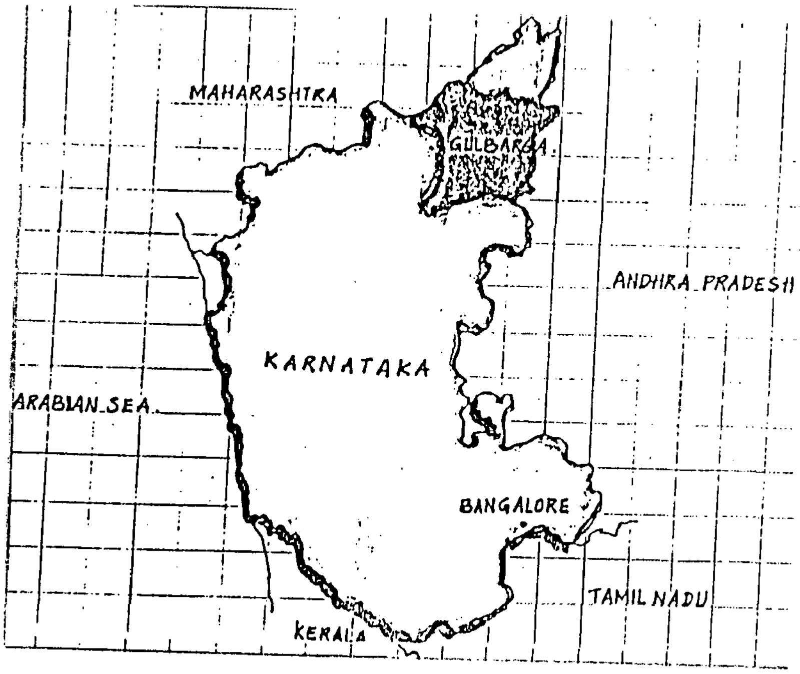



**Fig. 3.2 : Location of Gulbarga**

**AREA:** The total area of the district is 6,271.2 Sq. Miles or 16,242.4. sq. km.

**RIVERS:** The main rivers of the district are the Krishna & the Bhima.

**CLIMATE:** The climate of the district is hot-dry. The district enjoys a bright sunlight almost throughout the year.

**BUILDING MATERIALS:** Stone, lime & timber are the chief building materials used in all old buildings.

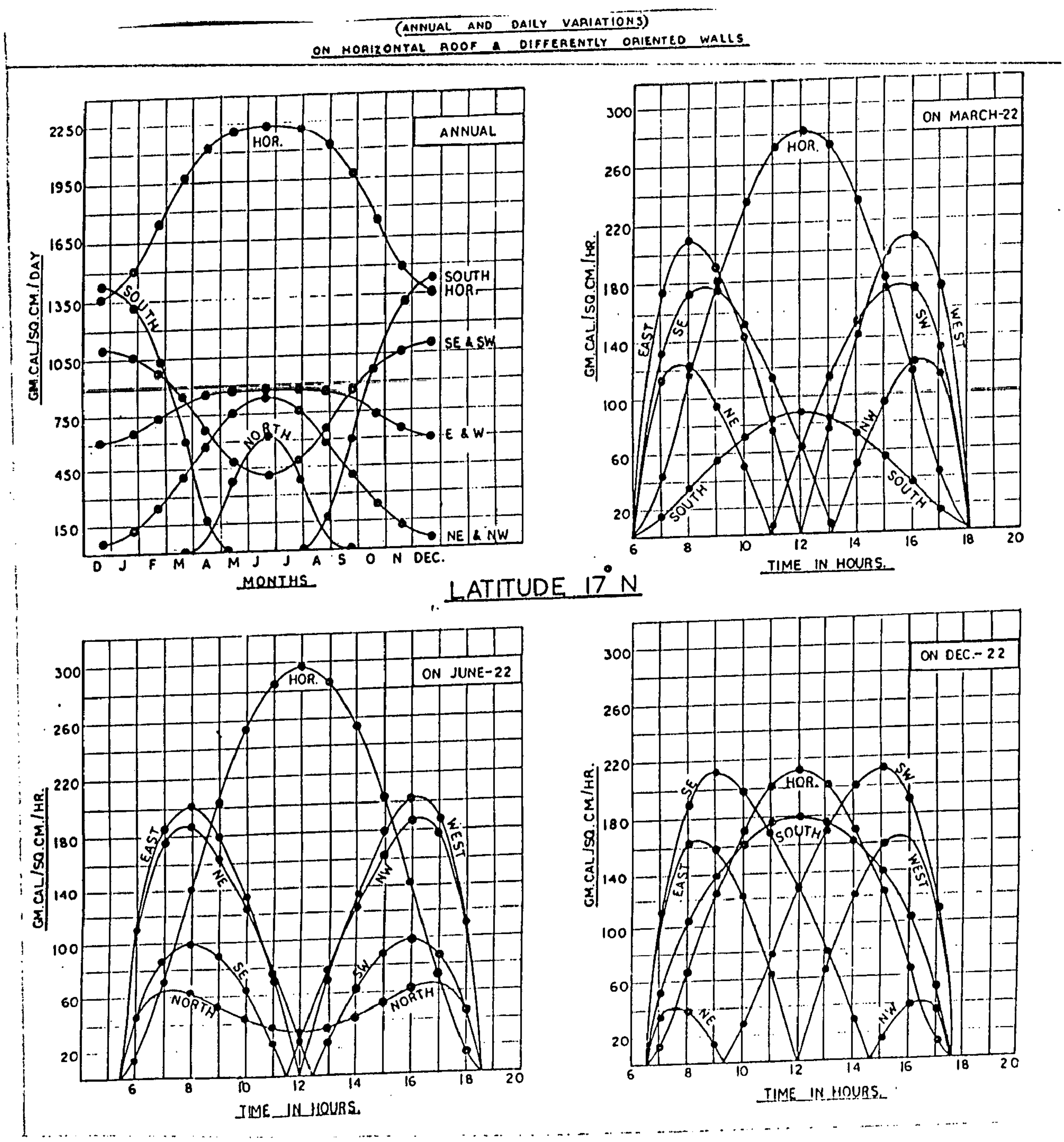



**Fig. 3.3 : Solar radiation incident on clear days**

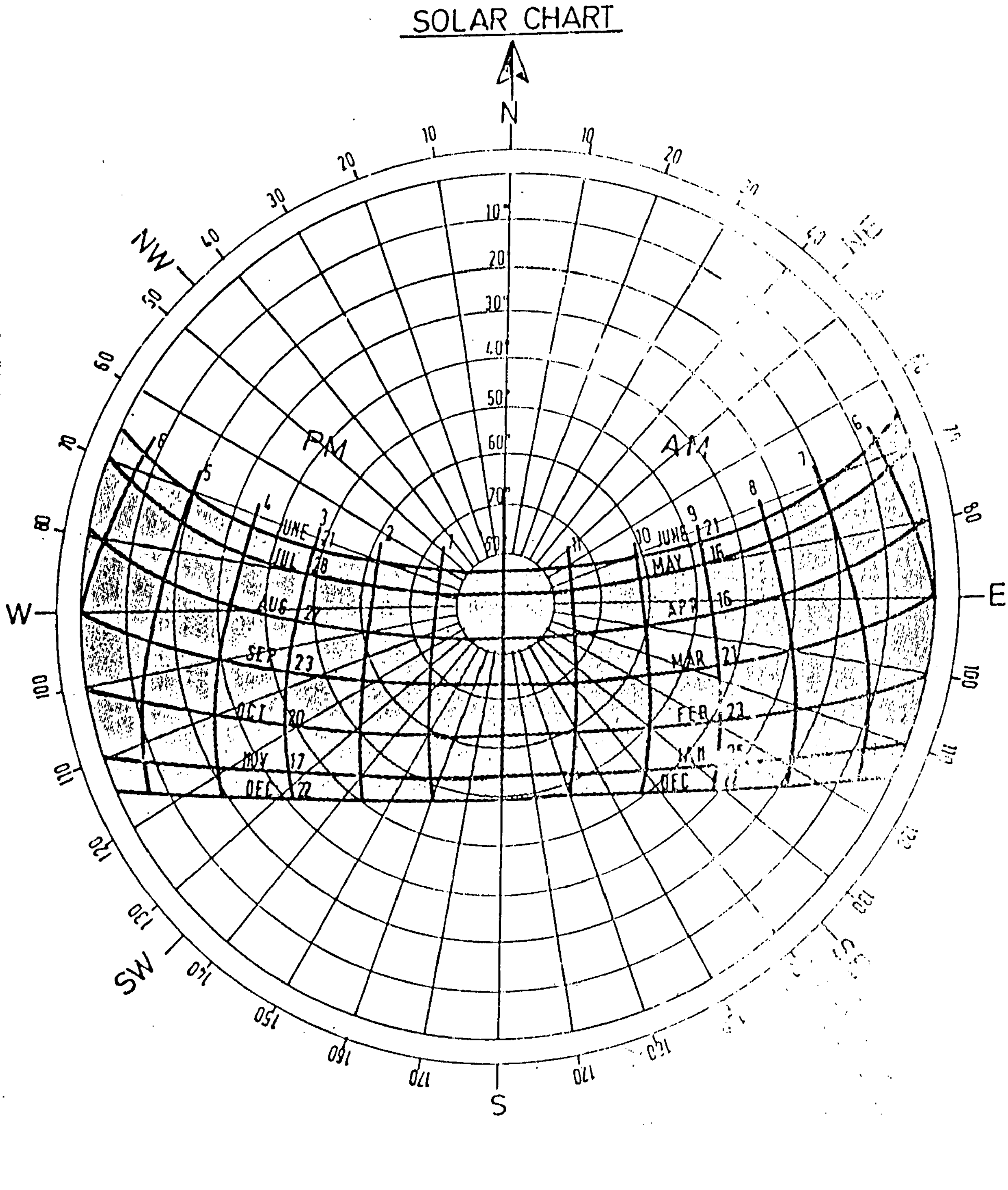



**Fig. 3.4 : Solar chart of latitude 17° North**

### TABLE 3.5 : SOLAR AZIMUTHS AND ALTITUDES

| Time | June 22nd | | May 16th & July 28th | | April 16th & Aug. 27th | | March 21st & Sept. 23rd | | Feb. 23rd & Oct. 20th | | Jan. 26th & Nov. 17th | | Dec. 22nd | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Az. | Al. | Az. | Al. | Az. | Al. | Az. | Al. | Az. | Al. | Az. | Al. | Az. | Al. |
| Sunrise & Sunset | $65^0$ | $0^0$ | $70^0$ | $0^0$ | $80^0$ | $0^0$ | $90^0$ | $0^0$ | $101^0$ | $0^0$ | $110^0$ | $0^0$ | $115^0$ | $0^0$ |
| 6 a.m. & 6 p.m. | $67^0$ | $7^0$ | $72^0$ | $5^0$ | $81^0$ | $3^0$ | -- | -- | -- | -- | -- | -- | -- | -- |
| 7 a.m. & 5 p.m. | $71^0$ | $20^0$ | $75^0$ | $19^0$ | $85^0$ | $17^0$ | $94^0$ | $14^0$ | $104^0$ | $11^0$ | $113^0$ | $8^0$ | $117^0$ | $6^0$ |
| 8 a.m. & 4 p.m. | $73^0$ | $34^0$ | $78^0$ | $33^0$ | $89^0$ | $31^0$ | $100^0$ | $29^0$ | $110^0$ | $25^0$ | $119^0$ | $21^0$ | $123^0$ | $19^0$ |
| 9 a.m. & 3 p.m. | $74^0$ | $47^0$ | $80^0$ | $47^0$ | $93^0$ | $46^0$ | $106^0$ | $43^0$ | $118^0$ | $38^0$ | $127^0$ | $33^0$ | $131^0$ | $30^0$ |
| 10 a.m. & 2 p.m. | $72^0$ | $61^0$ | $81^0$ | $61^0$ | $100^0$ | $60^0$ | $117^0$ | $56^0$ | $130^0$ | $50^0$ | $139^0$ | $44^0$ | $143^0$ | $40^0$ |
| 11 a.m. & 1 p.m. | $63^0$ | $75^0$ | $80^0$ | $76^0$ | $114^0$ | $74^0$ | $137^0$ | $67^0$ | $150^0$ | $59^0$ | $157^0$ | $51^0$ | $160^0$ | $47^0$ |
| 12 Noon | $0^0$ | $84^0$ | $0^0$ | $88^0$ | $180^0$ | $83^0$ | $180^0$ | $73^0$ | $180^0$ | $63^0$ | $180^0$ | $54^0$ | $180^0$ | $50^0$ |

## TABLE 3.6 : SHADOW THROWS FOR LATITUDE 17° N

| Time | June 22nd | | May 16th & July 28th | | April 16th & Aug. 27th | | March 21st & Sept. 23rd | | Feb. 23rd & Oct. 20th | | Jan. 26th & Nov. 17th | | Dec. 22nd | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | V | H | v | H | v | h | v | h | v | h | v | h | V | h |
| 6 a.m. | 0.13 | 0.42L | 0.09 | 0.32L | 0.05 | 0.16L | -- | -- | -- | -- | -- | -- | -- | - |
| 7 a.m. | 0.39 | 0.34L | 0.36 | 0.27L | 0.31 | 0.09L | 0.25 | 0.07R | 0.20 | 0.25R | 0.15 | 0.42R | 0.12 | 0.51R |
| 8 a.m. | 0.71 | 0.31L | 0.66 | 0.21L | 0.60 | 0.02L | 0.56 | 0.18R | 0.50 | 0.36R | 0.44 | 0.55R | 0.41 | 0.65R |
| 9 a.m. | 1.12 | 0.29L | 1.09 | 0.18L | 1.04 | 0.05L | 0.97 | 0.29R | 0.89 | 0.53R | 0.81 | 0.75R | 0.77 | 0.87R |
| 10 a.m. | 1.90 | 0.32L | 1.83 | 0.16L | 1.76 | 0.18L | 1.66 | 0.51R | 1.55 | 0.84R | 1.47 | 1.15R | 1.39 | 1.33R |
| 11 a.m. | 4.19 | 0.51L | 4.07 | 0.18L | 3.82 | 0.45L | 3.45 | 1.07R | 3.33 | 1.73R | 3.16 | 2.36R | 3.13 | 2.75R |
| 12 Noon | ∞<br>∞ | ∞L<br>∞R | ∞<br>∞ | ∞L<br>∞R | ∞<br>∞ | ∞R<br>∞L | ∞<br>∞ | ∞R<br>∞L | ∞<br>∞ | ∞R<br>∞L | ∞<br>∞ | ∞R<br>∞L | ∞<br>∞ | ∞R<br>∞L |
| 1 p.m. | 4.19 | 0.51R | 4.07 | 0.18R | 3.82 | 0.45L | 3.45 | 1.07L | 3.33 | 1.73L | 3.16 | 2.36L | 3.13 | 2.75L |
| 2 p.m. | 1.90 | 0.32R | 1.83 | 0.16R | 1.76 | 0.18L | 1.66 | 0.51L | 1.55 | 0.84L | 1.47 | 1.15L | 1.39 | 1.33L |
| 3 p.m. | 1.12 | 0.29R | 1.09 | 0.18R | 1.04 | 0.05L | 0.97 | 0.29L | 0.89 | 0.53L | 0.81 | 0.75L | 0.77 | 0.87L |
| 4 p.m. | 0.71 | 0.31R | 0.66 | 0.21R | 0.60 | 0.02R | 0.56 | 0.18L | 0.50 | 0.36L | 0.44 | 0.55L | 0.41 | 0.65L |
| 5 p.m. | 0.39 | 0.34R | 0.36 | 0.27R | 0.31 | 0.09R | 0.25 | 0.07L | 0.20 | 0.25L | 0.15 | 0.42L | 0.12 | 0.51L |
| 6 p.m. | 0.13 | 0.42R | 0.09 | 0.32R | 0.05 | 0.16R | -- | -- | -- | -- | -- | -- | -- | -- |

TABLE 3.7 : INCIDENT DIRECT SOLAR RADIATION ON HORIZONTAL ROOF AND DIFFERENTLY ORIENTED WALLS
(Clear Day)
DAILY MEAN FOR EACH MONTH – IN GM. CAL/SQ. CM/DAY

| Month | Horizontal | East or West | South East or South West | South | North East or North West | North |
|---|---|---|---|---|---|---|
| January | 392 | 171 | 291 | 372 | 28 | -- |
| February | 451 | 192 | 267 | 304 | 54 | -- |
| March | 524 | 216 | 231 | 188 | 99 | -- |
| April | 575 | 232 | 183 | 59 | 155 | 19 |
| May | 599 | 237 | 134 | 1 | 202 | 99 |
| June | 605 | 236 | 110 | -- | 226 | 163 |
| July | 603 | 236 | 118 | -- | 218 | 141 |
| August | 590 | 235 | 157 | 17 | 182 | 52 |
| September | 553 | 225 | 209 | 122 | 126 | 4 |
| October | 489 | 206 | 247 | 249 | 75 | -- |
| November | 418 | 181 | 281 | 346 | 38 | -- |
| December | 377 | 166 | 296 | 385 | 23 | -- |

TABLE 3.8 : DURATION OF POSSIBLE SUNSHINE HOURS ON EAST & WEST WALLS FOR DIFFERENT LATITUDES

(Change over time is given in solar time)

| Latitude °N | Dec. 22nd | | Jan. 26th & Nov. 17th | | Feb. 23rd & Oct. 20th | | March 21st & Sept. 23rd | | April 16th & Aug. 27th | | May 16th & July 28th | | June 22nd | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Change over time | Duration | Change over time | Duration | Change over time | Duration | Change over time | Duration | Change over time | Duration | Change over time | Duration | Change over time | Duration |
| 17 | 12-00 | 5-33 | 12-00 | 5-40 | 12-00 | 5-51 | 12-00 | 6-03 | 12-00 | 6-16 | 12-00 | 6-28 | 12-00 | 6-35 |

# CASE STUDY

## INTRODUCTION

To provide a thermal comfort in the buildings in hot-dry climate is most dependant on electricity i.e. Mechanical system of cooling. It is the most used form of energy exceptionally in hot-dry climate for the thermal comfort in residential and other type of buildings in summer so especially summer is the very critical season to achieve the thermal comfort in the building.

Here the investigator would like to point out that the maximum electricity consumed in the domestic sector for achieve thermal comfort because buildings are not designed based on the climatic response of hot-dry climate.

So electrical energy conservation method to succeed in the hot-dry climate of Gulbarga in Karnataka should concentrate on the need for reducing the use of Mechanical system for thermal comfort partially or completely by providing the comfort by using passive system the best place to look for guidance for best suitable passive methods of thermal comfort in any place would be its traditional architecture.

The vernacular architecture of any region must have been developed after so many years of innovation and the study of climatic problems of that particular geographical area our forefather had constantly tried to make ones living environment more and more comfortable, by trial and error methods, and of course from experience, and also from studies of regional macro-climate.

So for the purpose of understanding how the traditional building of Gulbarga (Hot-dry climate) used to be constructed before the mechanical system of thermal comfort ever become possible and how it is different today or not used in modern buildings, some case studies of traditional and modern buildings have been conducted to find out how the passive ways used in the traditional vernacular architecture of Gulbarga can be interpreted into modern building.

**TRADITIONAL BUILDING OF GULBARGA**

Before going into the case study, a brief description on the traditional residential architecture of Gulbarga is to be given.

The most prominent character of any traditional building in Gulbarga is the thick external wall having small openings which reduce transfer of heat and increase the time lag the plan of the building is in square or rectangular in shape with central courtyard, the rooms are arranged around the courtyard, the roof is constructed with well compacted mud supported by wooden joist and planks. All doors are opened towards the courtyard. Only main door is placed in the external wall. Minimum the external door openings from security point of view roof and courtyard is used for the sleeping at the night. The material for construction is stone, mud, and wood.

This type of plan is best for the hot-dry climate to achieve thermal comfort.

## 4.1 THE HOUSE OF SHRI RAMCHANDRA PATIL

This house is situated in Gulbarga district the building is 80 years old. It is two storied building with many details of Gulbarga buildings in hot-dry climate.

The plan of the building is simple, square, and symmetrical about East-West axis the building is functionally convenient.

The main entrance from the southern side. The first entry leads to the front yard. Than it goes to the main building the plan of the building is compacts all rooms are arranged around central courtyard doors of the all rooms are opened to the central courtyard.

The external wall thickness is 2'-9" and the internal walls are of 1'-6" th. Small openings are provided in external wall to get the required ventilation and stop the solar radiation glare, and dust. Two stair cases leads to the upper floor on either side of the entrance.

This house is without mechanical cooling system. It achieves the better thermal comfort.

The planning of the rooms is done according to the vastu.

All external and internal walls are constructed with stone mud and lime mortar the roof is flat in nature and constructed with compacted mud and lime mortar finish on the top the external walls are thick in nature and it reduces the heat in day time and having a more time-lag. The courtyard and roof top is used for the sleeping at night in summer.

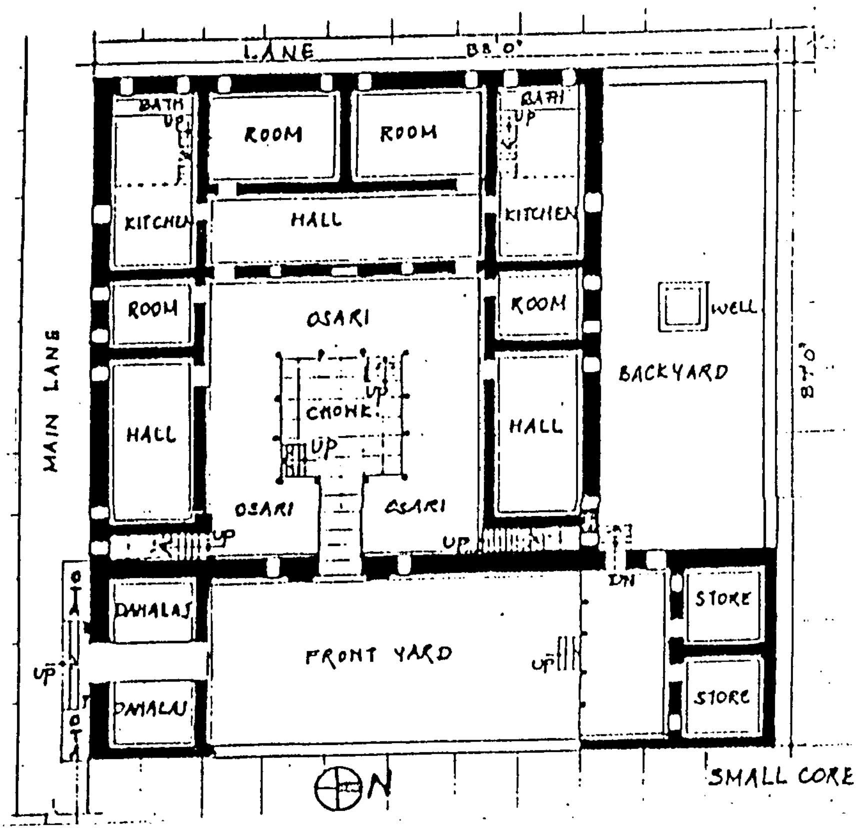



Fig 4.1 Ground floor plan of Ramchandra Patil House.

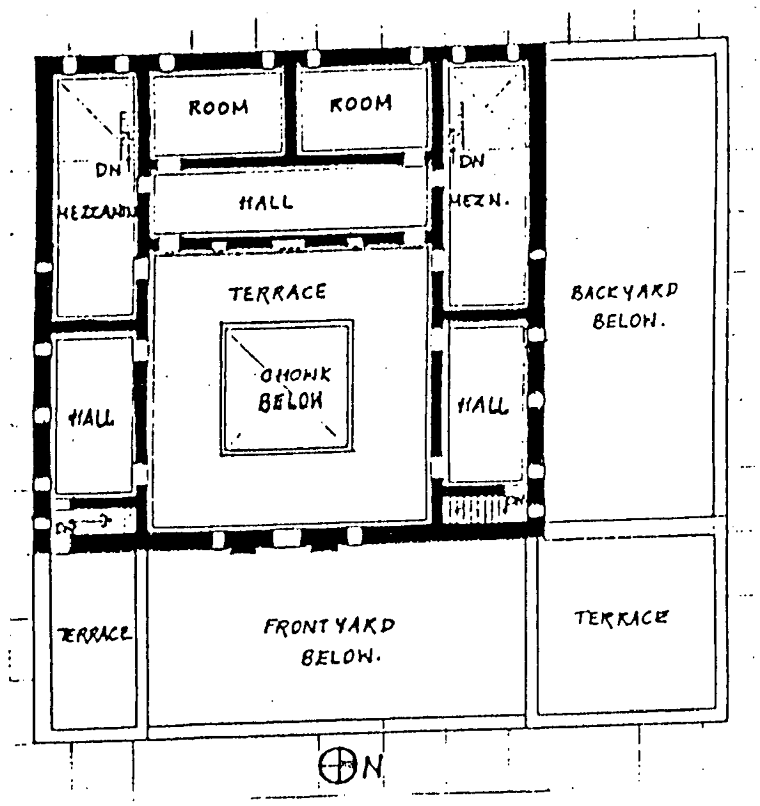



Fig. 4.2 First floor plan of Ramchandra Patil House.

Fig. 4.3 View of Courtyard of Ramchandra Patil House

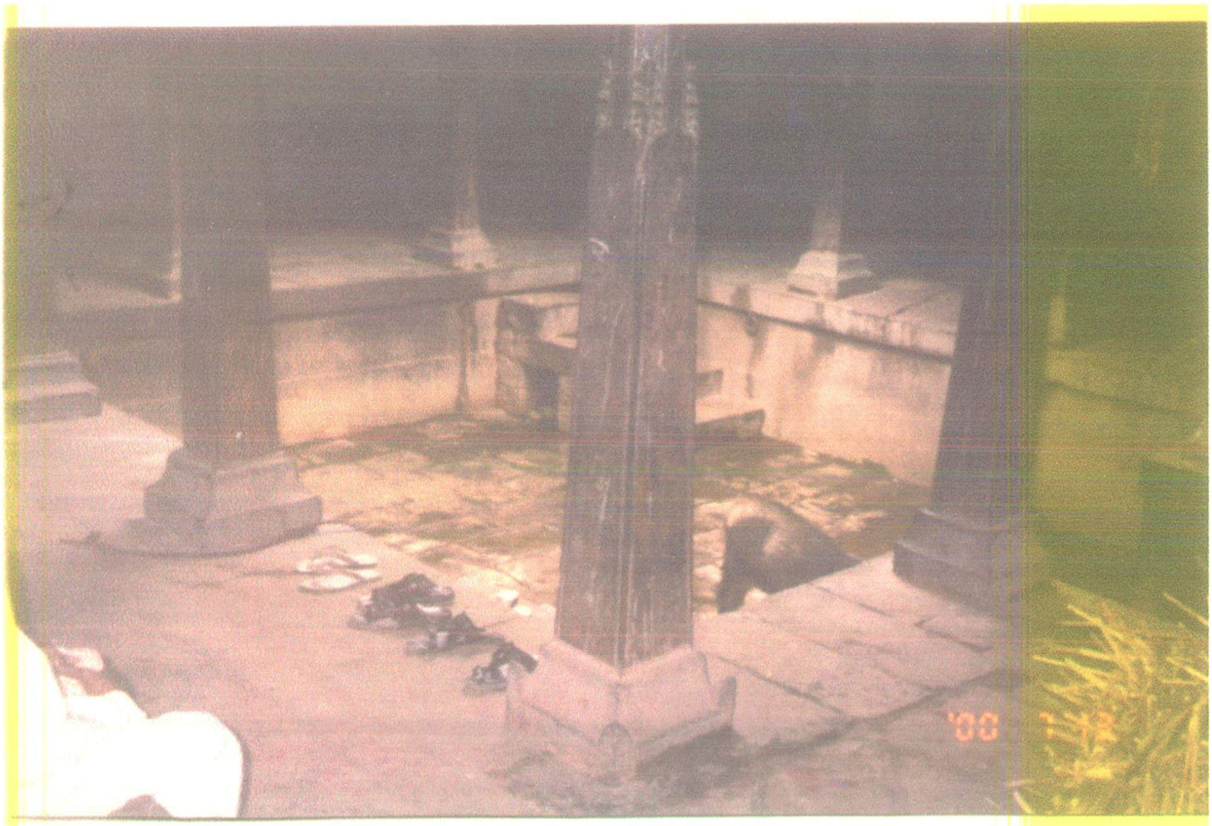


Fig. 4.4 View of Courtyard of Ramchandra Patil House

## 4.2 HOUSE OF BASWARAJ GOUDA PATIL

The house is located in Gulbarga district. The buildings is about 200 years old. The building is two storied. The main entrance is towards North and 6'-0" wide and 10'-0" height.

The plan of the house is simple but more functional and it is thoroughly symmetrical about North-South axis. It is almost square in shape the building is created with relatively strict adherence to the Vastushastra. The external walls of 3'-0" thick and internal walls of 1'-6" thick.

The main entrance leads to the varandaha and two either side of cattle shed there are four stair cases leads to upstairs two in front and two in the rear side. First floor is raised towards the south side it creates shadow on the Terrance in afternoon. The plan is very simple and more functional. All door openings leads to the central courtyard. The courtyard is measuring about 24' x 24' in size. It admits the light inside the building. The building is having only one external entry. For the security purpose minimize of the entries of the building. The backyard is used for the utility purpose.

The material used for the construction of walls are store mud, lime mortar roof is casted with well compacted mud. In the external wall minimize the opening to maintain privacy and prevent solar radiation, glare etc. the time-lag factor of external walls are more than 12 house. So it absorbs the heat at the day and release at the night. So that it maintain day time comfort, but at night some discomfort in summer because of minimum ventilation.

But throughout the year the building is comfortable without using the mechanical system to achieve comfort.

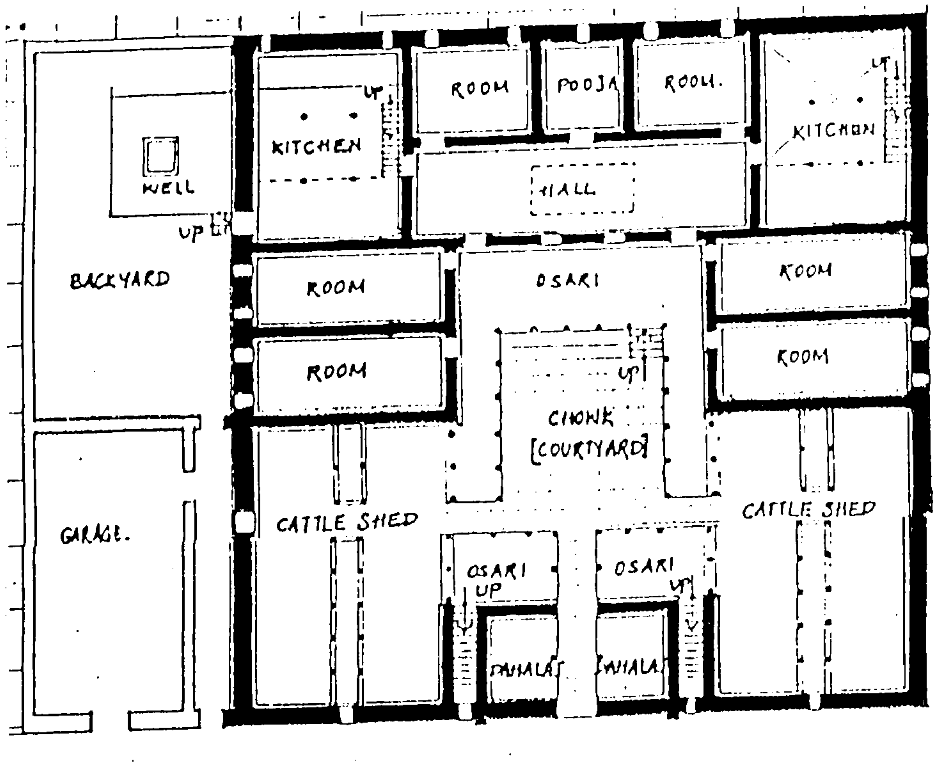



Fig. 4.5 Ground Floor Plan of Baswaraj Patil House.

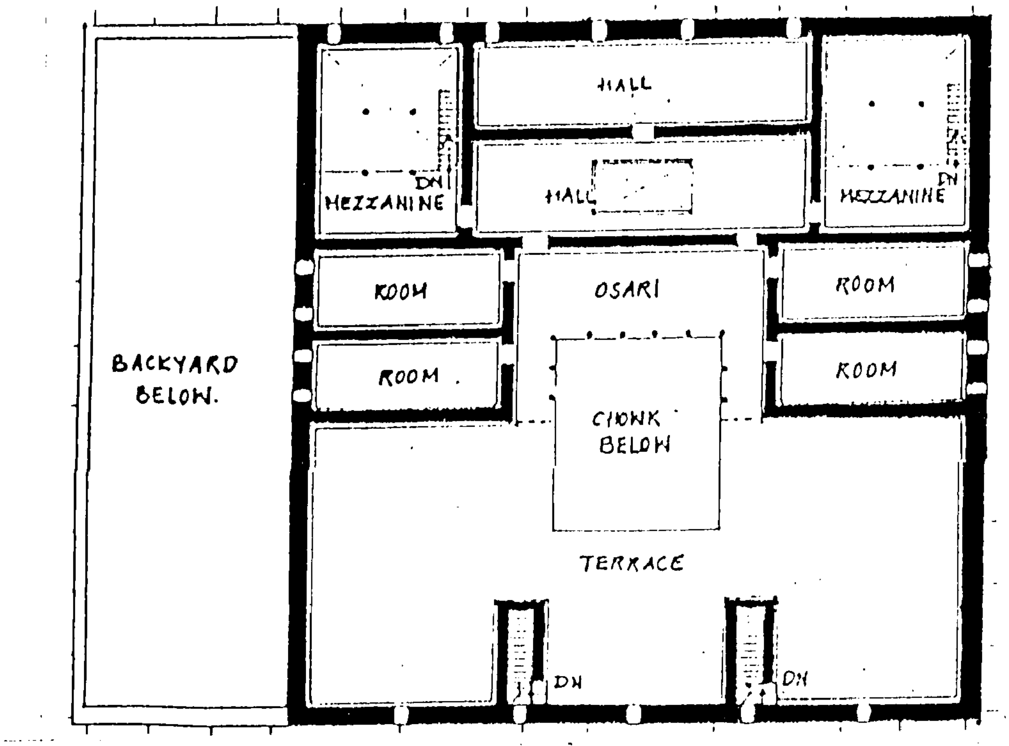



Fig. 4.6 First Floor Plan of Baswaraj Patil House.

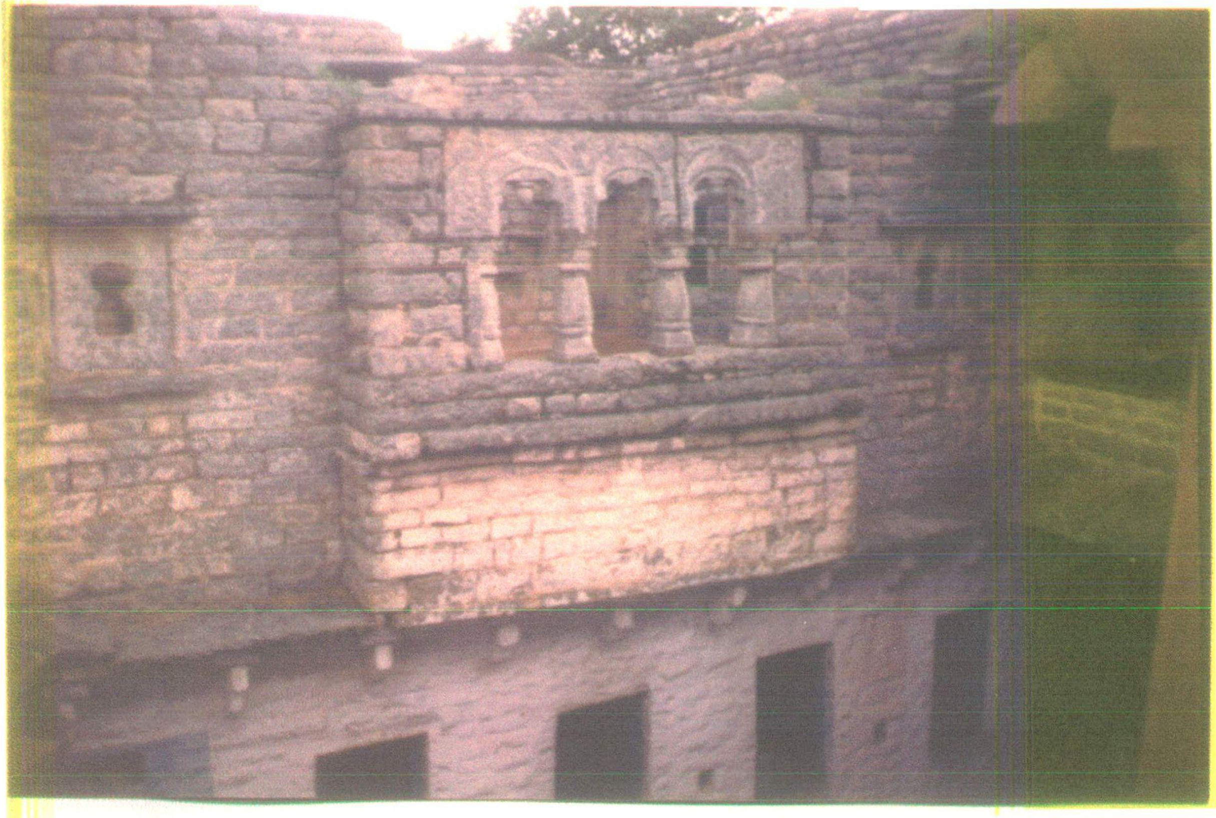


Fig. 4.7 Exterior View of Baswaraj Patil House

4.8 View of Interior Roof of Baswaraj Patil House

## 4.3 THE HOUSE OF PARVATH GOUDA

This house is situated in Gulbarga district the building is about 250 years old. The building is two storied the main entrance is from East side, entrance gate is 6'-0" wide and 10'-0" height.

The plan of the building square in shape with attached back yard building is compactly planned with central courtyard admeasuring 33'-0" x 23'-0". All side external wall of 3'-0" thick and internal walls of 1'-6" thick. Small openings are provided in the external wall to get light and required ventilation.

For the construction of wall and roof the materials used are stone masonary and for roof layers of well compacted mud till now also it is in good condition the plan is done according to vastu. Southern side of the building first floor room are constructed and remaining portion is open Terrance. The major light is admitted through central courtyard. The building is designed based on the study of climate of Gulbarga. From the main entry there is separate entry for cattle shed. Only one external entrance is provided in the building for the security measures.

The building is function according to the season change. In summer it feel cool and provide comfort as well as in winter. The heat stored in walls rediated at night in the rooms and provide the comfort without using mechanical system the building function effectively throughout the year. In summer the rooms are heated at night. There is very less ventilation system. So in summer courtyard and roof top is used for the sleeping. The backyard of the building used for the utility as well as it maintain privacy.

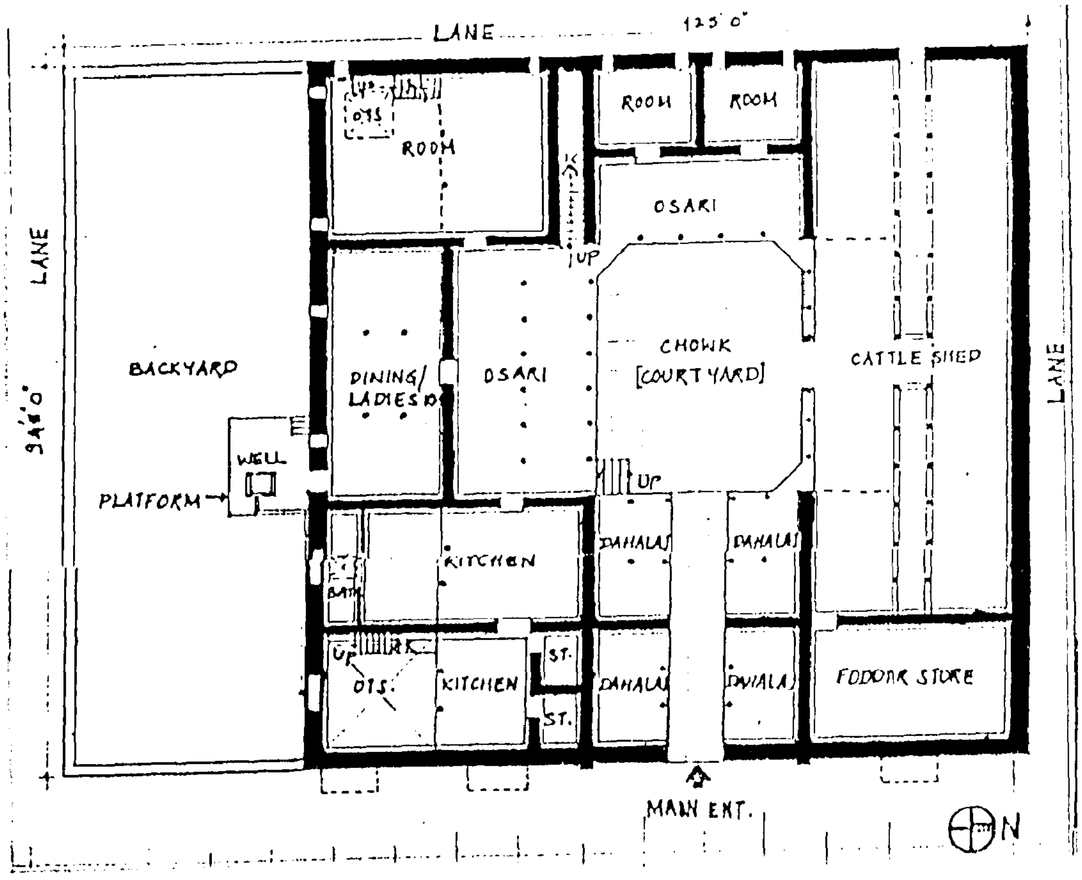



Fig. 4.9 Ground Floor Plan of Parvath Gouda House.

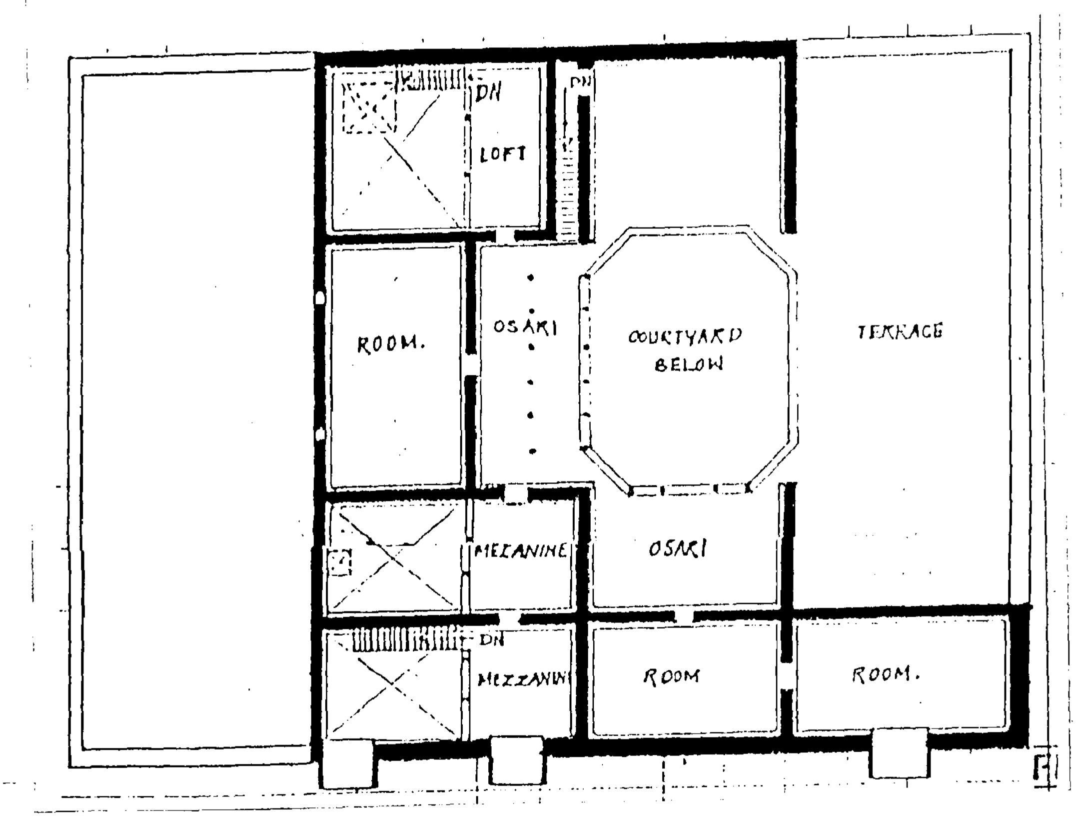



Fig. 4.10 first Floor plan of Parvath Gouda House.

Fig. 4.11 View of Courtyard of Parvath Ganda House

4.12 Exterior View of Parvath Ganda House

## 4.4 S.S. HEBBAL RESIDENCE

The house, located in Gulbarga is a typical example of a modern conventional middle class residence, a common pattern followed for most conventional building for its plan & elevation. It was built in 1998 all conventional building having a style of flat roofs, big glass windows, sun shade details etc. The case study of this particular house is done as a prototype of conventional residential building.

Flat roof is one of the typical features of most conventional buildings, by using R.C.C. as a roof casting materials. As in traditional building, the roof is flat but materials used for casting the roof is well compacted mud. It absorbs the maximum heat but is modern building because of R.C.C. roof the indoor temperature suddenly rise because of transfer of heat from external space to internal space through roof.

It has been calculated today that almost half of the heat goes into a single story flat roofed building comes via the roof.

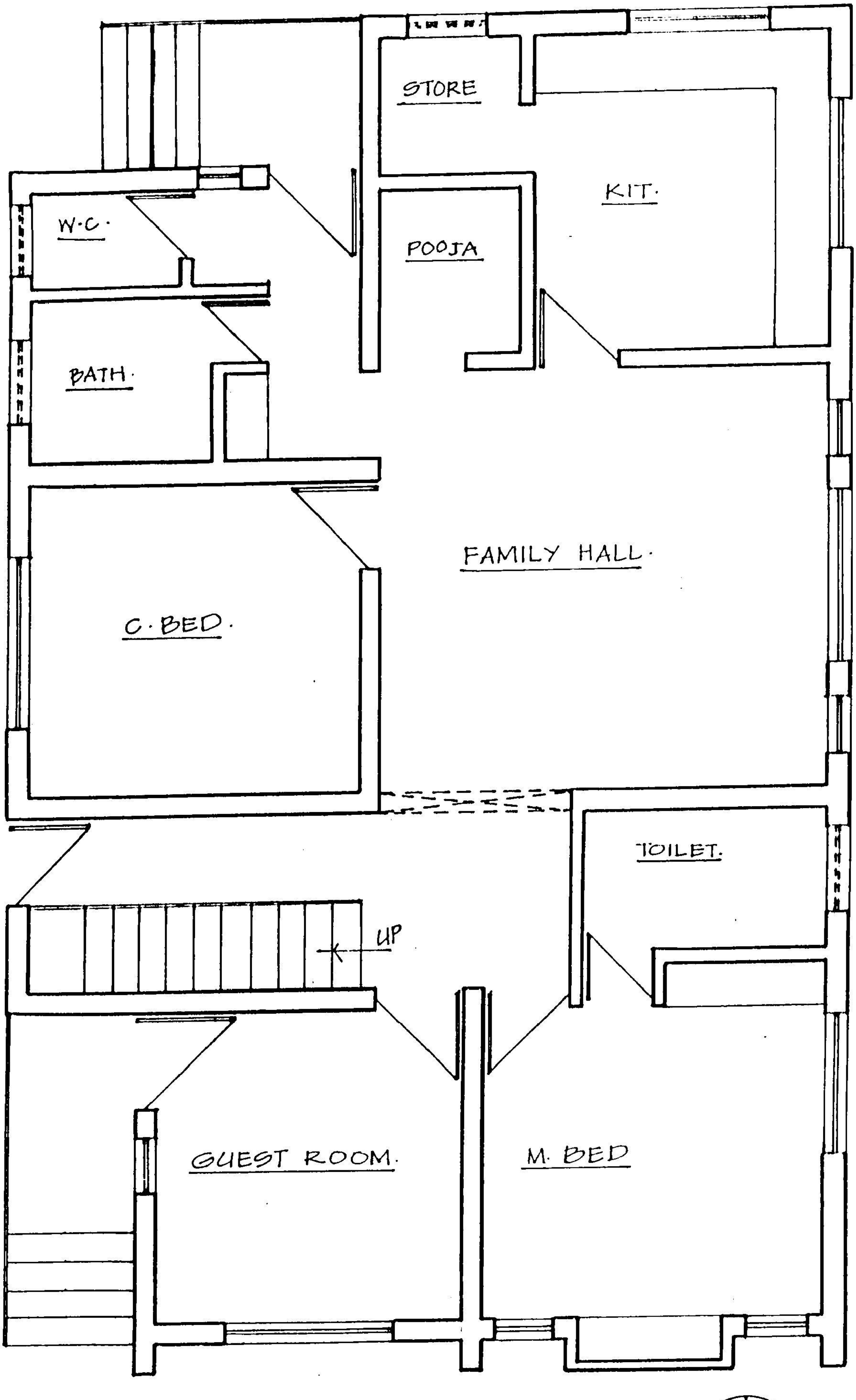
Another common feature in most of today's buildings are the big glass windows not only this Adds the cost, but also increases the heat inside by greenhouse effect. (it is observed open). Solar rays once gets inside the room, through there glass windows in the absence of adequate sun control shade, as long wave radiation and gets trapped there because the reflected rays, being short wave, can not though glass.

The increasing use of glass on building facade in conventional building is more. But in earlier building windows with wooden shutters are used in hot regions. Even curtains will not help in reducing this. Actually not only that the curtain will not be able to reduce this but curtain can actually contribute to enhance the heat inside by acting as trombe walls. The solar rays falls on there curtains becomes heat energy and slowly spreads into the room by conduction and convection.

As said earlier and study of traditional building. The window openings provided in the wall as small but in conventional building because of large window openings and admit more heat it produces thermal discomfort for ventilation purpose also thinking about its location to the window position is also important for air movement.

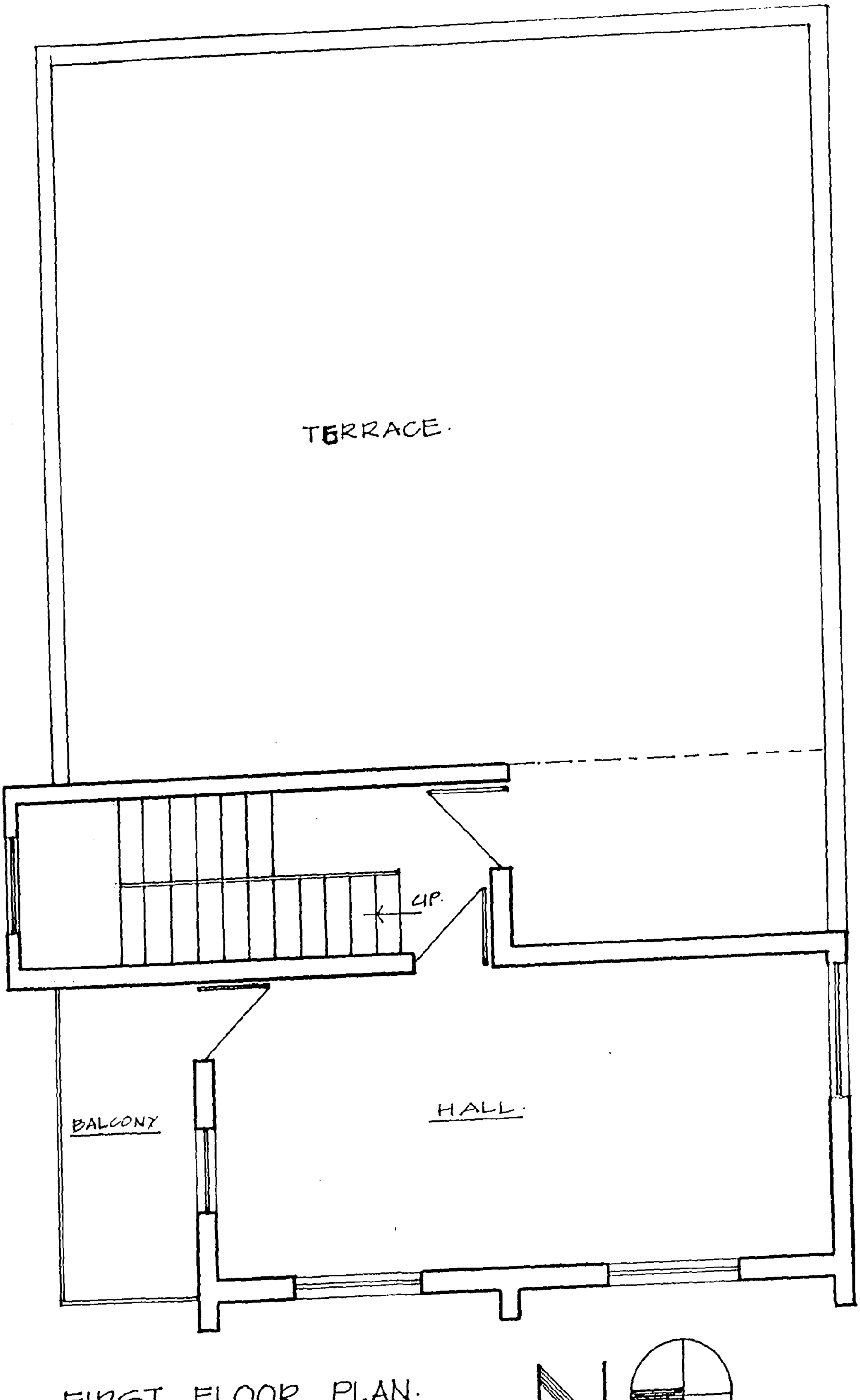
Some of the rooms have only one window facing outside because of improper planning. It more thought is given at planning stage about window placement and the importance of cross ventilation. It will make the rooms more comfortable.

So to conclude, both the basic necessary needs for thermal comfort in hot-dry climate like avoidiry the heat from coming inside the building.




GROUND FLOOR PLAN.

SCALE :- 1" = 4'-0". FIG-4.13




FIRST FLOOR PLAN.

SCALE :- 1" = 4'-0"  FIG- 4.14

Fig.4.15 Front View of Hebbal House

Fig. 4.16 South-West View of Hebbal House

## 4.5 RESIDENTIAL BUILDING AT GULBARGA (MODERN BUILDING)

**Owner** → **Smt. Ratna B. Kalamdani, Gulbarga**

**Architect** → **Ashok W. Joshi, Nagpur**

**(International Housing Expert)**

**Year of Completion** → **1994**

### EVAPORATIVE COOLING SYSTEM OF RESIDENTIAL BUIDLING

### DESCRIPTION

The building is two storied located near the main road on Gulbarga Bangalore highway. The building is facing towards the south. While designing the building Architect is considered all climatic factors in the planning of the building.

### PLANNING

The plan of the building is almost square in shape few offset are given. The main offset is provided near the main entrance in the South West direction where water pond is located. From water pond the water channel is provided below the flooring. Few openings are provided on the water channel in the floor. The direction of wind from South-West to North-East. When hot wind is funneled from South West direction the pressure is created in the main offset and hot air pass through the water channel and water pond and cool the air by evaporation and is came inside the building through opening provided in the flooring.

### INTERIOR

The stair case is located in the centre of the building between hall and Dining room the advantage of stair case is it gives double height to the roof. If gives free air circulation inside the building. Hot air passes through openings provided in the roof.

## WALLS

The materials used for the construction of wall as brick. All external walls of one and half brick thick wall and all internal walls are one brick thick.

## CONSTRUCTION TECHNIQUES

The construction used for the external wall as similar to the rat-trap bond as followed by Laurie Baker and all internal walls are solid walls of 9"th. The techniques used for the construction of external wall is to minimise the heat transfer from outside to inside the building.

## EXTERNAL SURFACE TREATMENT

Architect is not used the plastering or any treatment to external surface of wall. He exposed the brick with red oxide coat on it. Because, cement is an good conductance of heat.

## OPENINGS

All windows and ventilators opening are provided in external wall is 2'-0" × 5'-0". In vertically window is divided into two parts ventilator and window. The ventilator is of fixed glass of 2'-0" × 1'0" and the remaining portion of the window is of made up of wooden shutter. The purpose of providing wooden shutter is a good insulator of heat.

## ROOF

The materials used for the construction of roof is R.C.C. slab. But slab is casted in slopping roof. The inclination of the roof is given considering sun path diagram. So that the maximum reflection of solar radiation takes place. The holes are provided in the ground floor slab to pass lighter air from ground floor to first floor and from first floor dormer window is provided in the slab of top floor to pass hot air. Like the circulation of air is occurs in the building. No plastering is done inside surface of the R.C.C. slab of both the floor.

**VENTILATION**

No roof ventilator is provided in the building only one dormer window is provided in the first floor slab. The hot air pass through the dormer window.

**FLOOR**

The flooring used in the building is Shahabad stone flooring. Which is locally available material.

**EXTERNAL SPACES**

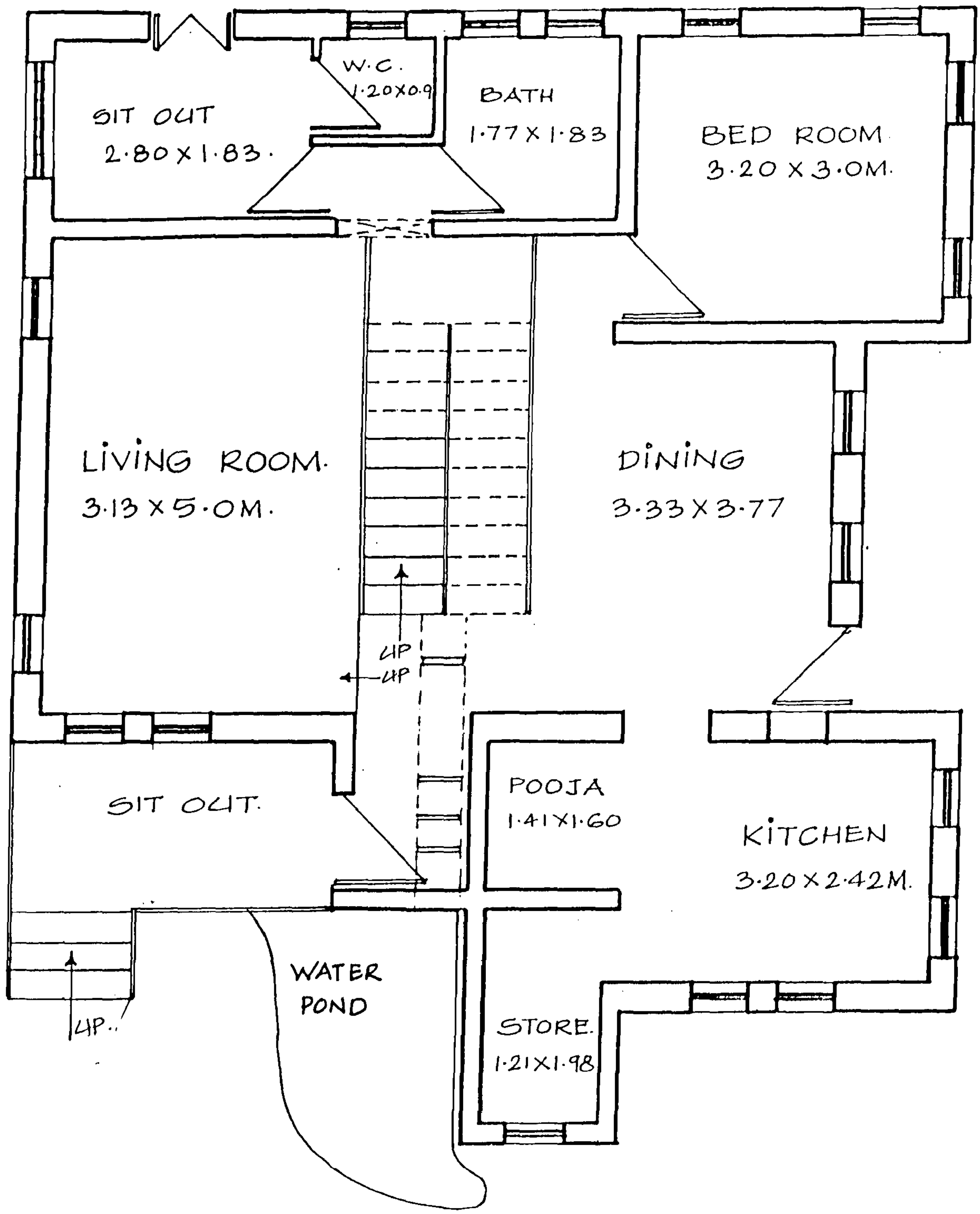
Architect planed very good landscape which is suitable for hot-dry climate. On West and South side planted the trees of having more height it creates shadows on the building to cut the direct solar radiation also keep the open spaces cool by shadows.

**MATERIAL USED**

All materials which is used for the construction work is locally available like, brick wall, R.C.C. slab, and wooden doors and windows, Shahabad stone flooring.

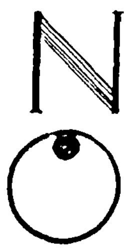
**CONCLUSIONS**

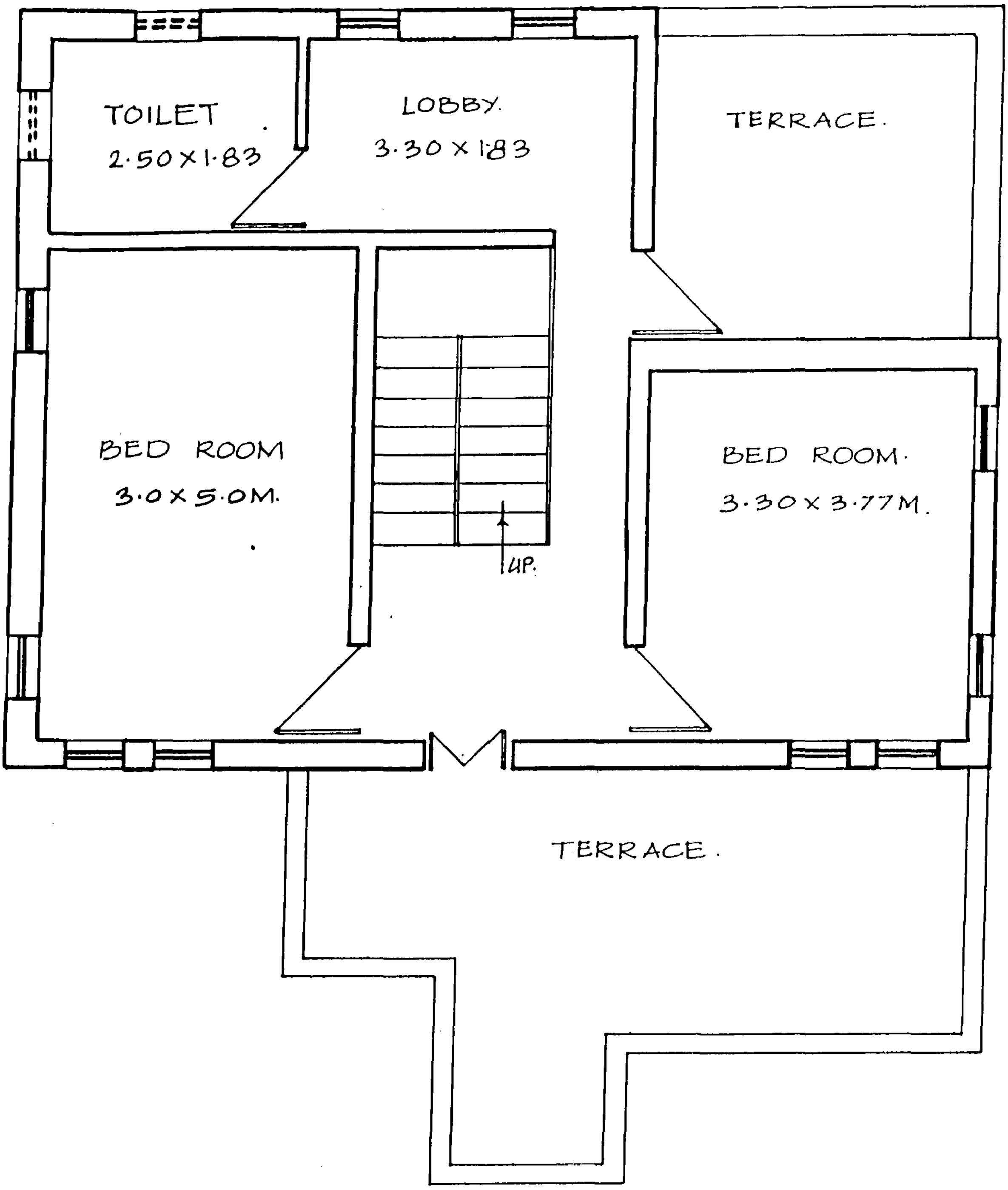
By using local building materials for construction. Architect is provided a evaporative passive cooling system in the building. So he provided a maximum thermal comfort in the building by natural way in summer.




# GROUND FLOOR PLAN.

SCALE :- 1:50. FIG - 4.17






# FIRST FLOOR PLAN.

SCALE :- 1:50. FIG- 4·18

Fig. 4.19 Entrance view of Kalamdani House

Fig. 4.20 View of Roof and Chajja of Kalamdani House

Fig. 4.21 View of Water Pond of Kalamdari House

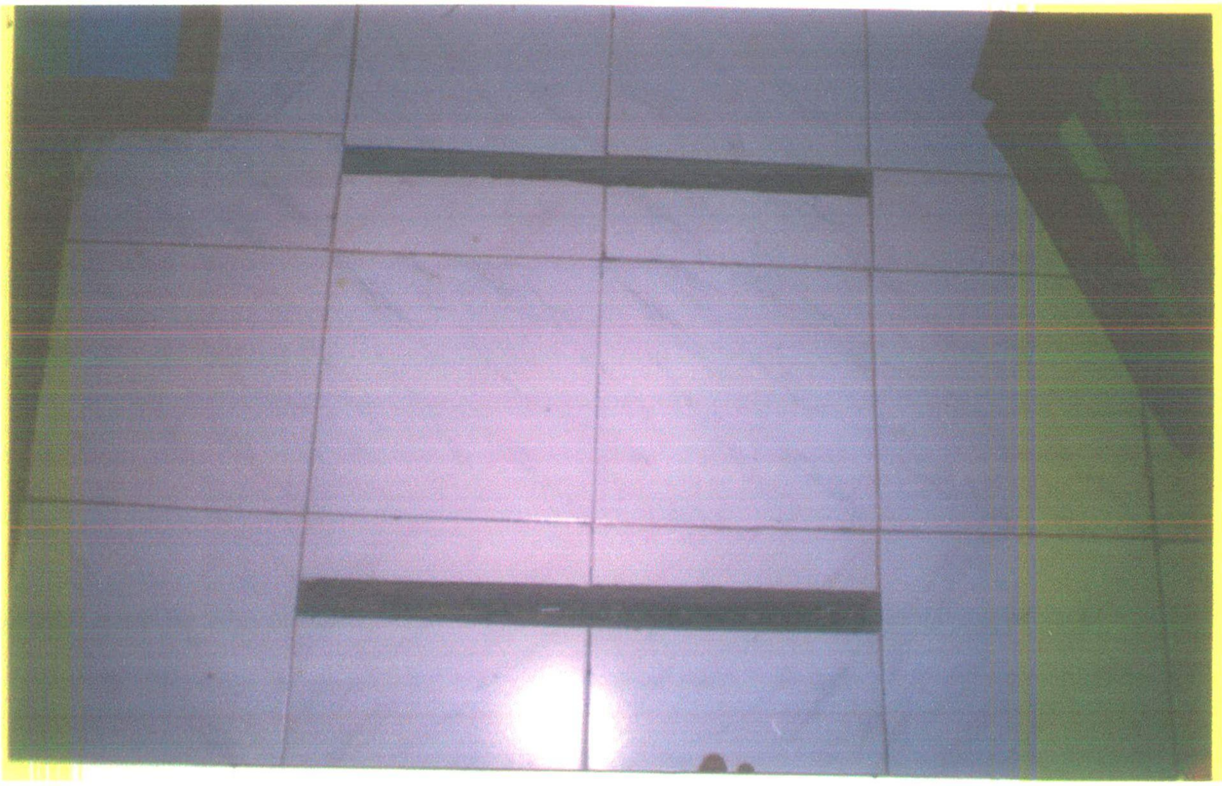


Fig. 4.22 View of Openings Provided in Flooring of Kalamdari House

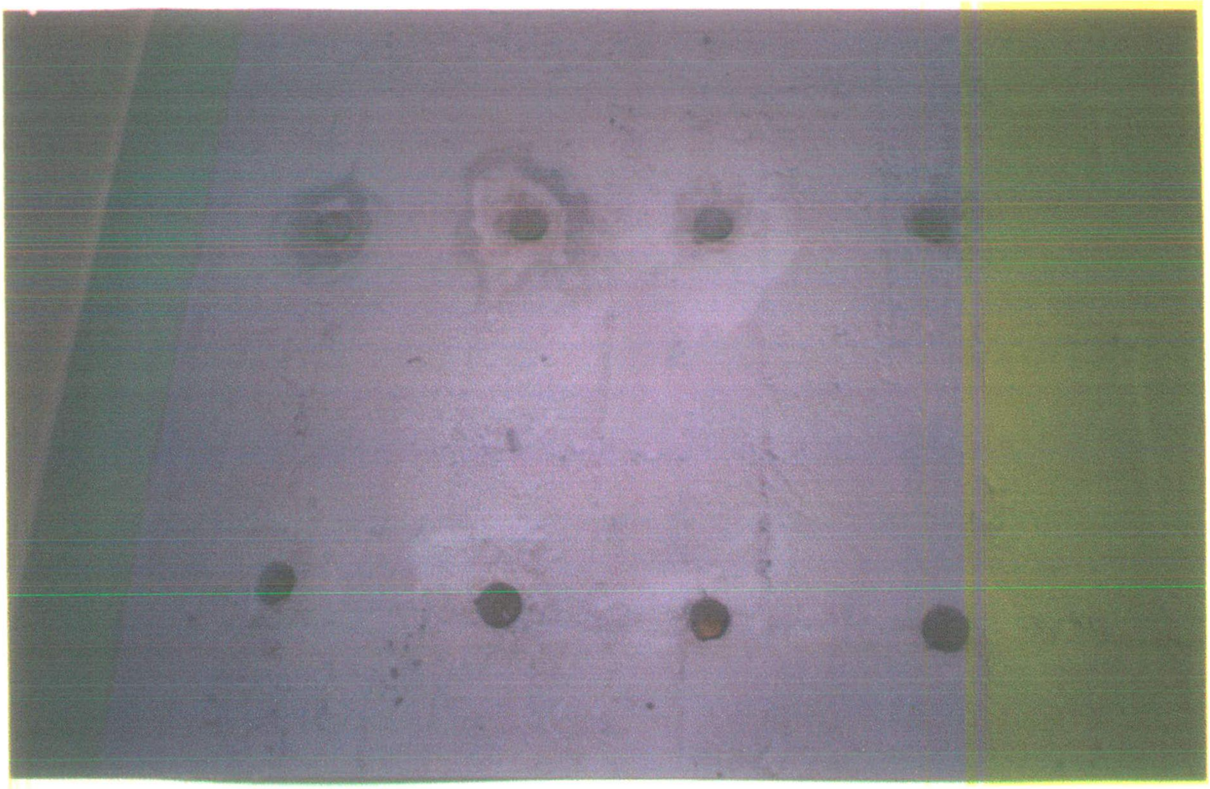


Fig. 4.23 View of Opening Provided in R.C.C. Roof to Pass Hot Air

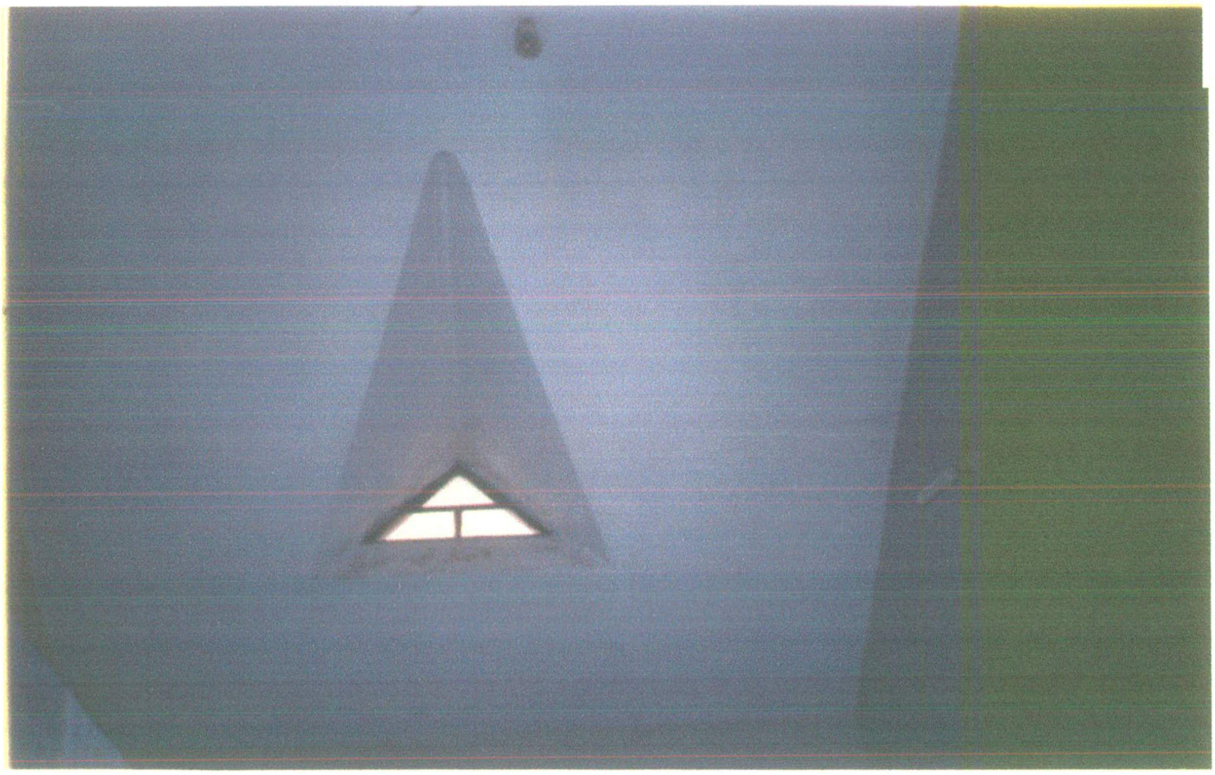


Fig. 4.24 View of Dermer Window in R.C.C. Roof

Fig. 4.25 View of Window Showing Material Used

## 4.6 RESIDENTIAL BUILDING

### PASSIVE DOWNDRAFT EVAPORATIVE COOLING (PDEC) SYSTEM

**Owner** **M.B. Patel**

### DESCRIPTION

The building is of two storied. Architect has considered the climatic factors in the design of building. The road is facing toward the South-West of the plot.

### PLANNING

The building is planned such a way that the Central Courtyard and around the courtyard rooms are arranged. The plan is fitted in to site at $45^0$ to the main road. The main concept of this system is to generate the required movement of air in different spaces of the building by a minimum use of Mechanical or electrical energy. Rain water collection and recycling of water at the domestic level is achieved. Hence making it an energy conscious. Four vertical tower is used to extract hot air from the building. Above the courtyard the techniques used such a way that the cool air passes downward and it circulate through all rooms. In South and West direction to avoid direct solar radiation provides pergola to create a shadow. There is no windows towards East and West side of the wall direction to avoid the direct sunlight.

### INTERIOR

Interior arrangement is provided such a way that from the courtyard the air can easily circulate through all the rooms to achieve thermal comfort in the rooms.

### WALLS

All wall internal and external are constructed with brick masonry with one and half brick thick, as a load bearing structure. Walls oriented towards east and west plastic barrels are placed very close to wall for rain water collection, used for the evaporative cooling.

## CONSTRUCTION TECHNIQUES

For the construction of wall not used any special technique to reduced the heat transfer. For the construction of roof Architect used Madras hallow block and semicircular terracota tiles to minimize the heat transfer.

## OPENINGS

Architect minimizes window openings the window openings are of 2'-0" to 3'-0" wide and 4'-6" height. In window the evaporative cooling system has provided. The openings are provided to duct tower to extract the hot air from the room. Above courtyard the openings are provide to pass hot air and convert it into down draft evaporative cooling system.

## ROOF

The roof is constructed with R.C.C. slab with insulation materials covering laid by Madras hallow block and curved terracota tiles over Madras hallow blocks. The roof is provided sloppy to create a wind pressure and pass through the openings provided above courtyard for evaporative cooling.

## ROOF VENTILATOR

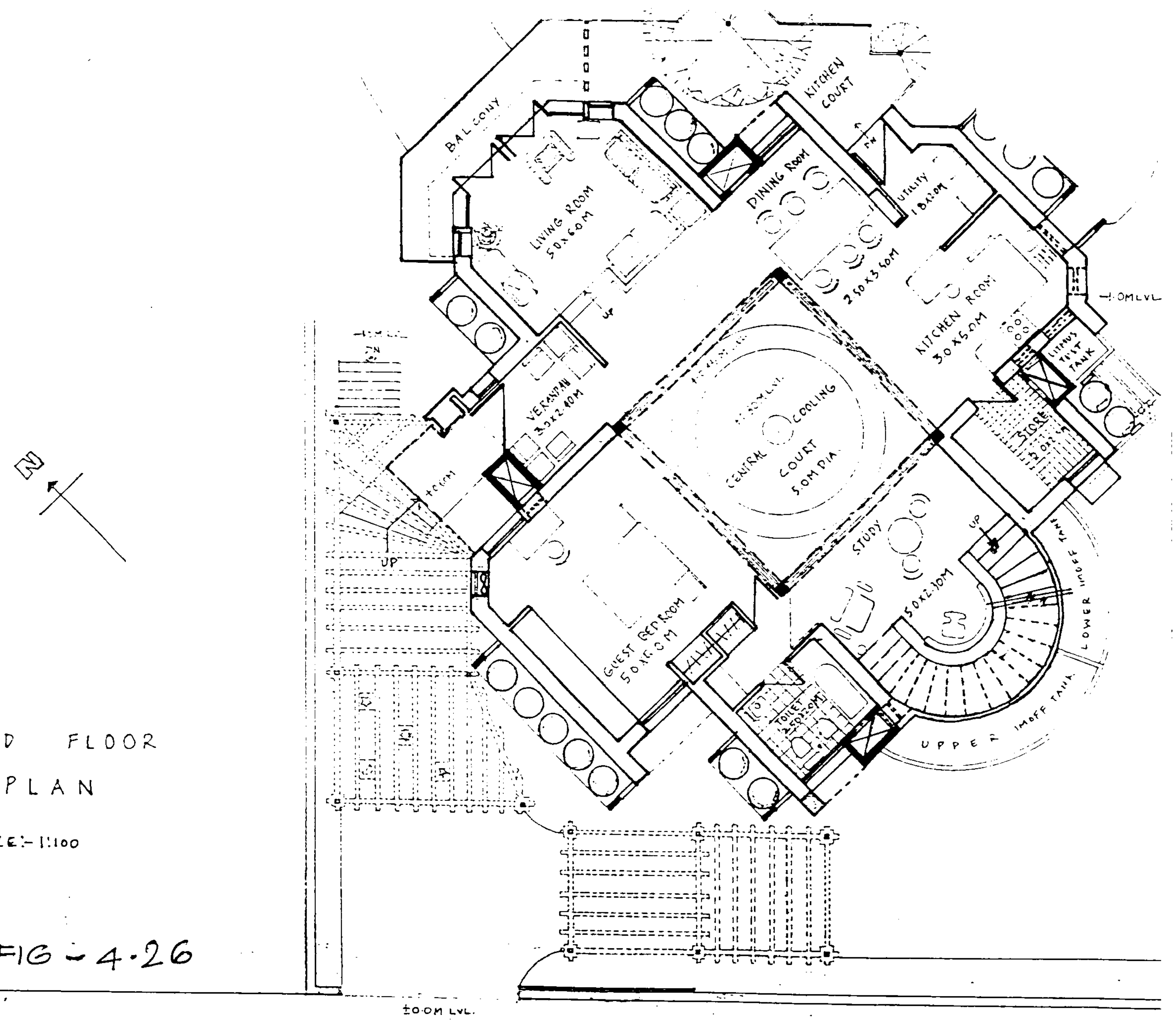
Roof ventilators are not provided in the building in place ventilator, duct are provided connecting to each room to remove hot air.

## EXTERNAL WALL TREATMENT

The wall facing towards east and west is plastered and placed plastic barrel very close to wall and filled with water to avoid the transfer of heat from solar radiation. The external surface is exposed minimum to the solar radiation.

## MATERIALS FOR CONSTRUCTION

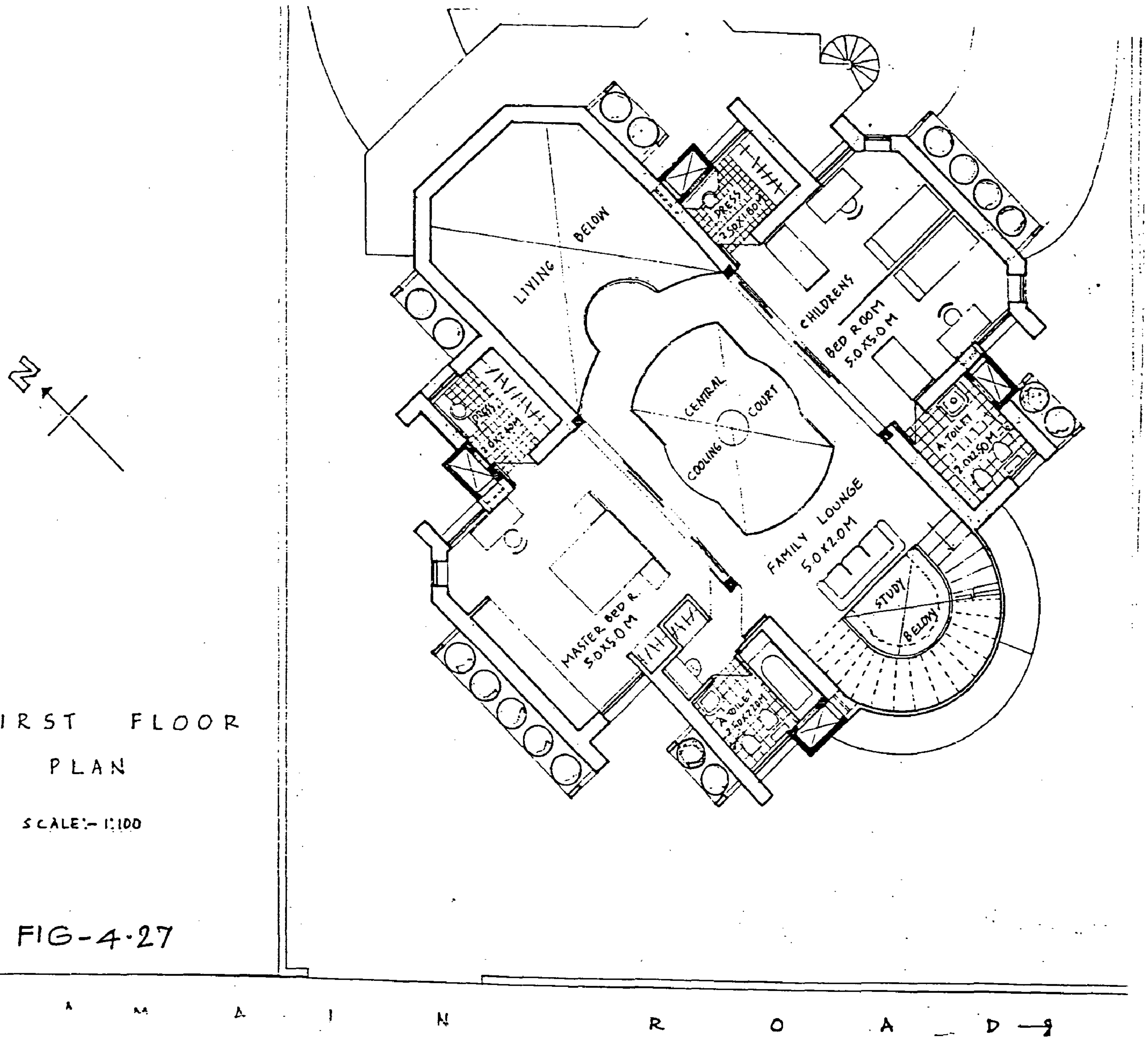
The materials used for construction is brick, R.C.C. slab, wood, Madras Hallow Block, curved terracota tile etc.




GROUND FLOOR PLAN

SCALE:- 1:100

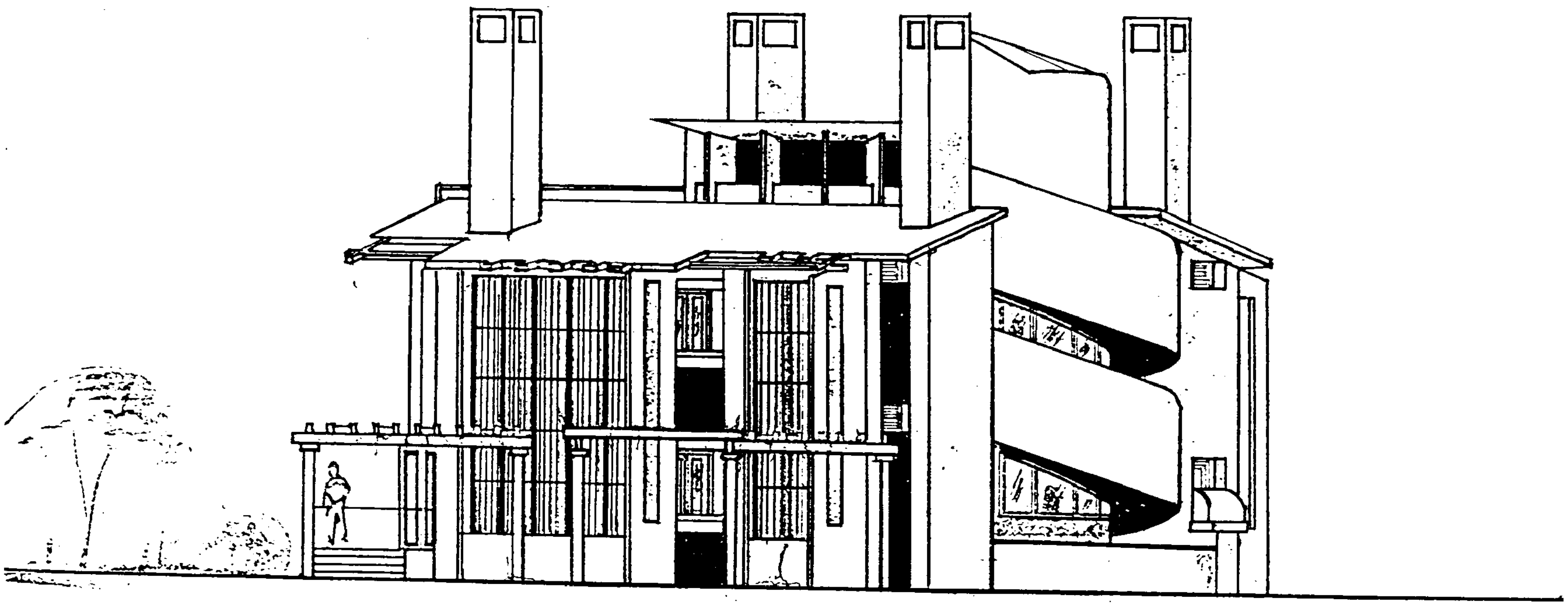
FIG - 4.26




FIRST FLOOR PLAN

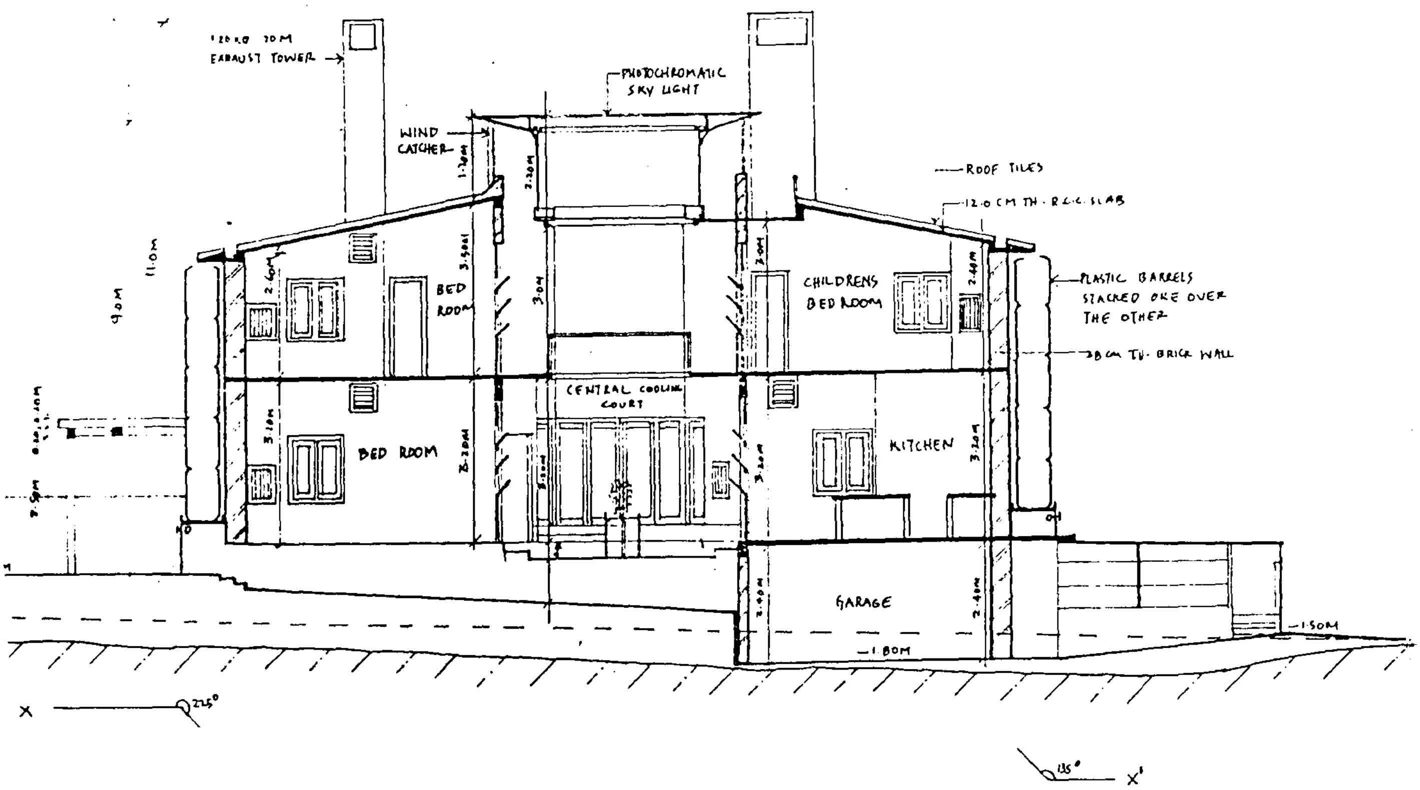
SCALE:- 1:100

FIG-4·27



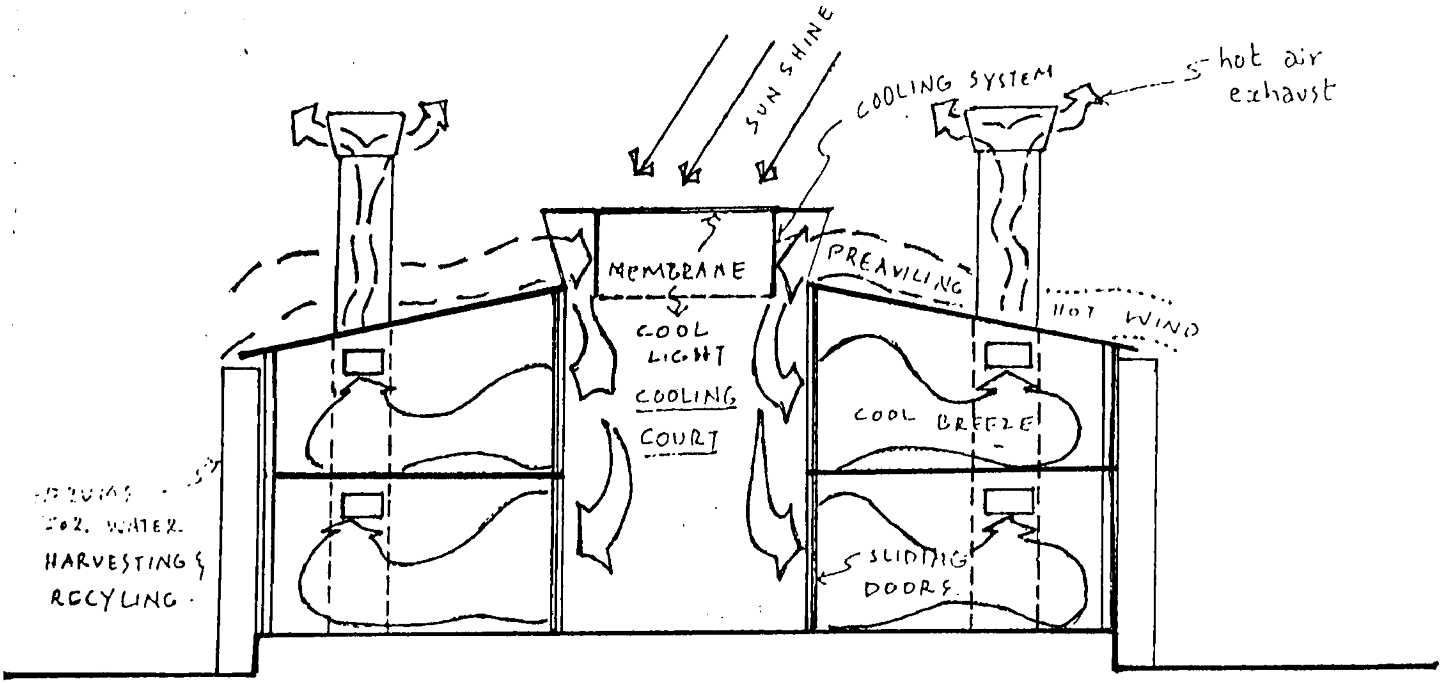
MAIN ROAD ELEVATION.

FIG - 4·28




E C T I O N A T X X'

FIG-4.29




SECTION · SHOWING AIR MOVEMENT.

FIG - 4·30.

# SLIDING DOOR CUM LOUVERED WINDOW DETAIL.

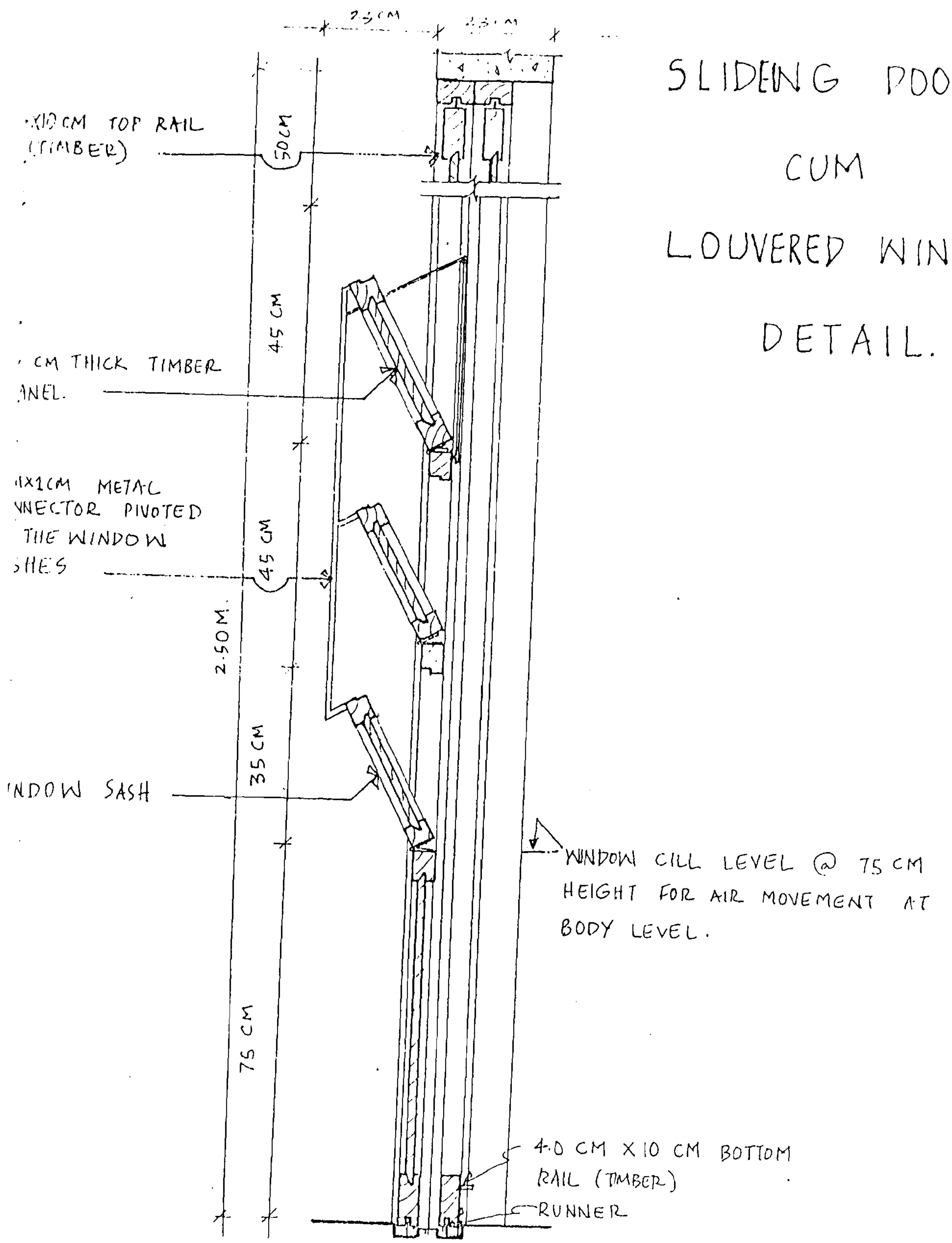



FIG- 4·31

# DETAIL OF WIND CATCHER AND COOLER.

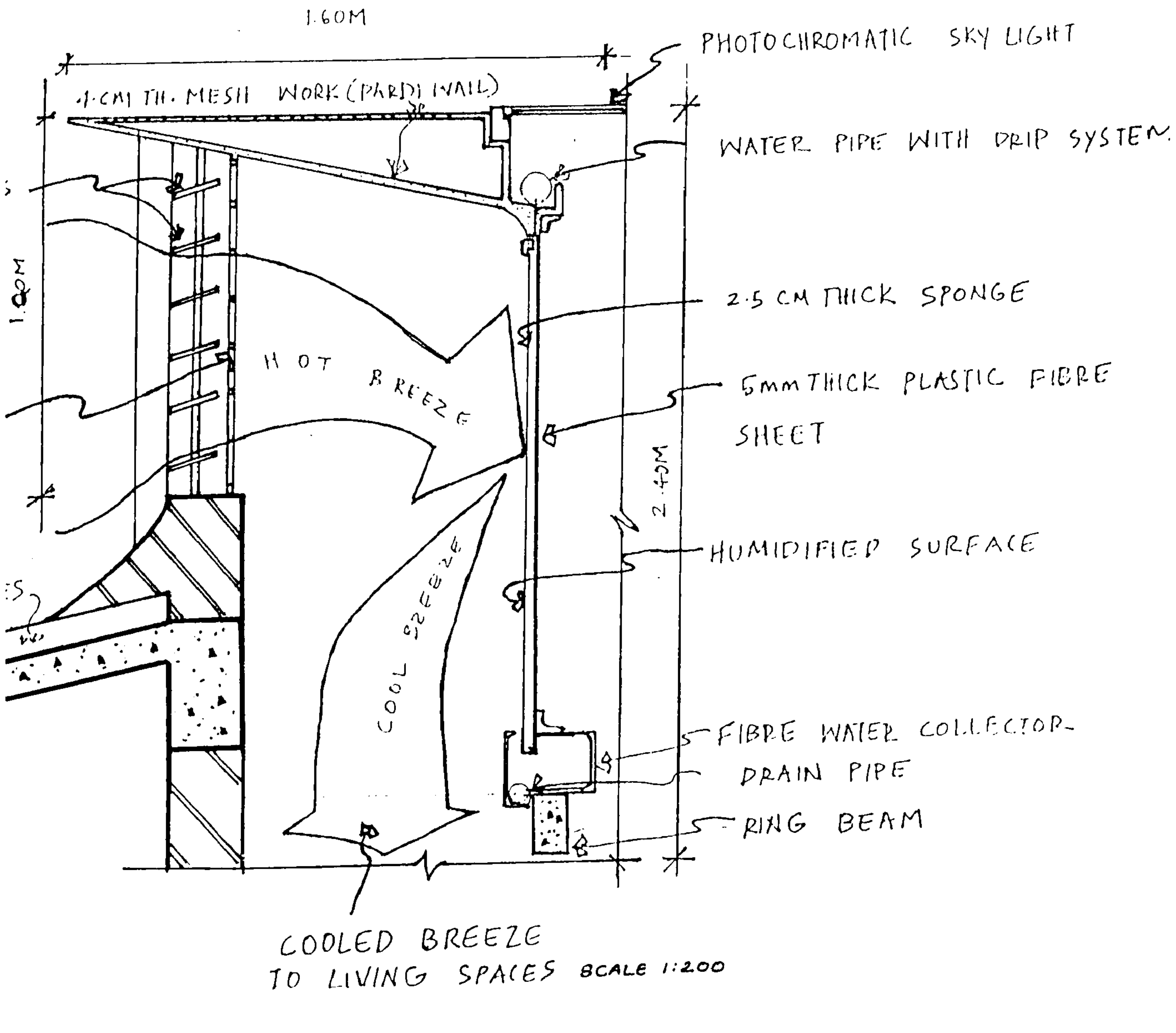



FIG - 4·32

## 4.7 HOUSE OF SHRI S.V. BARSHI

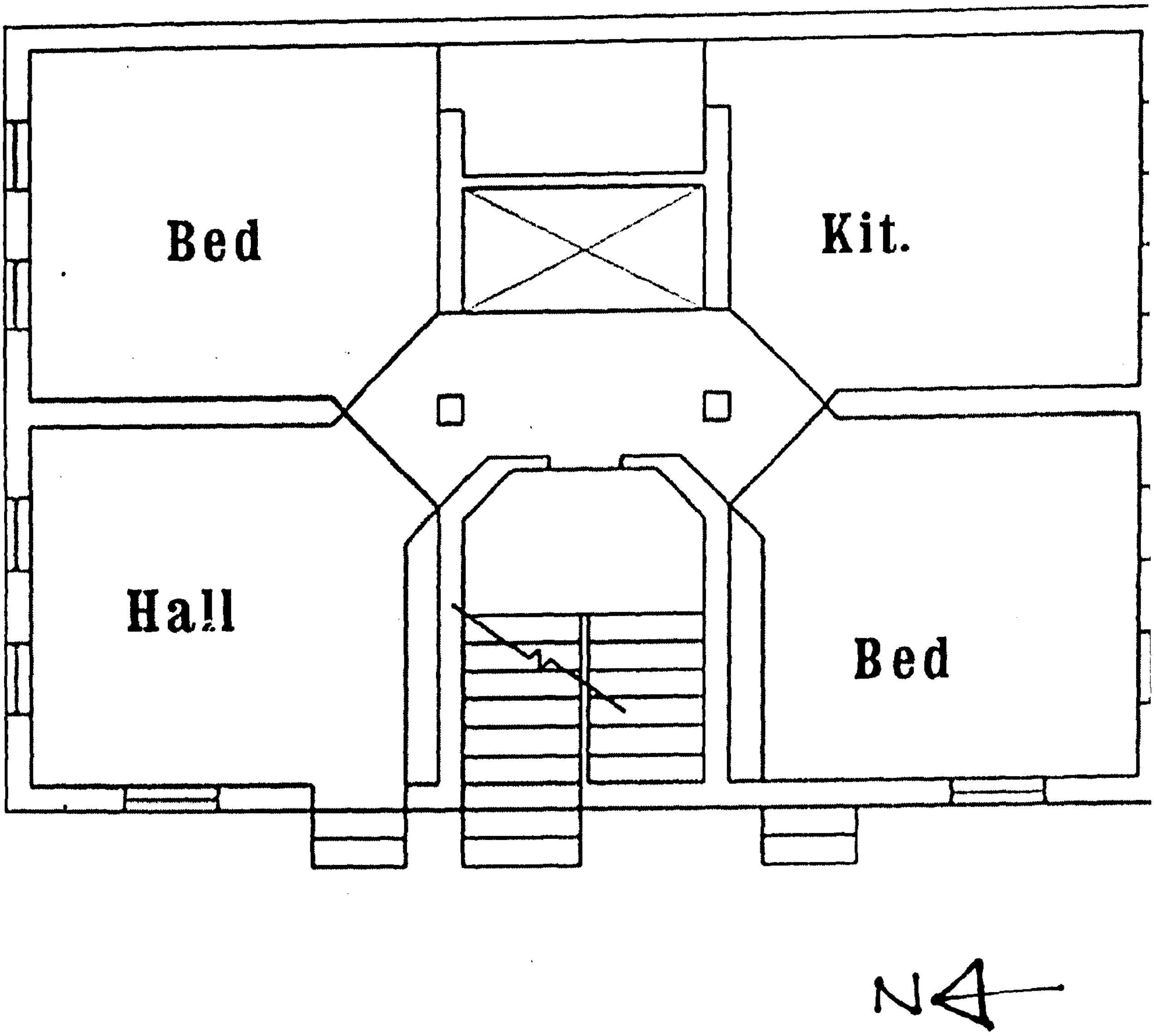
**Architect – Ar. Ashok W. Joshi**

The plan of the house is Rectangular is shape with one of the longer and side is common wall. Building is completed in 1995. Building is single story. Total built up area is 850 sq.ft. The main entrance of the house is from is from East side. The total construction cost of the building is 2,50,000.00 (Two lakh fifty thousand). All windows in the building of same size of 2'-6' × 4'6'. The building is symmetrical along shorter axis. The material used for the window is precast block laid over are one over other. The design of the block such a way that it maintained privacy and air flow pattern. The theory of window is derived from the lamp which is used in the mines.

The central courtyard is act as a passage to flow hot air form the room. The courtyard can be operated according to the season to control the air flow. For the construction of wall Architect used a Rat-trap bond to reduce the Temperature by providing the cavities in the wall. No plastering is done on both the side.

Architect tries to provide a maximum comfort with the help of passive cooling technique with minimum energy and cost. Architect is provided climatic as well as physiological comfort. He provided a kitchen platform height of 40cm above floor level lady of a house can prepare a food by sitting on the stool instread of standing.

# House of Sri S.V.Bakshi




## Ground Floor Plan

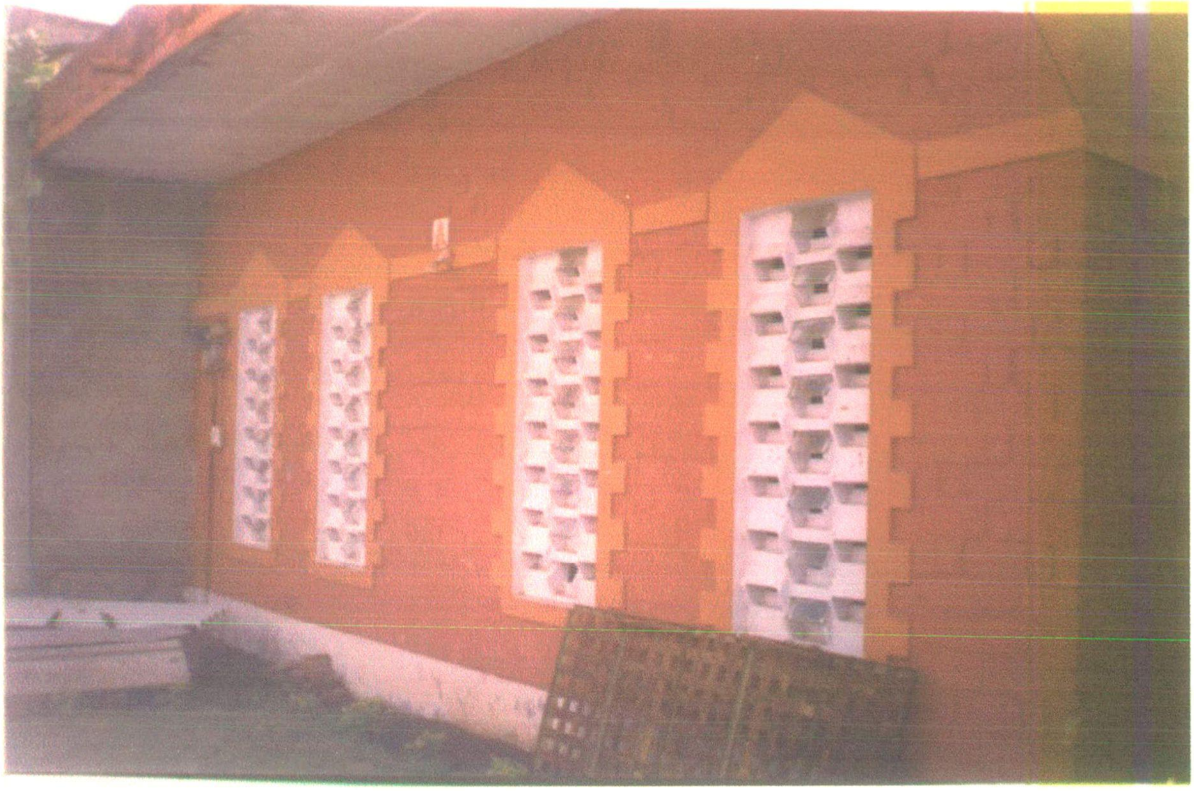


Fig. 4.34 Front View Showing Windows of S.V. Bakshi House

Fig. 4.36 View Showing Precast Block used for Window

Fig. 4.36 View of the Opening Above Courtyard

Fig. 4.37 View Shows The Wall Construction Technique

## CONCLUSION

The vernacular architecture of any region must have been evolved after so many years of innovation and the study of climate problem of that particular geographical area air forefather had constantly tried to make one living environment more and more comfortable, by trial and error method, and of cause *from experience, and also from* dedicated studies of regional climate.

All house are almost square or Rectangular in plan and well oriented. Most of the houses are planned as per the vastu. The buildings are constructed as per the need or requirement of the people. These buildings are well protected from the climate.

Now in the wake of so called 'modernity' and new construction techniques we have been consciously rebelling against the vernacular climate-conjoins design which have been perfected through years centuries of work and innovation and which are 'did' felt giving us the near comfort conditions, and considering them as superstition and irrelevant, even though the new modern structure we live in are found to be not appropriate for our climate.

Actually what we understand as passive design is nothing but a further improvement of climate control system, as applied to traditional architecture for a long time already. So much we can learned from the part. So it is very much essential to bridge the gap between the traditional and modern building approaches for this careful study is necessary.

So this study is a useful in re-discovering of the building techniques used in traditional buildings, & adopt them in the present day architecture with certain modifications with the help of modern technology.

# CLIMATE CONTROL STRATEGIES FOR HOT-DRY CLIMATE

Buildings, as they are designed and used today, contribute to serious environmental problems because of excessive consumption of energy and other natural resources. The close connection between energy use in buildings and environmental damage arises because energy-intensive solutions sought to construct a building and meet its demands for heating, cooling, ventilation, and lighting cause severe depletion of invaluable environmental resources.

However, buildings can be designed to meet the occupant's need for thermal and visual comfort at reduced levels of energy and resources consumption. Energy resource efficiency in new constructions can be effected by adopting an integrated approach to building design.

Passive systems provide thermal and visual comfort by using natural energy sources and sinks, e.g. solar radiation, outside air, sky, wet surfaces, vegetation, and internal gains. Energy flows in these systems are by natural means such as radiation, conduction, and convection with minimal or no use of mechanical means. The solar passive systems vary from one climate to the other. For example, hot climate, the architect's primary aim would be to reduce solar gains, and maximize natural ventilation.

The pressure on the earth's non-renewable resources can be alleviated by judicious use of earth's renewable resources, i.e. solar energy. Use of solar energy for meeting electrical needs of a building can further reduce consumption of conventional forms of energy.

Landscaping creates different airflow patterns and can be used to direct or divert the wind advantageously by causing a pressure difference. Additionally, the shade created by trees and the effect of grass and shrubs reduce air temperatures adjoining the building and provide evaporative cooling. Properly designed roof gardens help to reduce heat loads in a building.

Also, the building form determines the airflow pattern around the building, directly affecting its ventilation. The depth of a building also determines the requirements for artificial lighting – greater the depth, higher the need for artificial lighting.

## 5.1 THE BUILDING CONFIGURATION

In a hot-dry climate in summer it is desirable to lower the rate of Temperature elevation of the interior during daytime house to this end the building should preferably be compact the surface area of its external envelope should be small as possible, to minimise the heat flow into the building. Also the ventilation rate should be kept to the minimum required for health. In order to minimize heating of the interior by the hotter outdoor air. A small surface area of the walls and the roof, when the construction is not completely air tight.

The main impact of layout, from the indoor climate point of view, is its effect on the envelope's surface area, relative to the floor's area of the space volume, and consequently on the rate of heat exchange of the building with the outdoors. It also has a effect on the building's potential for natural ventilation and for natural illumination.

The ratio of the building envelope's surface area to its volume or floor area to its volume or floor area determines, on the one hand, the relative exposure of the building to solar radiation and, on the other hand, it exposure to the ambient air layout is that of a patio, or a courtyard, surrounded by walls and thus partially isolated from the full impact of the outdoor air. This configuration is very common in hot-dry climate.

With such geometrical configuration and operating procedure of building is "compact" during the summer daytime hours and during the winter and is "wide spread" during the summer nights. The changeable surface area of the effective envelope minimises the rate of heating of the interior during summer daytime and maximum the rate of cooling in the evening.

A configuration that has a special role in hot-dry regions is an internal courtyard. It is often suggested that such internal patios and courtyards help in maintaining cooled indoor temperature. Courtyard houses were developed in response to different needs and limitations and climate was the factors.

Vernacular buildings in hot-dry regions traditionally have incorporated different forms of open spaces as integral elements of the habitat. As internal patio provides completely private open space, visually and acoustically separated form the external public environment.

## 5.2 BUILDING ORIENTATION

The main objective in deciding upon a given orientation in hot-dry regions is to minimize the impact of the sun on the building in summer. Ventilation in the evening hours is also very important in hot-dry regions. The highest intensities of the impinging solar radiation in summer, for roof, eastern and western wall.

Pattern of solar radiation on the different walls results in a clear preference for north-south orientation of the main facades, and especially of the window. Such orientation enables easy and in expensive shading of the southern window in summer.

The amount of radiation transmitted through a window with conventional glazing the amount of absorbed radiation depends, of course, on the absorptivity of the wall's surface.

The issue of orientation in hot-dry regions concern mainly the windows and other glazed areas. The heating effect of solar radiation impinging on walls can easily be minimized by choosing reflective colors of the walls. in fact, a white western wall exposed to the sun in summer. In a hot-dry location and southern wall fully protected from direct radiation by a overhang.

## 5.3 BUILDING INSULATION

**What is it – And Why ?**

Insulation is a material used to slow down conductive heat flow through the building envelope. The building envelope consists of the walls, the ceiling, and the floor that enclose the space you want to keep warm in winter and cool in summer. In most homes the garage is unheated, so it is regarded as outside the building envelope.

Insulation comes in many forms : batts, blankets, rigid board, loose fill (either poured or blown in), spray, and foam. Each form may come in several types, so insulator can be a confusing subject. Insulation is measured in R-value. R stand for thermal resistance and the R –value is a number that tells you how much the insulation resists heat flow through it –how well it slows down heat transfer.

The higher the R-value the more effective the insulation. Different materials will require different thickness to get the same R-value. Recommendation for R-value will vary according to such factors as climate the part of the house to be isolated and the kind of materials used in the construction.

There has been an increasing interest in making the air in occupied buildings more comfortable and healthful and in conditioning the air in manufacturing building to suit the manufacturing processes. There has also been interest in reducing the operating costs involved in such improvements. Two important factors in bringing about these conditions are the temperature and the humidity of the air in the buildings.

Usually the savings in this cost which can be brought about by proper design and construction, including insulation, will much more than justify the additional expenditure involved.

***Types of insulating materials.*** Insulating materials may be divided into two general classes according to the way they function. In the first group may be included all the low-density, porous, or fibrous materials with low conductivity or high resistance to the passage of heat, whose effectiveness is due to the minute air spaces of which they are largely composed. This group includes three general types of insulating materials as follows: rigid or board and slab insulation., flexible or quilt, blanket, and batt insulation, and fill insulation.

The second group of insulation materials includes those of the reflective type which is used to form boundaries of air spaces and whose insulating value lies in its effectiveness in reflecting radiant energy.

The rigid, flexible, and fill insulators consist of wood cane, and other vegetable fibers, mineral wool, cork, hair felt, expanded mica, foamed glass or plastics, or light granular materials. They owe their insulating properties to the minute air spaces they contain. The insulating value per inch of thickness is about the same for all these materials.

## RIGID INSULATION

To be effective, the fibers are not highly compressed as in the hardboards. Moisture and water vapor partially excluded from some of the fiberboards if the boards are coated with asphalt of encased in a bituminous waterproof paper. For increased insulating value, fiberboards and gypsum boards are available with aluminum foil coating on one surface to serve as reflective insulation.

## FLEXIBLE INSULATION

This type of insulation may be in the form of quilts or blankets and batts, often spelled bats. The quilts and blankets consists of a fibrous material such as treated wood fiber, hair felt, flax fiber, eel grass, or shredded paper stitched between sheets of waterproof paper to form a flexible material available in various thicknesses up to 1 in.

Another form of flexible insulation is made from mineral or rock wool, formed by blowing molten rock into fibrous form by steam under pressure. Glass wool is a fibrous glass insulating material similar to mineral wool. It is available in batt, blanket, and fill form.

## FILL INSULATION

This material consists of granulated rock wool in the form of nodules or pellets, granulated cork, expanded mica, and other material which is blown through large tubes or dumped into open spaces in the walls and ceilings of buildings, such as the stud space in frame walls and the ceiling joist space. Fibrous mineral wool and glass wool are also furnished in loose form for packing by hand into open spaces.

## REFLECTIVE INSULATION

Reflective insulation is placed in air spaces and functions by reflecting a large percentage of the radiant energy which strikes it. The materials used for reflective insulation are very thin tin plate, copper or aluminum sheets, or aluminum foil on the surface of rigid fiberboards or gypsum boards. A common form of reflective insulation is aluminum foil mounted on asphalt-impregnated kraft paper, the strength of which may be increased by the use of jute netting. This material is used for lining air spaces or for curtains to increase the number of air spaces in a given overall space. To be effective, the edges of such curtains must be tightly sealed.

## 5.4 DESIGN OF WINDOW OPENINGS

The window design in hot-dry regions. In such a climate, where the outdoor daytime temperature is much higher than the indoor temperature conventional windows tend to raise the indoor temperature. Also, the larger the window area the greater the heating effect, especially when sun penetration is not effectively prevented by shading or orientation sunlight in hot-dry regions is very intense, and large windows may cause glare discomfort, reinforcing the nation that small window are more suitable than larger one for hot-dry regions this view is supported by the observation that vernacular buildings in hot-dry regions, built mainly form compacted mud, stone. Usually have very small windows.

However, it should be pointed out that the traditional way of life of inhabitants in vernacular houses in hot-dry regions was to sleep on the roof or in a courtyard, testify to the uncomfortable indoor conditions which perverted during the night. In fact, effective night ventilation is of primary importance for the cooling of the building's structural mass. By proper design (with large windows) to provide acceptable indoor comfort in hot-dry regions both during the daytime and night house from the physiological view pint, night comfort is more important than during the day time.

With special design details, large windows can be provided in these regions with advantages from the thermal point of view. When highly insulated shutters are added to large operable windows. Their thermal effect can be adjusted to varying needs, both diurnally and annually. In summer, the shutters can be closed during the hot hours, admitting light into the house only through small, shaded windows. In the evening, the shutters and the windows can be opened increasing the rate of cooling of the interior.

In hot-dry areas insects may be abundant in certain periods. Screens should then be included as an integral part of the window system. It should be possible to keep the screens closed when the windows and shutters are open.

The possibilities to reduce the direct and the indirect solar load by shading is there fore of particular interest of hot-dry region.

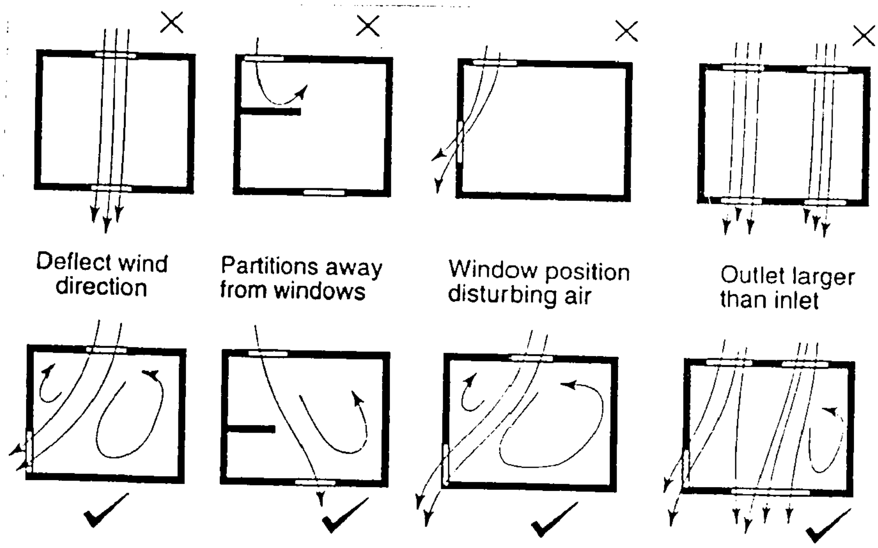



**Fig. 5.1 : Thumb Rules for Windows Configuration**

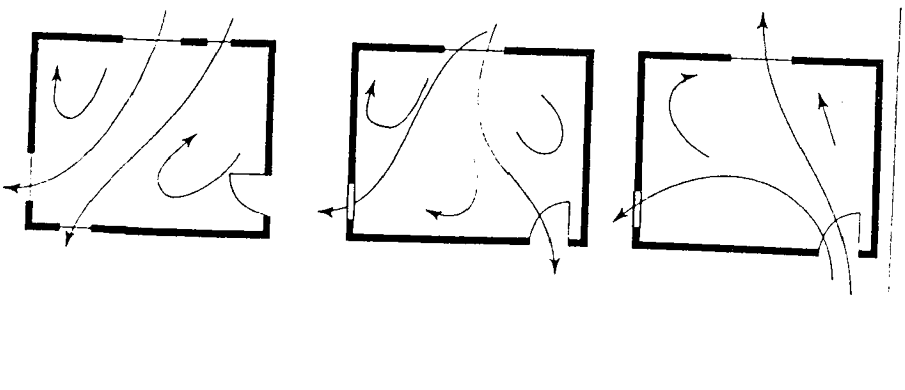
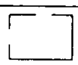
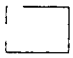
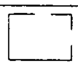
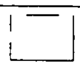
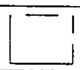


**Fig. 5.2(a) : An Ideal Case of Windows Positioning**

## TABLE 5.1 : EFFECT OF WINDOW LOCATION ON INDOOR AIR MOTION

| Window location \ Orientation | Change in % 0° wind | 45° wind |
|---|---|---|
|  | 0 | 0 |
|  | - 10 | + 40 |
|  | - 10 | - 15 |
|  | - 15 | 0 |
|  | - 15 | 0 |
|  | 0 | 0 |
|  | - 10 | - 10 |
|  | 0 | - 60 |
|  | - 20 | - 10 |
|  | - 20 | - 60 |

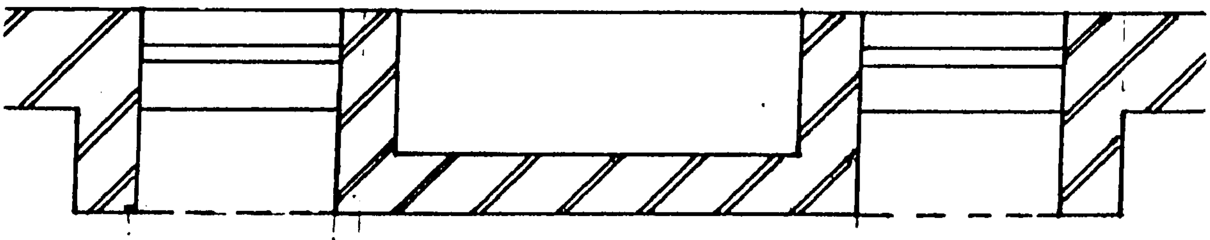


Fig. 5.2(b) : Window Location in West Wall

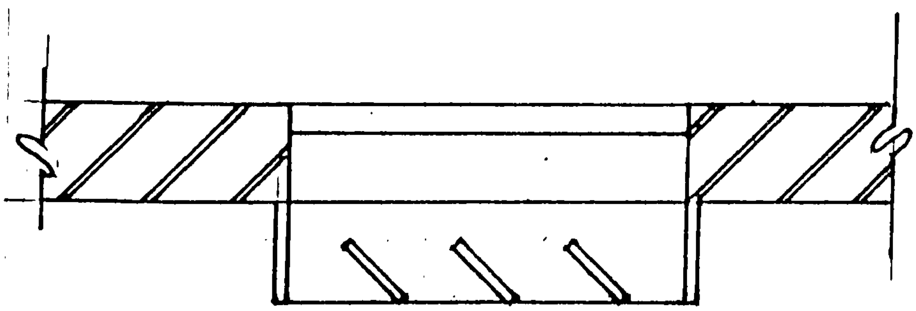


Fig. 5.2(c) : Window Design in West Oriented Wall

## SHADING DEVICES

Heat gain through windows is determined by the overall heat loss coefficient U-value ($W/m^2K$) and the solar energy gain factor, and is much higher as compared to that through solid wall. Shading devices for windows and walls thus moderate heat gains into the building. In a low-rise residential building in Gulbarga (hot and dry climate), shading a window by a horizontal 0.76 m deep chajja can reduce the maximum room temperature by 4.6°C (from 47.7 to 43.1°C). Moreover, the number of uncomfortable hours in a year with temperatures exceeding 30°C can be reduced by 14%.

Shading devices are of various types (Bansal, Hauser, and Minke 1994).

1. Moveable opaque (roller blind, curtains, etc.) can be highly effective in reducing solar gains but eliminate view and impede air movement.
2. Louvres (adjustable or fixed) affect the view and air movement to some degree.
3. Fixed overhangs.

Relative advantages and disadvantages of these shading devices are given below :

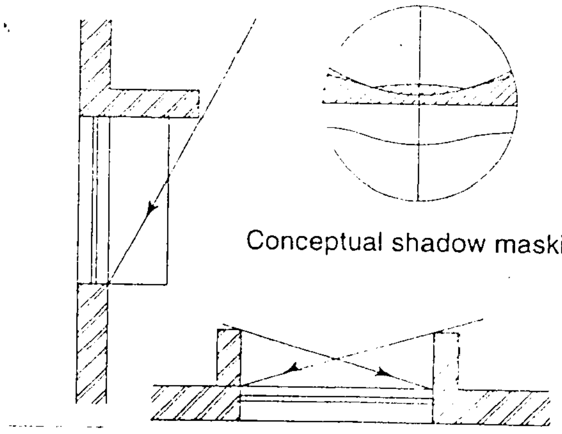



**Fig. 5.3(a) : Window Shades for Hot-Dry Climates**

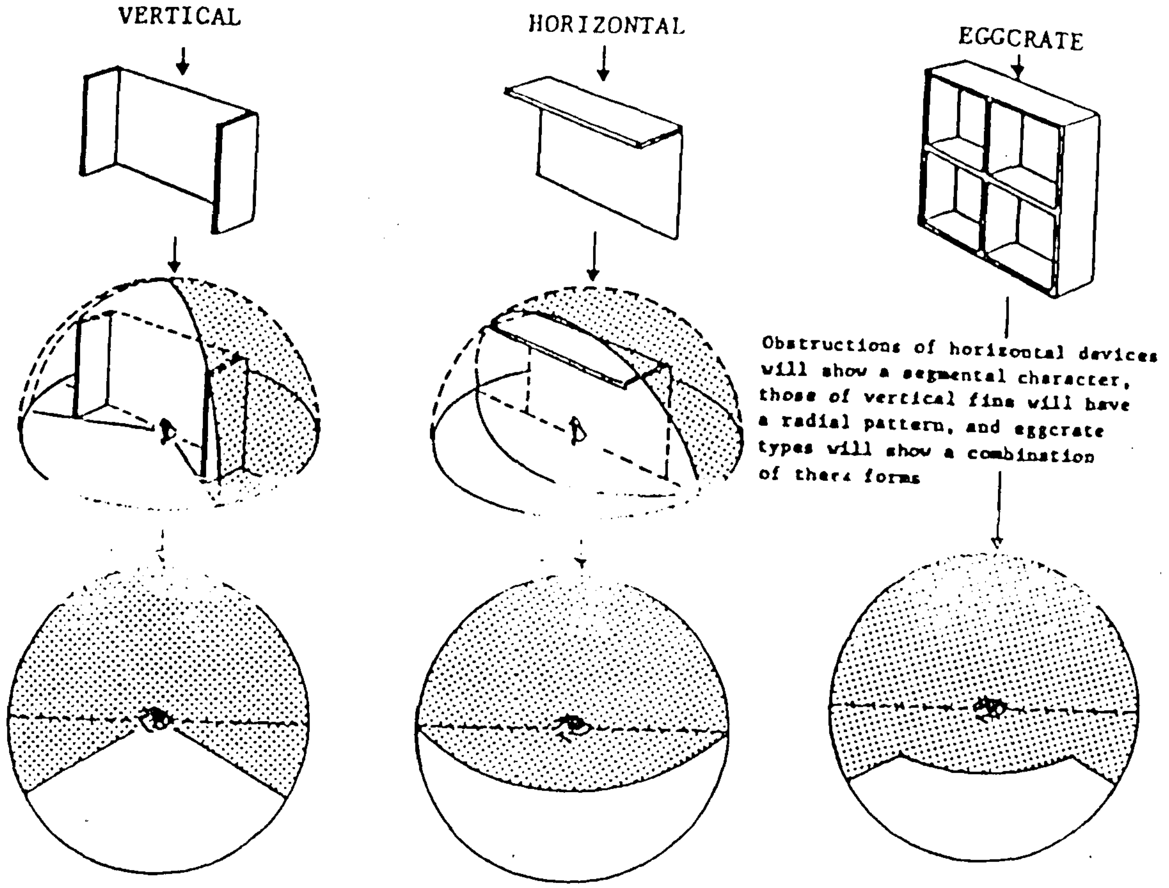



Fig. 5.3(b) : Three General Types of Shading Devices

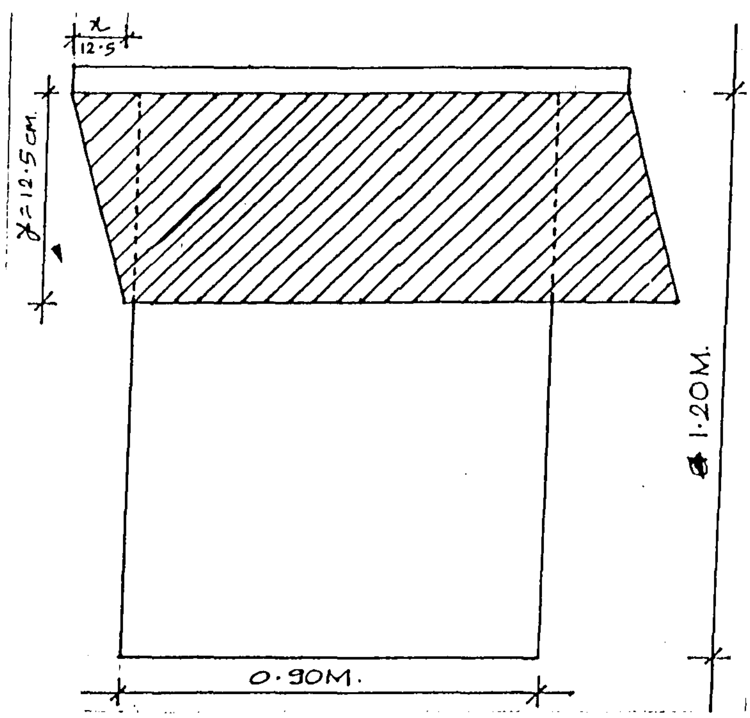



Fig. 5.3(c) : Shadow Diagram of Window 0.9m ×1.2m in West Wall on 15 May 4.00 P.M. of Latitude 17°N on West Oriented Wall of Chajja having 60 cm Projection and 15 cm bearing on Either Side of the Window

**MOVEABLE BLINDS OR CURTAINS**

- Block the transmission of solar radiation through glazed windows, especially on the east and west walls.
- In hot and dry climates, when ambient air is hotter than room air, they help to reduce convective heat walls.
- In warm, humid climates, where the airflow is desirable, they impede ventilation.
- For air-conditioned buildings, where the flow of outside air is to be blocked, they can reduce cooling load.

**OVERHANGS AND LOUVRES**

- Block that part of the sky through which sunlight passes.
- Overhanges on south-oriented windows provide effective shading from the high-altitude sun.
- An extended roof shades the entire north or south wall from the noon sun.

Before the turn of the century, buildings were designed to take advantage of daily temperature variations, convective breeze, shading, evaporative cooling, and radiation cooling. However, with a thoughtless imitation of the west, these concepts took a back seat and buildings became energy guzzlers. Today, with high energy costs and growing environmental concerns, many of these simpler techniques are once again becoming attractive. Passive cooling systems rely on natural heat-sinks to remove heat from the building. They derive cooling directly from evap[oration, convection, and radiation without using any intermediate electrical devices. All passive cooling strategies rely on daily changes in temperature and relative humidity. The applicability of each system depends on the climatic conditions.

The relatively simple techniques that can be adopted to provide natural cooling in the building have been elaborated earlier.

These design strategies reduce heat gains to internal spaces. This section briefly elaborates the passive techniques that aid heat loss from the building by convection, radiation, and evaporation, or by using storage capacity of surrounding spaces.

## 5.5 BUILDING MATERIAL AND THEIR THERMAL EFFECT

Traditional building in hot-dry climate are built of high-mass, thick walls, made of heavy materials, such as stone, bricks, and mud. Vaulted roofs with flat impervious external finish covered with earth, also provide high mass to the building. windows are of wooden shutters. The thick and heavy structure of the walls and the roof suppress the swing of the external temperature and stabilize the indoor.

In hot-dry climate, high thermal resistance of the envelope elements is necessary in order to minimise the conductive heat flow into the building's mass during the day time hours.

The conductive heat flow, from the external surface inward, depends on the external surface temperature and external temperature is depend on the sol-air temperature.

Consequently the required thermal resistance of the external walls and the roof can be specified for a given region as function of the "design" maximum outdoor air temperature and the peak intensity of solar radiation and the absurdity of materials.

Today, the availability of modern insulating materials, together with application of passive cooling system, make it possible to maintain indoor temperature significantly below the average of the outdoor air temperature with such design details it is possible to provide natural comfort through longer periods of the year and to use much less energy for summer cooling and winter heating.

**TIME LAG AND TRANSMITTANCE VALUE**

The behavior of light and heavy weight structures under the same climatic circumstances.

In light construction the faster the transmittance of heat and reduce the time lag factor. It is not suitable in hot dry climate but in massive construction. The time lag factor is more for day time comfort. Using heavy mass construction is suitable in hot dry climate.

**Table 5.2: Overall Heat Transmission Coefficient (U) and Time-Lag Characteristic Data for Homogeneous Walls**

| Material | Thickness, Inches | U Value , Btu/sq ft / hr | Time lag, Hours |
|---|---|---|---|
| Stone | 8 | 0.67 | 5.5 |
| | 12 | 0.55 | 8.0 |
| | 16 | 0.47 | 10.5 |
| | 24 | 0.36 | 15.5 |
| Solid Concrete | 2 | 0.98 | 1.1 |
| | 4 | 0.84 | 2.5 |
| | 6 | 0.74 | 3.8 |
| | 8 | 0.66 | 5.1 |
| | 12 | 0.54 | 7.8 |
| | 16 | 0.46 | 10.2 |
| Common Brick | 4 | 0.60 | 2.3 |
| | 8 | 0.41 | 5.5 |
| | 12 | 0.31 | 8.5 |
| | 16 | 0.25 | 12.0 |
| Face Brick | 4 | 0.77 | 2.4 |
| Wood | ½ | 0.68 | 0.17 |
| | 1 | 0.48 | 0.45 |
| | 2 | 0.30 | 1.3 |
| Insulating Board | ½ | 0.42 | 0.08 |
| | 1 | 0.26 | 0.23 |
| | 2 | 0.14 | 0.77 |
| | 4 | 0.08 | 2.7 |
| | 6 | 0.05 | 0.5 |

## 5.6 HOW TO MINIMISE HEAT TRANSFER THROUGH BUILDING ENVELOPE

### (i) Roof and wall

### (ii) External surface treatment

All external heat impact must pass through the building shell before they affect indoor temperature conditions. As heat flow into the shell materials the process is comparable to the absorption of moisture by a porous materials successive layers of the structure become "saturated" with heat untill finally the effect is felt on the inside surface. The function of the materials can be utilized favorably to approach balanced conditions in the interior of a structure.

The thermal force acting on the outside of a structure are combination of radiation and connective impacts. The radiation component consist of incident solar radiation and of radiant heat exchange with outdoor surrounding and with the sky. The connective heat impact is a function of exchange with the surrounding air temperature, and may be accelerated by air motion.

The first line of heat control lies at the surface. Since the surface temperature of a sunlit materials will be higher than that of the air.

The heat flow between a building and its environment takes place in several physical modes. Conduction, convection, and Radiation and through different path and element of the building envelope. The roof, wall, and openings.

The most important thermal-control characteristic of materials is their transmission behavior.

The reduction of heat flow is most efficiently achieved by the resistance insulation property of the material. The desired insulation magnitude is in direct relationship to the difference between outside thermal conditions and comfort requirements.

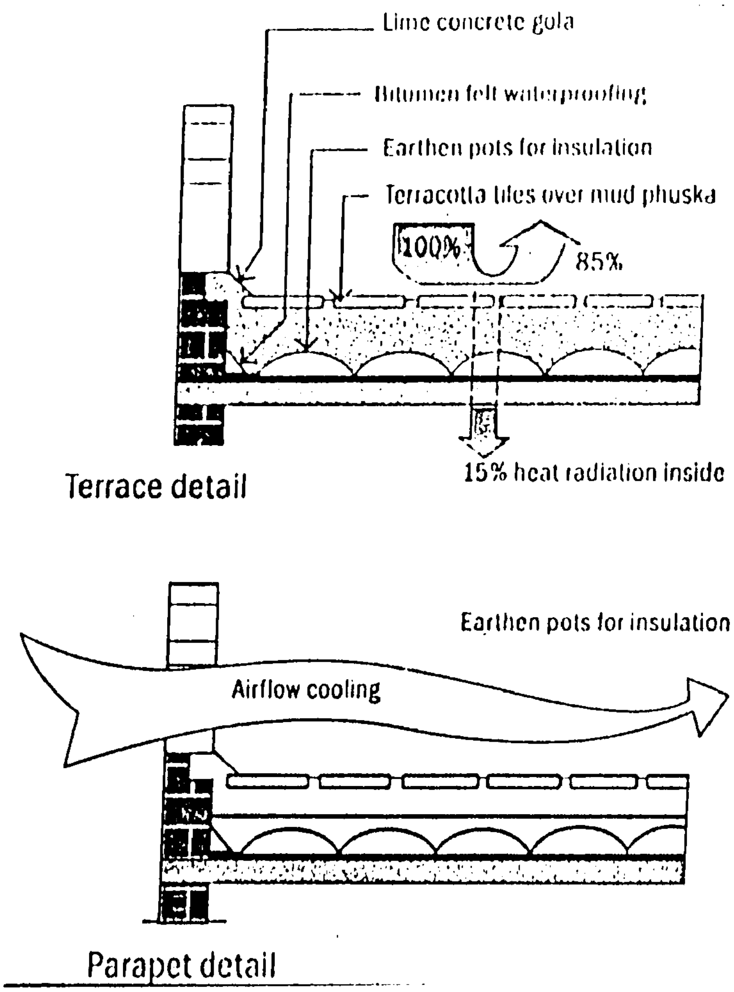



**Fig. 5.4 : Roof Details showing use of Earthern Pots for Roof Insulation**

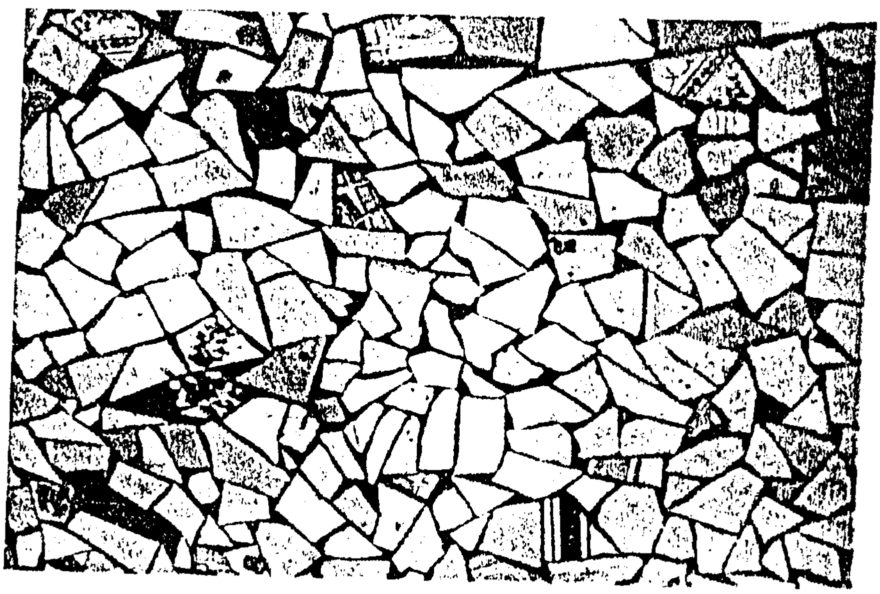


**Fig. 5.5 : Broken China Mosaic can be Used Top Most Layer in Roof for Reflection of Incident Radiation**

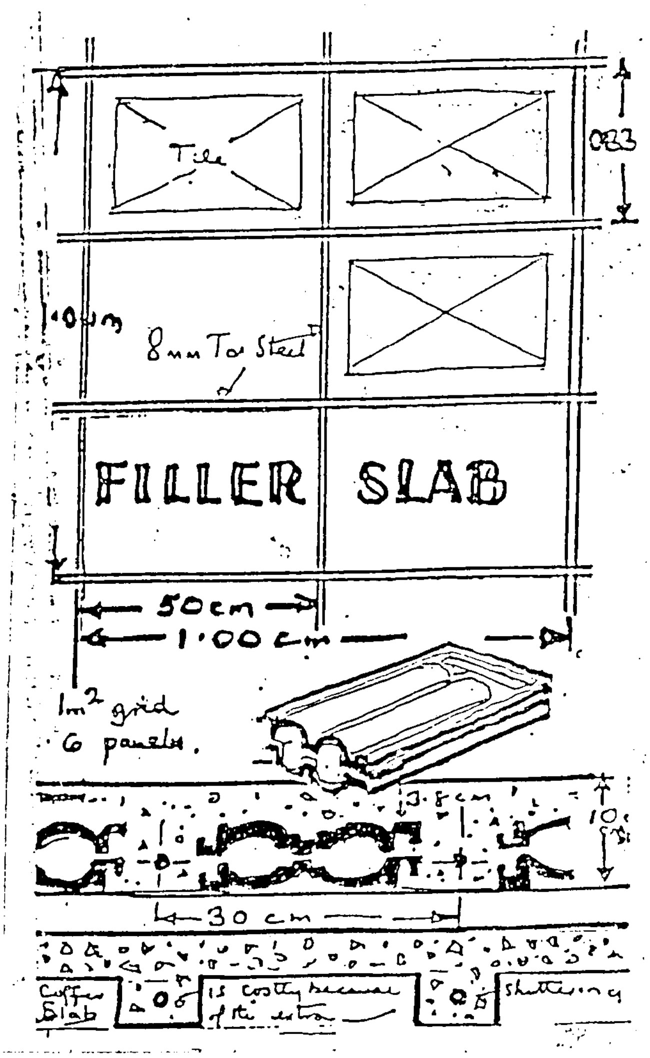



Fig. 5.6(a) : Manglore Tile Used in R.C.C. Slab to Minimise Heat Transfer (Filler Slab)

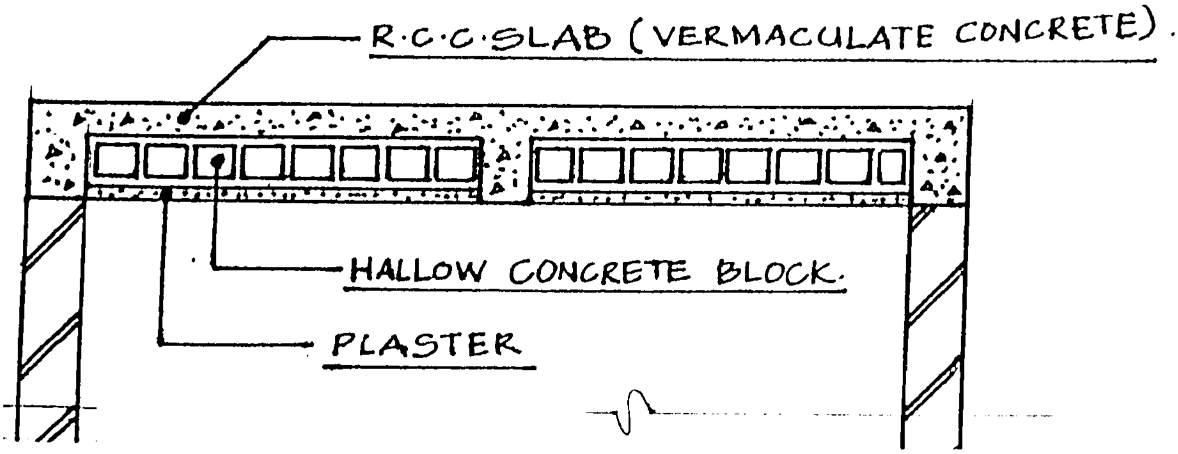



Fig. 5.6(b) : Figure Shows the Section of Roof and Hallow Block to Minimise Heat Transfer

Roof and Walls with high thermal capacity and adequate resistance will reduce this external range so that the temperature variation at the internal surface is only about 15 to 20% of the external air or sol-air temperature range.

The average of the decreased internal temperature range is usually less than the average sol-air temperature acting on the external surface, though this will depends on the absorptivity of the surface.

The reduction in the internal temperature range will also be associated with an advantages time lag. The maximum heat load, which will be experienced at or just after mid-day will be delayed and will not affect the interior until the cooler hours of the evening or the night. The time lag should be at least eight hours and time lags of upto fourteen hours are still advantages. Larger time lags will not necessarily improve internal conditions since the heat gain through a roof with a time-lag between 20-30 hours will reach the interior at the same time as the ventilation heat gain. A concrete slab of 30 cm would be required to give a time lag of 8 hours.

This is unlikely to be economic since not only is the volume of materials excessive, but also the weight will require larger structural member to support it. A time lag of eight hours can be achieved more economically is a roof construction has a insulating layer on the outside of a heavy layer.

While the construction of roof main objective is to minimize the transfer of heat by using filler slab.

For the construction of wall using some construction technique which creates the void cavities inside the wall. And simultaneously economize the cost of construction. Providing cavities ( Ref. Fig. 5.9 & 5.10) in external walls. So that will reduce the temperature up to 8°c. while transferring from outside to inside surface of the wall.

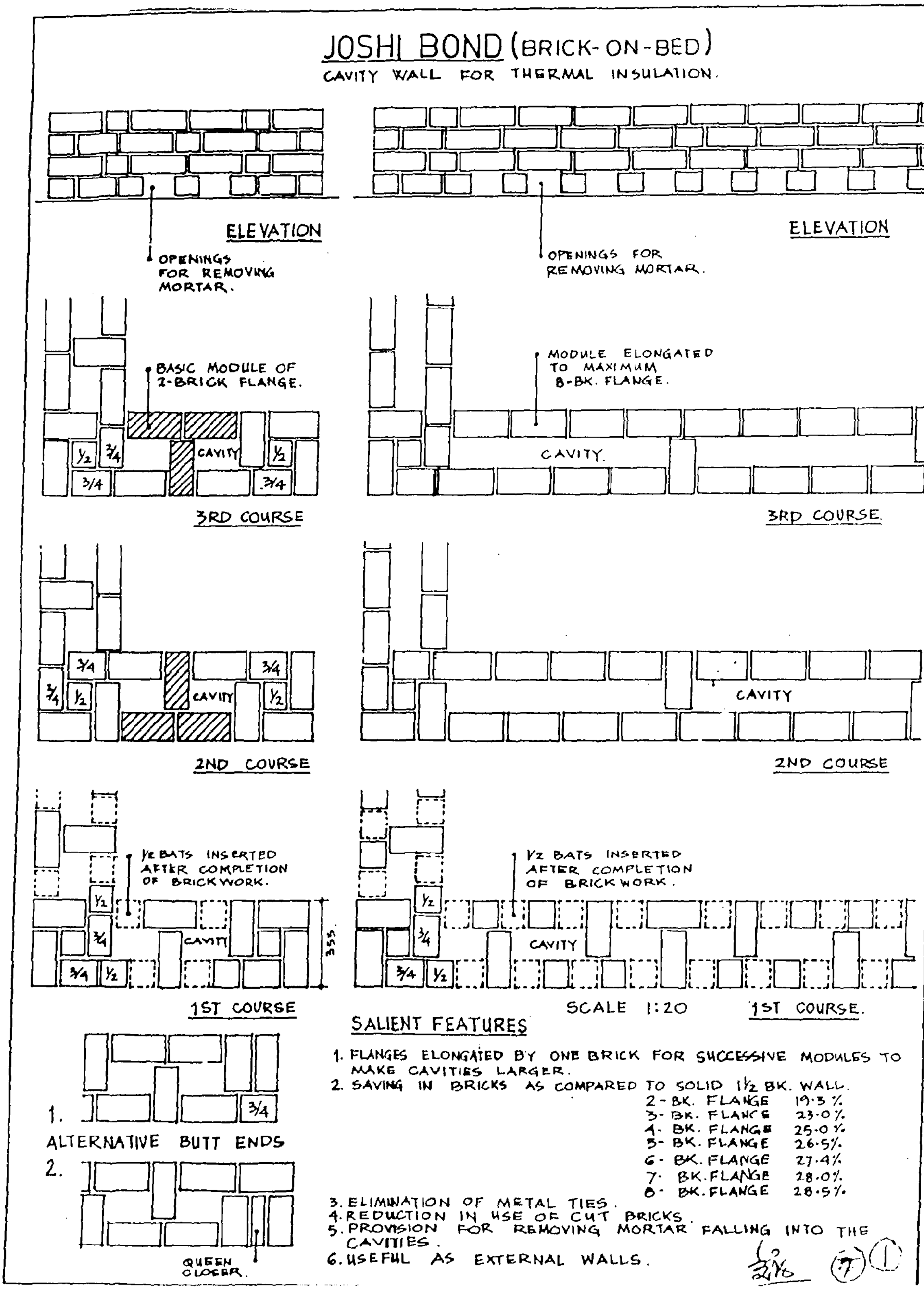



**Fig. 5.7 : Providing Cavities in Brick Masonary Wall to Reduce Heat Transfer (Joshi Bond)**

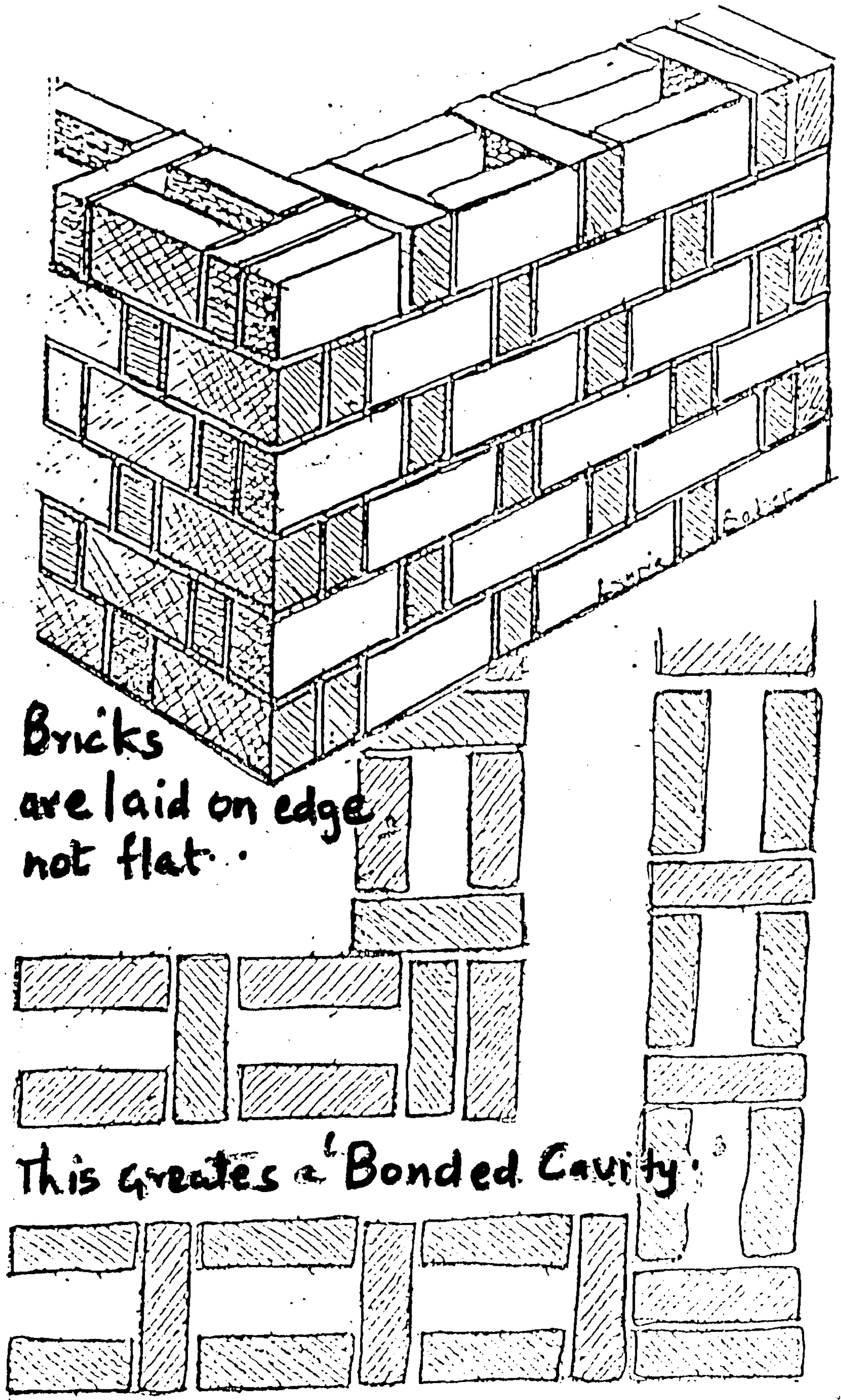



**Fig. 5.8 : Using Rat-Trap Bond Construction Technique in External Wall to Minimize the Heat Transfer**

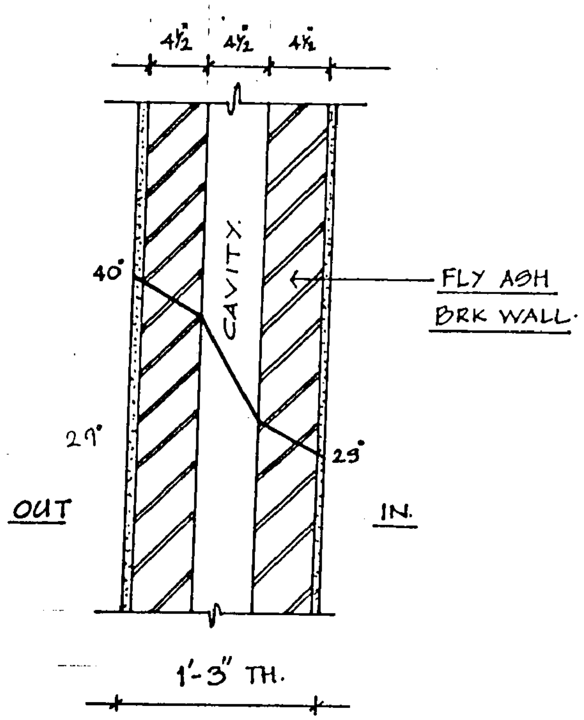



**Fig. 5.9 : Section of Wall Shows the Temperature Gradient Line in Cavity Wall**

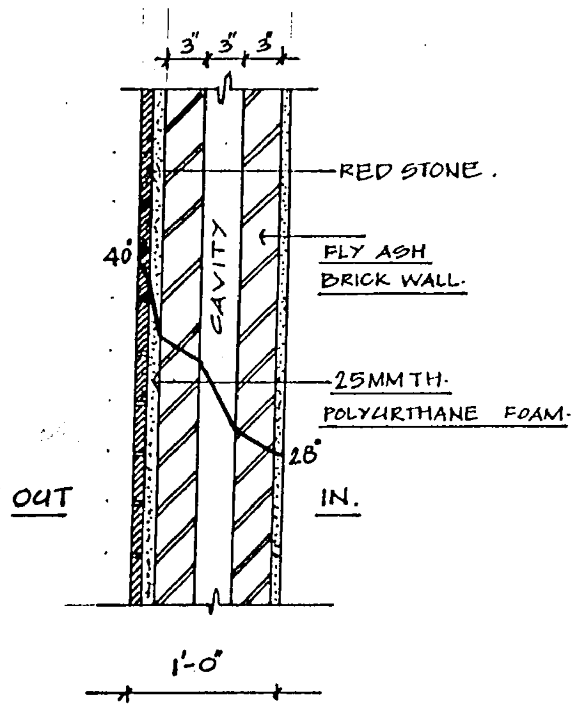



**Fig. 5.10 : Using Insulation and Cavity Wall Construction Shows the Reduction in Heat Transfer**

Walls only receive about two-thirds of the maximum solar radiation that falls on the roof, and considerably less than this on the wall which faces away from the equator. The period of reception of direct solar radiation on walls is also shorter than on roofs. East and west wall will only receive direct sunlight for half of the day.

When solar radiation strikes on opaque building surface, a portion of the heat is reflected away and the reminder is absorbed. The percentage of the incident radiation that is reflected by a given materials is designated as the reflectance value of the surface. The percentage of radiation that is absorbed accordingly, is called the absorptance of the materials.

*White washing a dark wall can considerably reduce solar heat gain*

It is commonly acknowledged that painting a house a light colour will keep it cooler in summer. From this in hot dry climate that external surfaces are protected from the minimise conduction heat flow, minimise solar gain promote Radiant cooling.

Use heat reflective materials on surfaces oriented to the summer to the summer sun. The material like, polished Aluminimum surface and white painted surface have more reflectance value of 85% and 80% of total radiation falling on the surface.

Provide insulating control at glazing the insulating value of a window assembly can be improved by increasing the R value of the glazing unit itself, as well as by adding intellective controls to the inside or outside of the assembly minimise the window openings on west and south wall.

## 5.7 PASSIVE COOLING

Before refrigeration technology first appeared, people kept cool using natural methods breezes flowing through windows, water evaporating from springs and fountains as well as large amounts of stone and earth absorbing daytime heat. These ideas were developed over thousands of years as integral parts of building design. Today they are called "passive cooling." Cooling is considered an "alternative" to mechanical cooling that requires complicated refrigeration systems. By employing passive cooling techniques into modern buildings, you can eliminate mechanical cooling or at least reduce the size and cost of the equipment. Natural Ventilation Depends solely on air movement to cool occupants. Window openings on opposite sides of the building enhance cross ventilation driven by breezes. Since natural breezes can't be scheduled, designers often choose to enhance natural ventilation using tall spaces within buildings called stacks. With openings near the top of the stack, warm air can escape, while cooler air enters the building from openings near the ground ventilation requires the building to be open during the day to allow air flow. High thermal Mass Depends on the ability of materials in the building to absorb heat during the day. Each night the mass releases heat, making it ready to absorb heat again the next day. To be effective, thermal mass must be exposed to the occupied spaces. Residential buildings are considered to have average mass when the exposed mass area is equal to the floor area. So, for every square metre of floor area there is one square metre of exposed thermal mass. High mass buildings would have up to three square metres of exposed mass for each square metre of floor area. A slab floor and face-brick walls may be one way to accomplish this in a residential design, however an exposed concrete ceiling may be more appropriate in a commercial building (with underfloor services).

High thermal mass with nigh ventilation relies on the daily heat storage of thermal mass combined with night ventilation that cools the mass. To work, the building must be tightly closed during the day and have as much of the mass exposed as possible (not hidden behind carpets, shelves and pin-up boards). As heat loads rise during the day, much of the energy is absorbed within the exposed building fabric. Given the difference in specific heat, what could have resulted in a 10°C rise in air temperature may only increase mean radiant temperatures by 1-2°C. as night, the building is completely opened up and ventilated, with the exposed mass loosing any heat it absorbed to the passing cool night air. Evaporative cooling lowers the indoor air temperature by evaporating water. In dry climates, this is commonly done directly in the space.

**WIND TOWER**

In a wind tower, the hot air enters the tower through the openings in the tower, gets cooled, and thus becomes heavier and sinks down. The inlet and outlet of rooms induce cool air movement. In the presence of wind, air is cooled more effectively and flows faster down the tower and into the living area. After a whole day of air exchanges, the tower becomes warm in the evenings. During the night, cooler ambient air comes in contact with the bottom of the tower through the rooms. The tower walls absorb heat during daytime and release it at night, warming the cool night air in the tower. Warm air moves up, creating an upward draft, and draws cool night air through the doors and windows into the building. The system works effectively in hot and dry climates.

A wind tower works well for individual units not for multi-storeyed apartments. In dense urban areas, the wind tower has to be long enough to be able to catch enough air. Also protection from driving rain is difficult.

**COURTYARD EFFECTS**

Due to incident solar radiation in a courtyard, the air gets warmer and rises. Cool air from the ground level flows through the louvred openings of rooms surrounding a courtyard, thus producing air flow.

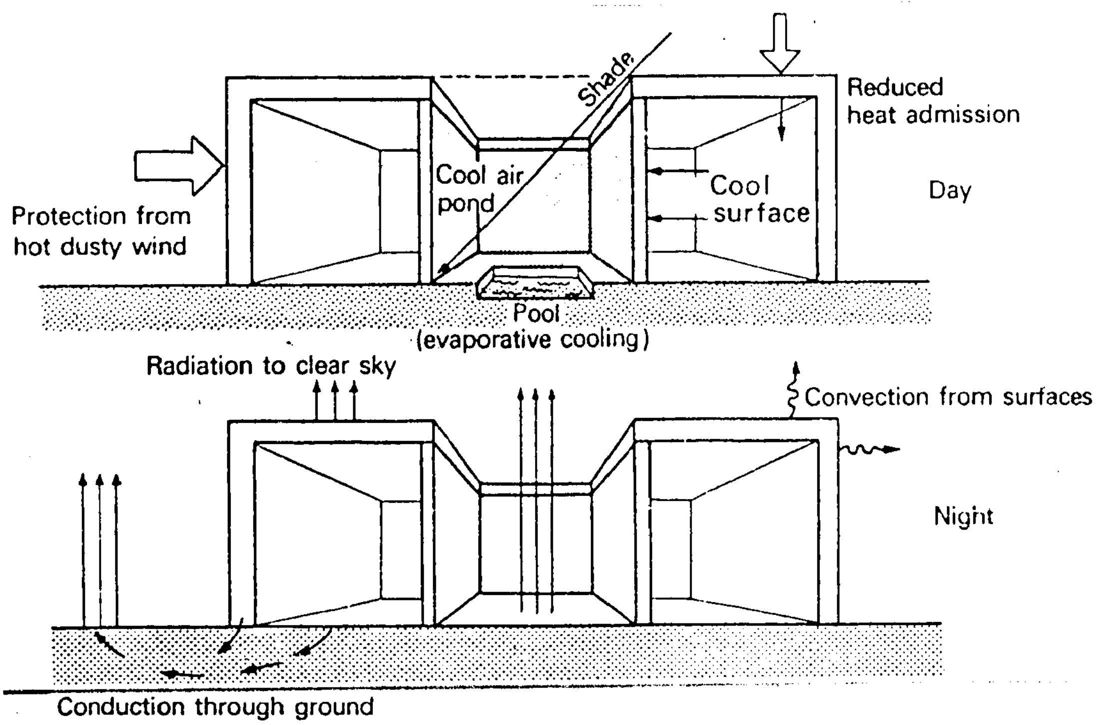



**Fig. 5.11 : The Thermal System of a Courtyard House**

At night, the warm roof surfaces get cooled by convection and radiation. If this heat exchange reduces roof surface temperature to wet bulb temperature of air, condensation of atmospheric moisture occurs on the roof and the gain due to condensation limits further cooling. If the roof surfaces are sloped towards the internal courtyard, the cooled air sinks into the court and enters the living space through low-level openings, gets warmed up, and leaves the room through higher-level openings. However, care should be taken that the courtyard does not receive intense solar radiation, which would lead to conduction and radiation heat gains into the building. Intensive solar radiation in the courtyard also produces immense glare.

## 5.8 PASSIVE VENTILATIVE COOLING

In designing window system for passive ventilation cooling, essential steps can be identified.

1. It is important to have a clear picture of the directional range of the wind on the site involved throughout both diurnal and annual cycles.
2. It is necessary to make an assessment of the need for ventilative cooling for thermal comfort.
3. It is necessary to evaluate the 'wind shadow" effect of neighboring structures or topography.
4. It is vital to choose a window system which corresponds in its functional characteristics.

**ORIENTATION**

The effect of orientation to wind or wind angle on ventilative cooling was found to vary with the physical characteristics of the window configuration used, and in particular the characteristics of window location, shape, size and accessories. This is finding of particular importance since wind direction is of course rarely if ever constant. If window systems are to take maximum advantage of wind-powered ventilation, they should be selected where possible to provide a reasonably "broad band", not a strongly "peaked" directional response, providing greater effectiveness under customary conditions for optimum ventilative cooling, a sufficient effective area of inlet and outlet openings is required, with the inlet/s located in a zone of positive pressure and the outlet/s in a zone of negative pressure. Rooms equipped with inlets only tend to provide very much reduced indoor speed ratios.

Where the single opening is located on a windward façade, the relative improvement produced by oblique wind can amount to as much as 25%, but the overall result even under this condition at best amounts to only one third of the average speed ratios provided by a cross-ventilating configuration.

**INLET/OUT AREA RATIO**

Where inlet and outlet opening are equal cool their areas increase, increases occur in the amount of indoor ventilative utnling they produce. Since, however, window sizes are not determined by ventilation alone but must also take into account other architectural factors as daylighting, privacy, security, and solar control, a significant question for ventilation purposes is how best to distribute a given and usually low amount of opening area. An important parameter here is the relative dissolution of area as between the inlet/s and outlet/s.

**INLET SHAPE**

Inlet shape is the most important widow design parameter in determining the efficacy of with driven ventilative cooling.

Horizontal inlets not only have a substantially higher average performance for all wind angles, but in contrast to square and vertical inlets, horizontal inlets actually improve their effectiveness in angled winds, producing two maxima at wind angles in the vicinity of 45° to either side of the perpendicular, while showing a relatively flat, or "wide-range" response throughout this 90° quadrant of wind angles (or orientations). Horizontal inlets were found to increase their performance in oblique winds in fully cross-ventilated rooms. Better ventilation is often achieved when the wind is oblique to inlets.

**WINDOW LOCATION**

Ventilative cooling performance is improved when the inlet and outlet are arranged so that the ventilate and axis is parallel to the wind. This conditions occurs either (a) when the and outlet are located directly in line with one another on opposite walls a room.

WINDOW ACCESSORIES

Windows accessories have been traditionally designed to work as sunshade privacy or security devices, not as airflow controls. However, window "equipment" designed to produce solar or rain protection.

## 5.9 EVAPORATIVE COOLING

Evaporative cooling is not a substitute for refrigeration but rather a type of air conditioning that meets and fills a particular need in hot and dry regions.

Both dry bulb temperature and relative humidity effect the comfort of an individual. Various combinations of these two properties are known to result in desirable conditions of comfort.

The evaporative cooler functions through a process known as adiabatic cooling. By definition, this process changes the air and water vapour mixture without varying the heat content. Evaporative cooling units work on the principle of passing air over a constantly wetted surface. They thus increase the relative humidity and decrease the dry bulb temperature of the air, for, as heat energy is required to evaporate a liquid, heat flows from the air to the water. The human body finds it easier to lose heat by conduction to this evaporatively cooled air than to lose heat by evaporation. The net effect is therefore an improvement in comfort conditions, providing that the evaporative device does not reduce the possible rates of air movement.

When water evaporates energy is absorbed by the water as it changes its state from liquid to vapour. The latent heat of evaporation of water is 2400 kJ/liter (kg) at normal temperature 0.5 gramme of water will cool $1 m^3$ of dry air by about $1^{o}C$, so that 1 litre of water will cool $500\ m^3$ of dry air by $1^{o}c$. in practice, much of the latent heat of evaporation of water will be used to modify the temperature of the building surface so that the cooling effect will be reduced.

For humans a sweat rate of 100 grammes per hour is probably the maximum that can be considered comfortable, and this provides cooling at the rate of 66 watts. This is less than the metabolize rate of heat producing when at rest. Indicating that at high temperatures when cooling can only be achieved by evaporation. The sweat rate will be too high for comfort.

Evaporative cooling is used throughout the world in regions with composite hot-dry and Mediterranean climate. In its simplest form it can be achieved by the frequent wetting of flours, external paving, patios, courtyards. It serves the multiple function of washing humidifying and cooling.

Vegetation will also cool the air by evaporation. Seasonal plants, such as vines on trellises and pergolas, will shade and cool the space beneath them during the hot season. In the winter month the leaves fall and the branches and pruned back, allowing the space below to benefit from solar radiation on a larger scale vegetation in hot dry climate will have a cooling effect comparable in magnitude with the heating effect of solar radiation.

The evaporative cooling is of many types.

1) Direct evaporative cooling.
2) Evaporation due to water dispersion
3) Evaporation due to compressed-air water.
4) Evaporation at moistened surfaces.
5) Passive down draft evaporative cooling.
6) Ground water evaporative cooling.

In hot dry climate evaporative cooling method is very effective in summer consuming less energy and giving the maximum comfort.

## INDIRECT EVAPORATIVE COOLING

Instread of cooling by evaporation the air with high vapour content that is introduced into the building, it is possible to cool by evaporation the roof or a wall of the building, either by having a shaded pond over the roof or by wetting impermeable walls by water circulation over their external surface.

In spite of the impressive performance of passive cooling by roof ponds their application has some practical limitations.

- The roof have to be capable of supporting a significant local, a factor affecting their cost
- The application of the ponds is limited to single-story buildings, or only to the upper floor of multistory buildings.
- The waterproofing of the roof has to be perfect any crack or a small perforation may cause severe wetting problems and it is very difficult to locate such small cracks or holes.

## DOWN-DRAFT EVAPORATIVE COOLING DEVICES

Forced draft or "swamp" coolers have been used for many years in the hot-dry region. Natural down-draft evaporative coolers do not need the blower and require only the re-circulating pump; some designs eliminate the re-circulation pump and utilize the pressure in the supply water line to periodically surge water over the pads, eliminating the requirement for any electrical energy input.

Natural down-draft evaporative coolers, or Cool Towers, were originally designed and developed by scientists and engineers at the University of Arizona's Environmental Research Laboratory in Tucson Arizona, U.S.A. The towers are equipped with wetted pads, sprays, or other evaporative cooling devices at the top which provide cool air by gravity flow. These towers are often described as reverse chimneys; just as the column of warm air in a chimney rises, the column efficiency of cool air, in this instance, falls. The air flow rate depends on the efficiency of the evaporative cooling device, tower height and cross section, as well the resistance to air flow in the cooling device, tower and structure into which it discharges.

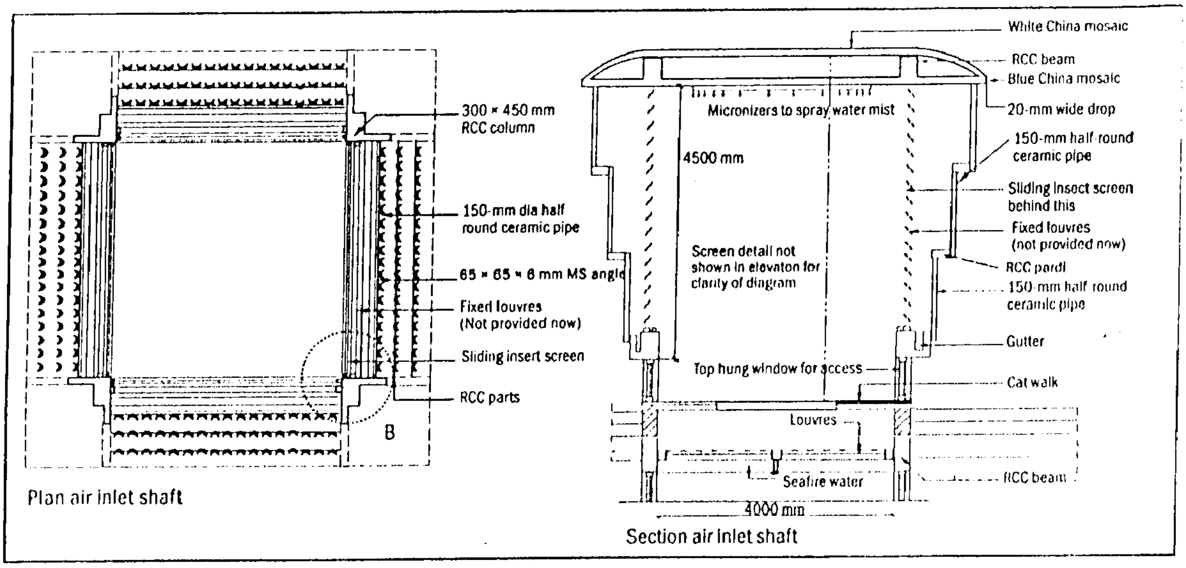



**Fig. 5.12 : Details of Passive Downdraft Cooling In let Shaft**

## 5.10 LANDSCAPING

The effect of the sun on a given site will, to a large degree, be determined by the size, nature, and texture of the various surfaces on which it falls. Every type of natural ground over-such as grass, shrubs and trees; paved surfaces: walls and roofs-will have a perceptible effect on the microclimate of the site.

Natural growths tend to stabilise temperature and minimise extremes in them. Man-made surfaces, on the other hand, tend almost without exception to exaggerate them. Generally, plant life acts as an absorbent material, blotting up heat, light, and sound. Because leaves give off moisture, they actually destroy a large part of the heat which falls upon them. Thus, they re-radiate far less heat than inorganic materials.

It is generally found that, on sunny summer days, air temperatures at about 3- cm above ground level are approximately 4 and 5°C lower than those at ground level itself. Grass is also cooler than exposed soil surfaces, the difference in temperature being between 5 and 6°C. The temperature differential may be much greater between grass and paved surfaces. Further, there is a considerable difference in temperatures between paved surfaces made of different materials. A table showing the range of temperature variations over different surfaces.

On a bright day, concrete and similar light coloured surfaces will reflect from ... of the incident light, while grass surfaces, reflect only about 10-15 ... ent light.

**OF TEMPERATURE VARIATION OVER DIFFERENT ...S**

| | Temperature (°C) |
|---|---|
| | 32.6 |
| | 25.9 |
| | 25.0 |
| | 21.1 |
| | 16.0 |
| | [illegible]1.2 |

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with viscous surfaces catch the dust and filter the air. Plants and trees also provide privacy from prying eyes and reduce annoying glare effects. Deciduous trees provide generous shade and that too only in the appropriate seasons so that they are quite valuable in climates where sunshine is needed in the winter and shade in the summer.

To achieve efficient shading, trees have to be placed strategically. As tr sun is at low angles in the morning and late afternoon, trees should be plac facing southeast and southwest. The trees will cast long shadows which can utilised effectively on those sides which are otherwise difficult to protect from sun's heat at this time of the day. At mid-day, the sun is high up in the sky ar rays can be intercepted easily by an overhang, trees being useless at this tir the day as they cast narrow shadows near themselves.

The type of trees used is of great importance. They should be selected the point of view of both their appearance and the amount of shade they provi

**EFFECT OF LANDSCAPE ON AIRFLOW**

The various landscape elements surrounding low structures ca definite effect both on air flow patterns and on wind velocities. Trees anc walls and fences, all create high and low pressure areas around a c relation to the position of openings in walls.

The effect of plant life on the microclimate in detail and the va that should be considered when trying to control climate through lan following are some of recommendations:

1. In areas where the sun's warmth in winter is needed, decidu be used.

2. If planted near a house, trees and grass allow the heavier cool air to flow inside, provided the house has low openings. High strip windows are, therefore, not decidable in this situation.

3. The greater the number and size of trees and the larger the lawn, the more cooling there is.

4. Shrubs may even increase heat levels if air circulation is cut off. Very low shrubs are therefore recommended.

5. Wind breaks may be necessary in order to keep out hot, dry winds in summer and cold winds in winter.

6. Deciduous vines, trained over trellises and covering windows, can be used to keep the sun out.

7. Radiation may be partially stopped by the use of a wall covered with vines. This creates a cool air space between the foliage and the wall.

8. A roof can be covered in the same manner as walls and this will have the effect of a double roof.

9. Paving should be shaded as much as possible by trees and vines to prevent heat absorption. It may be better to keep paving to a minimum in hot climates.

Trees usually reduce wind velocity, which also lowers the rate of thermodynamic exchanges between the air layers resulting in warmer temperature in areas sheltered from the wind. Prevailing winds have a tendency to change direction seasonally. Therefore, planting materials must be placed so as to protect the building form undesirable winds and yet allow desirable winds to flow through the building.

Plants may control wind by obstruction, guidance, deflection and filtration. Plant obstruction reduces wind speed by increasing the resistance to wind. Plants may be used in conjunction with landforms and architectural elements to alter and direct the airflow over, around or through a building or site.

## 5.11 COOLING EFFECTS OF PLANTS

- Provide shade by blocking the sun's rays.
- Use solar radiation for growth and nourishment, so do not radiate any stored heat.
- The position of the leaves rotate with the solar beam to expose the broad side of the leaf to the sun, thus providing maximum shade.
- As a result of its nourishment, the plant discharges large amounts of water vapor so cooling the air and breezes in its immediate surroundings.
- Absorb and deaden sound as it passes through the plant system.
- Absorb and retain precipitation as it passes through the plant system, thus cooling the air that will flow over and through it for some time after the precipitation stops.
- Will provide a layer of decaying matter that will serve to insulate the ground.
- Will obstruct, filter, deflect or guide airflow passing through it.
- Absorb solar radiation for nourishment during the day, releasing this stored heat at night in order to minimize drastic temperature changes.
- At night the canopy will also serve to keep the escaping heat that was absorb during the day near the soil by acting as an umbrella shield.

## FUNCTIONAL USES OF PLANTS

A primary purpose for using plant materials in our landscape is to solve environmental problems inherent in the build environment. They may additionally be employed to solve architectural and engineering problems, for their aesthetic qualities, to control the sun, wind, temperature and precipitation and humidity.

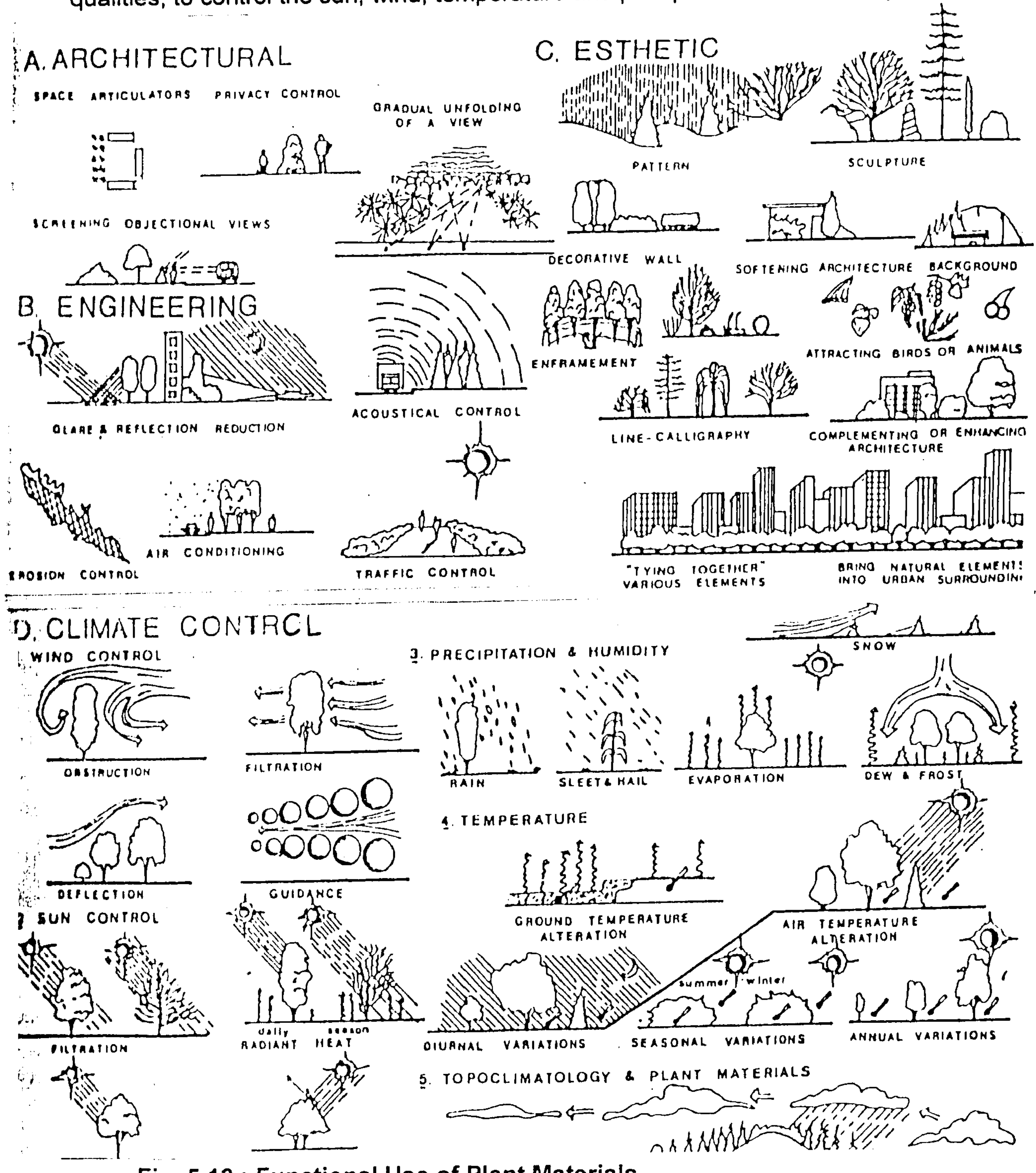



**Fig. 5.13 : Functional Use of Plant Materials**

The control of the temperature is directly related to the amount of solar radiation wind and humidity present at any point in time. Plants will affect all of these natural phenomena, and if used properly, the temperature may be modified to help keep the living environment at a comfortable level year-round.

**PLANTS AND TEMPERATURE CONTROL**

The sun, being our main energy source, effects our temperature and climate through several radiation channels. This heat may either be desirable or not, depending on geographic location, season, air temperature and the vapor pressure at any time.

Radiant heat transfer as experienced by man can simply be categorized into four types : direct short wave radiation, diffused short wave radiation from the sky vault, short wave radiation reflected from surrounding buildings and terrain, long wave radiation from the heated buildings and terrain.

Trees, shrubs and low growing plants are among the best solar radiation controller, this being one of their major functions. Plants can be used to control direct solar radiation by shading, or intercepting reflected radiation from a reflective surface; this interception may occur either before or after it strikes the surface. Plants used for shading may either completely block the sun's rays or filter them through the foliage.

As already indicated, a light smooth surface reflects more than a coarse, dark surface. Generally, plants have a darker surface than any man-made paving or architectural materials, thus reflecting less solar radiation. To minimize the heat and as much of the ground as possible should be covered with low growing plants in under to provide a buffer against the heat and reflection.

**FOLLOWING CRITERIA ARE ESSENTIAL WHEN LANDSCAPING A SITE, FOR COOLING;**

(1) In areas where the warm winter sun is desired, deciduous trees should be used. Even when leaves are not present thickness of branching and twigginess can screen out great quantities of radiation.

(2) The placement of trees and the use of grass near the house allows the heavier cool air to flow inside, providing low openings are present. High strip windows are not desirable in this respect.

(3) The greater the number and size of trees and square footage of lawn area the more cooling there is.

(4) Windbreaks, however, may be necessary in order to keep out hot-dry and winter winds.

(5) Keep sun off walls of prevent absorption and re-radiation, and off glass to prevent it from penetrating inside.

(6) Deciduous vines may be used on trellises over windows.

(7) Radiation may be partially stopped by the use of a wall cover of vines.

(8) Keep lawns and trees well watered during dry weather.

(9) Shade as much paving as possible by trees and vines to prevent heat absorption. It may be well to keep paving to a minimum in hot climates.

(10) Large fans for outdoor use should be seriously considered in warm-humid climates to increase evaporation and transpiration.

# CLIMATICALLY RESPONSIVE SCIENTIFIC METHOD OF DESIGN FOR HOT-DRY CLIMATE

## 6.1 DESIGN PROCESS

The relationship between builtform and the environment should become the driving force behind this scientific process, based on a scientific methodology.

The tools of analysis available allow critical performance and evaluation of built and overall space network. It seems logical to develop a process almost in the form of an algorithm which will help find the optimal form/solution for a given set of requirements and constraints. Evidently based on a design hypothesis it is possible to generate a set of solutions through this process/algorithm. From this set of solutions can be arrived at. However, the reverse is not true. Given a case and a rule one may obtain by deductive inference the unique possible result. It instead, on e defines the required result the there does not exist a mode of inference by which, using a given rule.

The idea of climatically responsive design in to modulate the conditions such that they are always within or as close as possible to the comfort zone. This is shown conceptually in the Fig. 6.1.

The ambient conditions over a twenty-four period is shown by the line A. for a majority of the time it is outside the comfort zone. For a majority of time it's outside the comfort zone. Modulations introduced by the landscape, built form, envelope, materials and other control measures brings the conditions with in the comfort range throughout the twenty-four cycle. This is the goal of climatically responsive design.

However, unlike industrial manufacture, designing is not a linear process. Parameters are inter-related and inter-active. Often they need to be considered simultaneously and in a cyclical manner. Any process of design must therefore allow for this flexibility and dynamism.

The basis of our attempt at climatically responsive design involves considering the climate in every aspect of the building & built environment. Our first task is to put forth these various aspects in a logical sequence. In effect, we are dissecting the design into its constituent elements, so that we can act upon each in turn. The sequence proceeds from macro-level details to micro-level details.

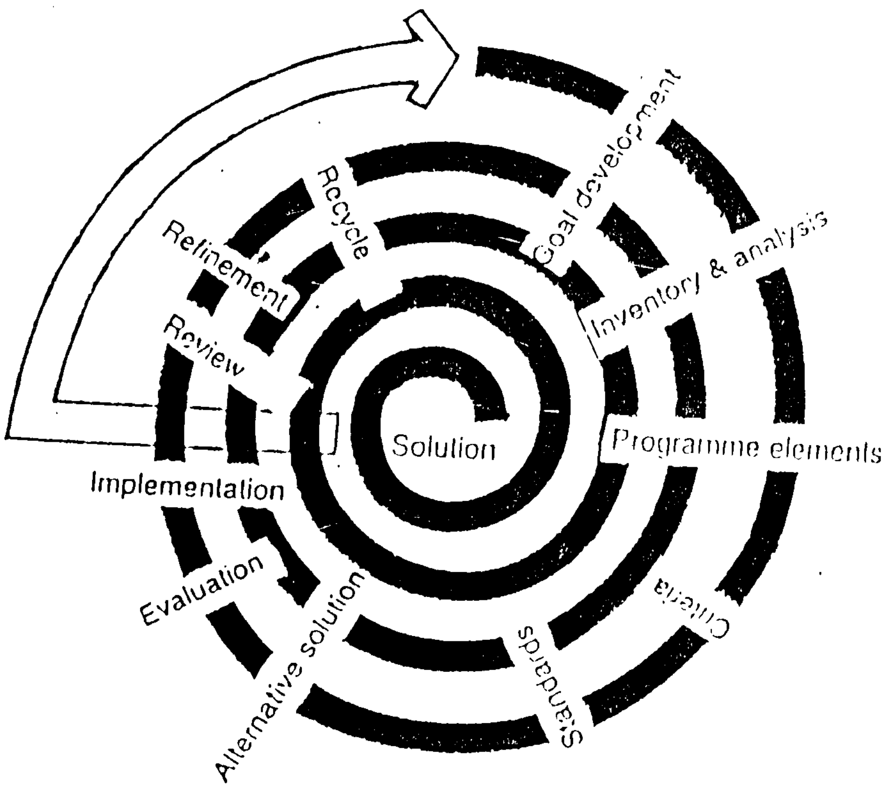



**Fig. 6.1 : Graphic Representation of the Process of Design**

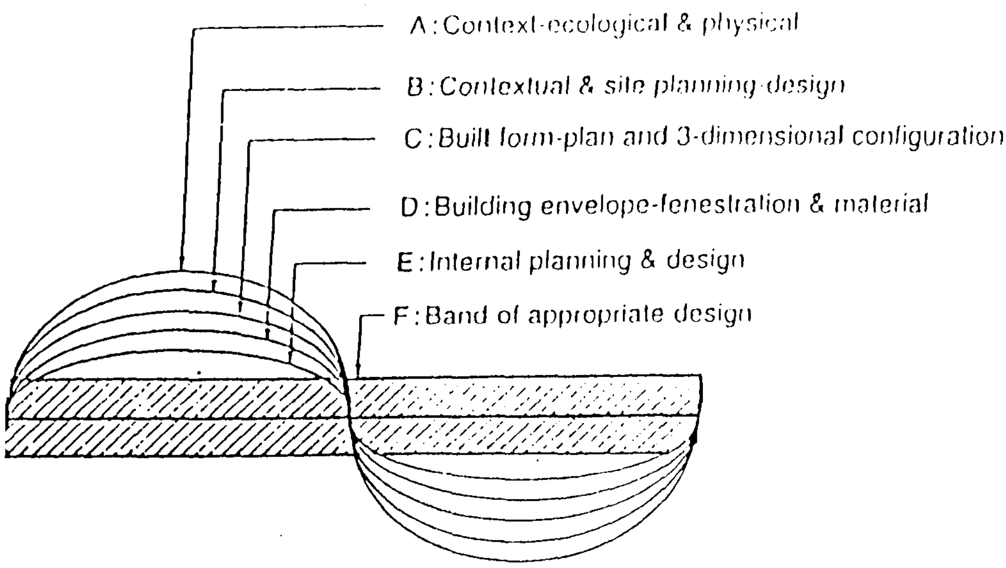



**Fig. 6.2 : The Ideal Climatic Design Successive Modulation of Ambient Conditions so as to Bring Internal Conditions Within the Comfort Zone**

The design sequence that is thus generated is as follows:-

- Landform - Topography , Slope orientation
- Vegetation type & pattern.
- Water bodies.
- Street widths & orientation.
- Open spaces & Built spaces.
- Ground Character.
- Plan form.
- Plan elements.
- Building Orientation.
- Surface area to volume ratio.

- Roof form
- Fenestration pattern and configuration
- Fenestration orientation
- Fenestration Controls
- Walls
- Roof
- External colors and textures.
- Internal layouts & partitions.
- Internal materials.
- Internal finishes.

A qualitative study of these modulations, at each level, is an essential pre-requisite to climatic design. What follows is just that. Each level is explained in terms of it's climatic implication, the conceptual understanding thereof and its effect on the building design. The various levels together provide an extensive understanding of the interaction of the building and the micro-climate.

The enable the qualitative and quantitative analysis of landform the energy balance at the surface should be analyzed and consequent effect of this be taken into account in the design process.

### 6.1.1 LANDFORM

The landform or topography of a site and surroundings could either be flat, sloping or undulating. if the land is flat, similar conditions would prevail over the entire site.

These phenomena can be easily understood. Cool air has a higher density than hot air. As a result cool air is heavier and tends to settle down in depressions while hot air rises. This in fact also explains convection currents in liquids and gases.

These phenomena would have an implication on our building design. In hot climates building in a depression implies relatively lower air temperature. When building on a slope, the leeward side is preferable, as long as the orientation is acceptable. In both cases warm winds would be minimized. The collection of water in a depression might allow for a water body. This would also be beneficial in cooling the place.

### 6.1.2 LANDFORM ORIENTATION

Landform orientation has little meaning when the land is flat. However, the orientation of slopes would made a difference.

In hot climates a north slope would be preferable as it would receive the least direct radiation is true only if the slope is steep enough to shade the building. As a result lope orientation is of little consequence. The building should be placed so as to maximize air flow.

Hot dry climates often have cool or cold winters. While the prime need is to minimize heat gain. The amount of daylight available needs to be considered.

### 6.1.3 VEGETATION PATTERN

Vegetation and trees in particular very effectively shade and reduce heat gain. They increase humidity levels. They also cause pressure differences thereby increasing and decreasing air speed or directing air flow. They can therefore direct air into a building or deflect it away.

Plants, shrubs and trees absorb radiation in the process of photosynthesis. As a result they actually cool the environment. Trees and hedges also affect air flow. On the other hand careful placement of trees and hedges can direct and increase air speed. This is achieved by planting trees and hedges so as to make a narrowing 'path' for he air. This reduction of area increases air speed.

The understanding of these pressure changes and the consequent air paths can be used to our advantage in building design.

In hot dry climates where heat gains is to be minimized, trees can be used to cur-off the east west sun. hot breezes can be effectively cur-off. Planting deciduous trees is very useful in hot dry climates. They provide comforting shade in summer and shed their foliage in winters allowing sun.

### 6.1.4 WATER BODIES

Water absorbs relatively large amounts of radiation. They also allow evaporative cooling. As a result, during the daytime areas around water bodies are generally cooler. At night however, water bodies release relatively large amounts of heat to the surroundings.

The above stated phenomena are rather easy to understand. Water has a relatively high latent heat of evaporation' as well as specific heat. In other words water uses up a comparatively large amount of heat in evaporating. It also absorbs or releases a comparatively large amount of heat for a unit rise or fall of temperature. So, when water evaporates by the movement of air, it cools the air. This is evaporative cooling. In the process humidity rises. Evaporation is slow if the RH. Is already high.

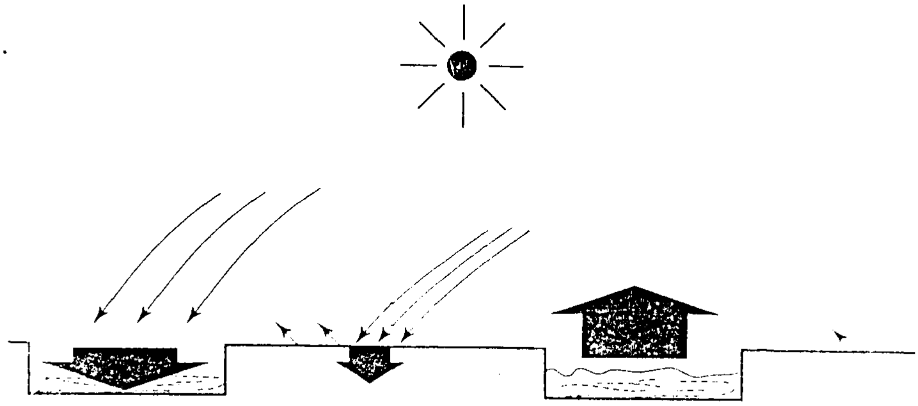


**Fig. 6.3 : Water Bodies Absorb Much Heat During the Day and Reradiate it at Night**

In hot-dry climates, water bodies can be used both for evaporative cooling as well as minimizing heat gain. Taking into account wind patterns, and vegetation they can be used to direct cool breeze into the house. A roof pond minimizes heat gain through the roof.

### 6.1.5 STREET WIDTH & ORIENTATION

The amount of direct radiation received on he street (and to an extent the lower floors) is determined by the street width. The orientation affects the time of the day when the radiation is received. Modulating the street width and orientation can very effectively to minimize or maximize heat gain. Street width to building height ratio also effects the daylight received.

In hot-dry climates the prime need is to minimize heat gain. This could be achieved by cutting off the sun. small street width to building height ratio ensures narrow streets and thereby shading. In particular, streets running north-south should be narrow. This would enable mutual shading from the horizontal morning and evening sun. East-west streets are avoidable as they allow uncomfortably, they too should be narrow. The exact orientation of streets can be determined by considering the solar geometry in combination with building heights. This will enable us to orient the streets such that uncomfortably low sun is shielded off by the buildings.

### 6.1.6 OPEN SPACES & BUILT FORM

Open spaces have to be seen in conjunction with the built form. Together they can allow for freer air movement and increased heat loss or gain.

Open spaces in any complex are inevitable. The question is-how should they be and how much should there be? After all, any built mass modifies the microclimate. An open area, especially a large one allows more of the 'natural' climate of the place to prevail.

Open spaces gain heat during the day. If the ground is hard and building surfaces are dark in color then much of this radiation is reflected and absorbed by the surrounding buildings. If however, the ground is soft and green then less heat is reflected. Shading by surrounding buildings and trees can reduced heat gain to some extent.

In hot dry climates compact planning with little or no open spaces would minimize both heat gain as well as heat loss. When the heat production of the buildings is low, compact planning minimizes heat gain and is desirable. This is how traditional settlements often are. However, in modern cities, buildings produce much heat of their own. In such cases heat loss becomes important. Infact, the phenomenon of heat build up in cities leads to the formation of heat islands. The size and scale of open spaces must therefore be optimized.

### 6.1.7 GROUND CHARACTER

Depending on the gourd surface, incident radiation would be either absorbed, reflected or stored and re-radiated later.

The color and texture of a materials surface determines its reflectivity. The lighter the color and the smoother the surface the more the reflectivity of the material.

In hot climates with a view to minimize heat gain ground surfaces should preferably be green. Where hard surfaces and paving are unavoidable they should be rough but not very dark. This would make then groundless reflective but not highly absorptive.

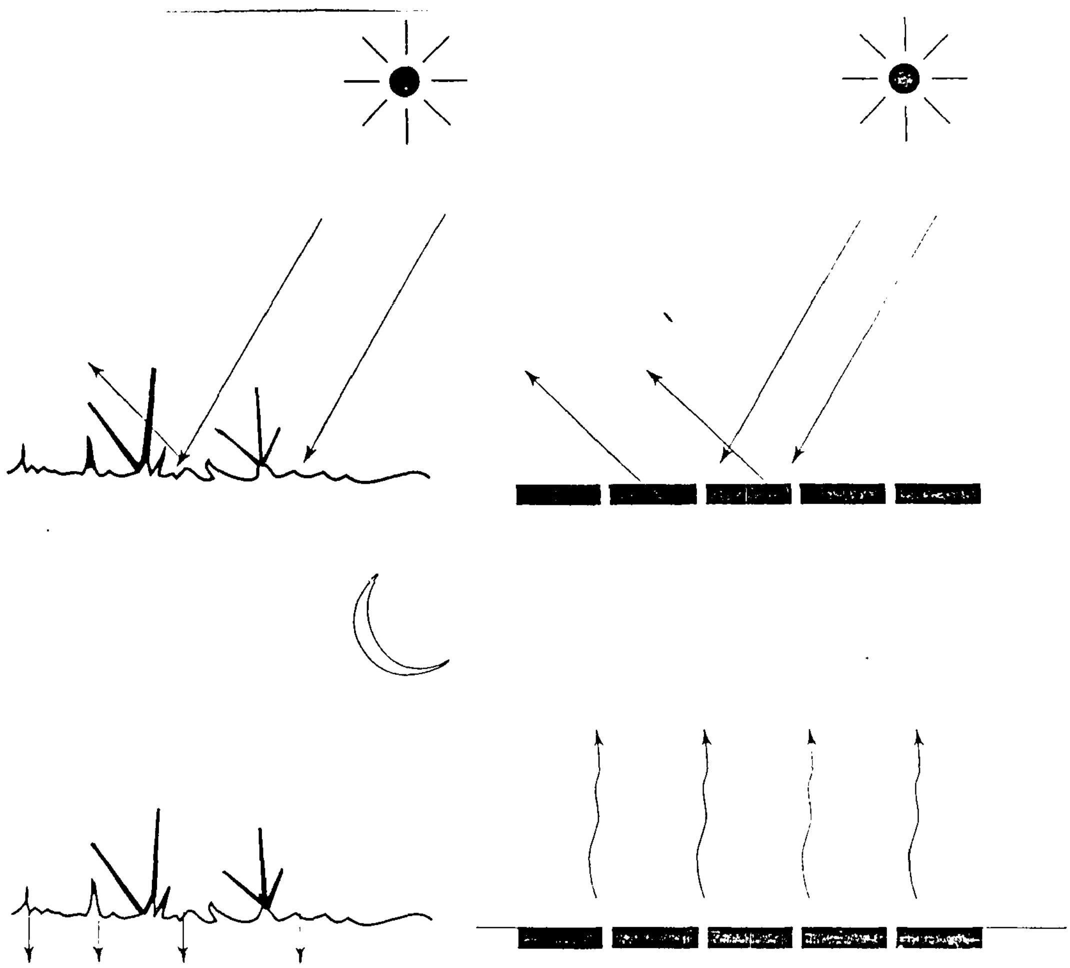


**Fig. 6.4 : Different Ground Materials Reflect, Store and Absorb Heat to Different Degrees**

The ground surface would also reflect daylight. Especially in sunny climates this could lead to uncomfortable glare. For this reasons also hard paving should be minimized and where necessary should be rough.

### 6.1.8 PLAN FORM

The planform of a building affects the airflow around and through it. It could either aid or hinder natural ventilation. The perimeter to are as ratio of the building is an important indicator of heat loss and gain. It therefore plays a role in ventilation, heat loss and heat gain.

In hot climates P/A should be kept to a minimum. This would cause minimum heat gain. Plan form for enhancing ventilation in not a compelling proposition as breezes are often quite warm.

### 6.1.9 PLAN ELEMENTS

The role of vegetation, water bodies radiative heat gain and air movement have been seen at the overall site level. These elements could be integrated with the building or the building complex for further benefits. In a sense, they can become elements of the plan.

Water bodies and vegetation help cool a space by evaporation and the absorption of heat. Water bodies and green houses also and in space heating. Water bodies are effective means of evaporative cooling.

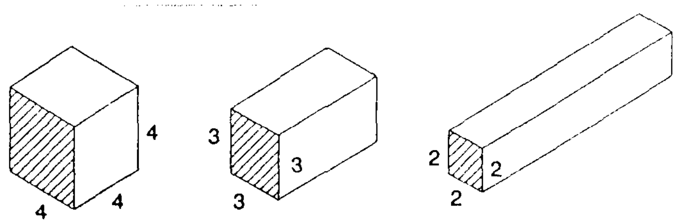
In hot climates it is very desirable to integrate plan and vegetation wherever possible into the plan form. Gardens, roof gardens and planters on Windows and shades could well reduce heat gain. If water bodies can be integrated that too would be beneficial.

Further, shaded courtyards would lead to lower air temperatures. In the cooler season also, roof gardens would be desirable. However, water bodies would either have to be drained or enclosed by glazing. Shaded courtyards would, however, become uncomfortably cold. They should either be avoided where winters severed or have operable glazing at the roof level. Screening off of glazing would cut-off cool air and increase heat gain. Fixed glazing would, however, be highly inappropriate as during summer it could lead to uncomfortable over heating.

### 6.1.10 BUILDING ORIENTATION

The building orientation determines the amount of radiation it receives. The orientation, with respect to air patterns, affects, the amount of natural ventilation possible.

In the northern hemisphere it is generally understood that north faces receive minimum direct radiation and south faces receive the maximum is not entirely true. For instance, at 17° N on June 22nd the sun is mostly in the northern hemisphere.




| *Solid shape type* | *Surface area (S)* | *Volume (V)* | *Ratio (S/V)* |
|---|---|---|---|
| a | 96 | 64 | 1.5 |
| b | 103.2 | 64 | 1.61 |
| c | 136 | 64 | 2.13 |

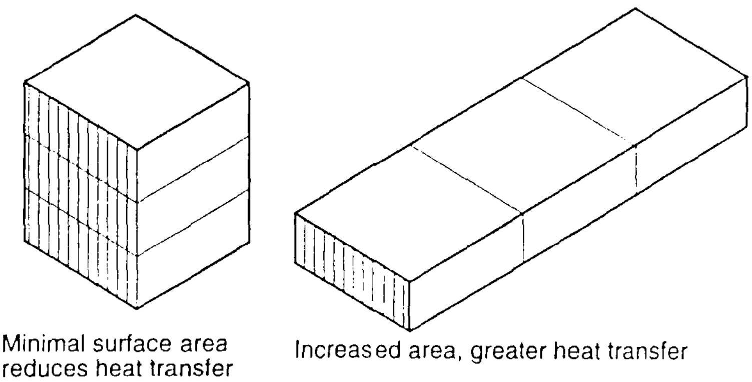



**Fig. 6.5 : Minimizing the Surface Area to Volume Ratio Minimizes Heat Transfer**

### 6.1.11 SURFACE AREA TO VOLUME RATIO

The S/V ratio (the three dimensional extrapolation of the P/A ratio) is an important factor determining heat loss and gain.

The greater the surface area the more the heat gain/loss through it. So small s/v ratios imply minimum heat gain and minimum heat loss.

In hot-dry climates s/v ratio should be as low as possible as this would minimize heat gain. In further, the materials of construction should be such that they do not store heat.

### 6.1.12 ROOF FORM

Daylight can be obtained by either a horizontal (unshaded) or vertical roof lights. In hot climates unshaded roof lights would be quite undesirable as they would further add to the heat gain.

In any climatic context, the roof can be relied upon as a means to enhance the light levels indoors. The nature of the roof light would change with the climatic context. In overheated areas, roof lighting would be shaded to prevent heat gain.

In under heated areas roof lighting would be unshaded making it a supplementary source of heat gain.

In hot climates the aim is to minimize natural ventilation. In order to minimize this, the building should have as flat a roof as possible and the building width, in the direction of air flow should be as large as possible.

### 6.1.13 FENESTRATION PATTERN AND CONFIGURATION

The fenestration pattern and configuration involve the area, shape, location and relative positioning of the windows. This would affect the air movement, daylight and glare indoors. If unshaded the area would also affect radiate heat gain.

That the area of the opening should affect air movement and daylight is understandable. After all, it directly affects the amount of light and breeze allowed in. The location of the opening (defined by the sill and lintel levels) also affects ventilation. This is because temperature differences cause air to rise. Openings at higher levels therefore aid air flow. This is known as Stack Effect. The position of the opening affects the distribution of light indoors as it affects internal reflections. So, equal size openings at the floor level window level and ceiling level distribute the light differently.

Theoretically an opening could have any shape. For our purposes, however, we are concerned with basically two categories narrow and long opening s and not narrow or broad opening. The first is typified by a strip window, the second by a square or circular one. Due to their dimensions they would affect internal air speeds. This would also affect light distribution indoors.

In hot dry climates windows need to be appropriately shaded. It is preferable if they are small in area. Being a sunny zone, smaller openings would allow sufficient daylight. Air flow need not be encouraged since day time air is hot. Due to the low night temperatures natural ventilation may be desirable. Window sizes, if increased for this purpose must be efficiently shaded from radiative heat gain. High openings or ventilators wold be effective as heat vents.

Window location makes a difference to the quality of light obtained indoors. High windows provide the best distribution of the direct and diffuse light. However, they also maximize the potential for glare and should have baffles. Low windows allow ground reflected light. Being reflected from the ceiling provides the most uniform ventilation. The middle located window in comparison distributes neither sky light nor ground reflected light well.

Some basic rules of thumb can be followed, in the positioning of windows, to enhance air movement. Windows should be staggered rather than aligned. Partitions should not be placed near windows causing and abrupt change of wind direction. Similarly, windows on adjacent walls should preferably not be as to cause an abrupt change of wind direction. It has been said earlier that indoor air speeds are greater if outlets are larger than the inlets.

It would be desirable to provide every room with windows on at least two walls. Each room would need to have a door, this should be on a third wall.

### 6.1.14 FENESTRATION ORIENTATION

The orientation of the fenestration determines the amount of radiation incident on the opening. The orientation with respect to the air pattern could increase or decrease natural ventilation.

Orientation with respect to solar geometry has been dealt with earlier. To obtain a good distribution of air flow within a building the wind direction and inlet to outlet direction and inlet to outlet direction should not be the same. This would lead to better air circulation. If they are in a straight line then the air flow will simply be through the room without much circulation. In hot dry climates the fenestration should be oriented north.

### 6.1.15 FENESTRATION CONTROLS

Glazing, shades, light selves, flywire nets and the cross-sectional area of the window can be important controls. They trap solar radiation, cut it off, increase daylight level, keep out insects (in the process reducing air speed) and modify air velocities. They are therefore able to affect and control heat gain, daylight and ventilation.

Glazing, the most commonly used 'control' device, traps solar radiation. This phenomena is known as the Greenhouse Effect. It can be a major cause of heat gain, desirable or undesirable. Shades, vertical and horizontal, control radiative heat gain. The solar altitude and azimuth during the over heated period can be determined. Therefrom, the projection of the horizontal and vertical shades can be adjusted so as to cut-off the sun. similarly, it can be ensured that during under heated periods the sun is allowed in.

In hot climates if glazed are used then they need to shaded from the sun. light shelves would be unnecessary. If the climate is consistently hot the window sectioned can be increased towards the interior to decrease the air speed.

### 6.1.16 WALLS

As in the case of roofs, wall materials are a major factor to consider in heat flow studies. Far as materials are concerned, what applies to roofs is valid for walls as well. The difference is that more direct radiation is incident on the roof than the wall.

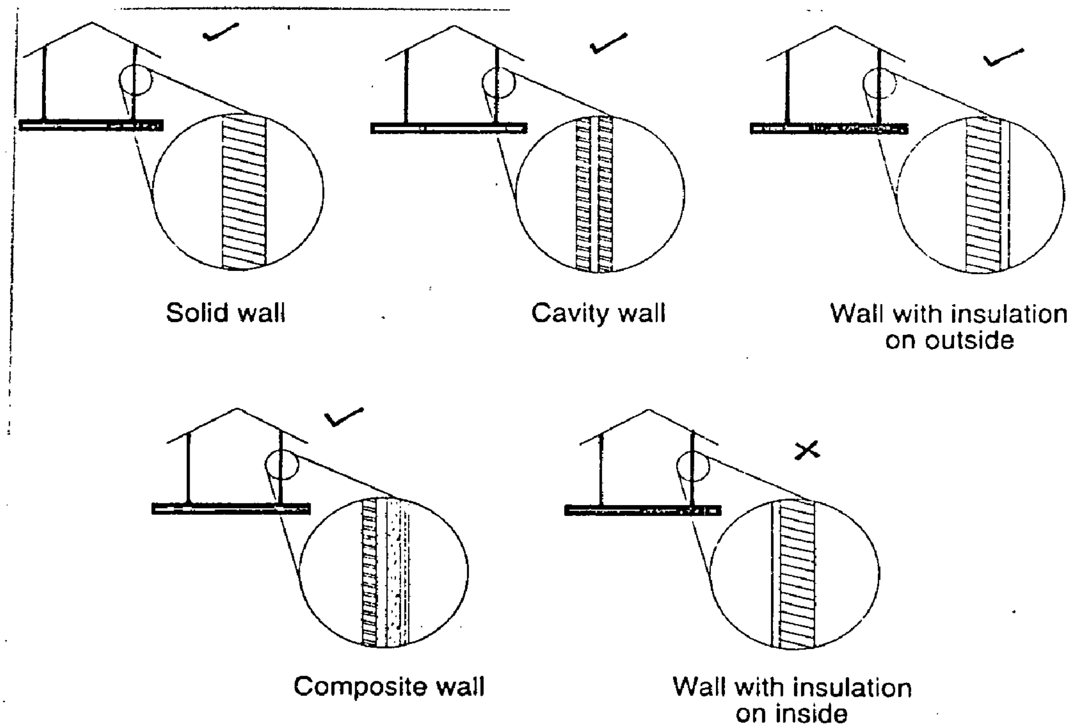



**Fig. 6.6 : Wall Type Used in Hot-Dry Climate**

There is more to walls than just their material. Cavity walls with air spaces of about 5 cm between the two layers reduce heat transmission. Further, the Greenhouse Effect is used to trap solar heat. A material like glass is transparent to the direct short wave radiation from the but opaque to be reflected longwave radiation. As a result, though heat is radiated inwards, it is not re radiated outwards. Thus, as steady heat build-up takes place. But this only half the story. In a 24 hour cycle radiative heat gain takes place only during the sunshine hours. At other times though radiative heat loss does not occur conductive heat loss does take place since glass has a very high U-value. Wall materials, like roof materials should be of low U-values in hot climates.

### 6.1.17 ROOF MATERIALS

Roof materials determine the amount of heat transfer through the roof inwards or outwards as well as the time taken for this heat transfer to take place. Each material has a characteristic specific heat. When it comes to heat exchanges we are concerned with both the specific heat of the material and the amount of the material.

The product of mass and specific heat, is known as the thermal mass. While the specific heat is a property of the material, the thermal mass depends on the amount of the material as well. The thermal mass (or capacity) is an indicator of the heat storing ability of a material. Heat flow through materials is determined by the conductance and resistance of the material. What we need to know is the heat flow from or to a space. For this we need to know the air to air resistance of materials.

So, for any material of a given thickness, there is a certain amount of time lag before the heat is transmitted. Since some of the heat is absorbed, not all of it is transmitted. This leads us to another two significant properties of materials the time lag and the decrement factor. The time lag is the time difference between the maximum outdoor and maximum in door temperatures and the decrement factor is the ratio between the two.

In hot climates the roof should have a low transmittance value. This would ensure maximum heat gain and heat loss respectively. Using insulation would minimize the heat stored by the roof. However, in the absence of insulation, a low U-value would generally imply a high thermal capacity.

### 6.1.18 EXTERNAL COLORS AND TEXTURES

The surface characteristics affect heat transmission into the building. This is easy to understand. The color of a surface affects it s reflectivity and therefore the heat absorbed. The surface texture could vary from smooth to rough. A rough textured surface (for example a grit finish with large aggregate size) causes self shading. It also increases the area for re-radiation. In comparison a flat surface allows greater heat transmission. However, a smooth flat surface would be more reflective. This again would minimize heat gain. Similarly, a light color would be more reflective while a dark color would be more absorptive.

In hot climates surface colors should be light while textures should be rough. This will result in greater reflectivity, shading and re-radiation. If a rough texture is not possible then a smooth surface would be preferable.

### 6.1.19 INTERNAL MATERIALS

Internal materials, primarily furniture, can store much heat making conduits more comfortable or uncomfortable.

As discussed earlier, different materials have different values of specific heat. So the thermal capacity of different types of furniture items would be different.

In hot climates furniture should be as light so possible so that they do not store heat.

### 6.1.20 INTERNAL FINISHES

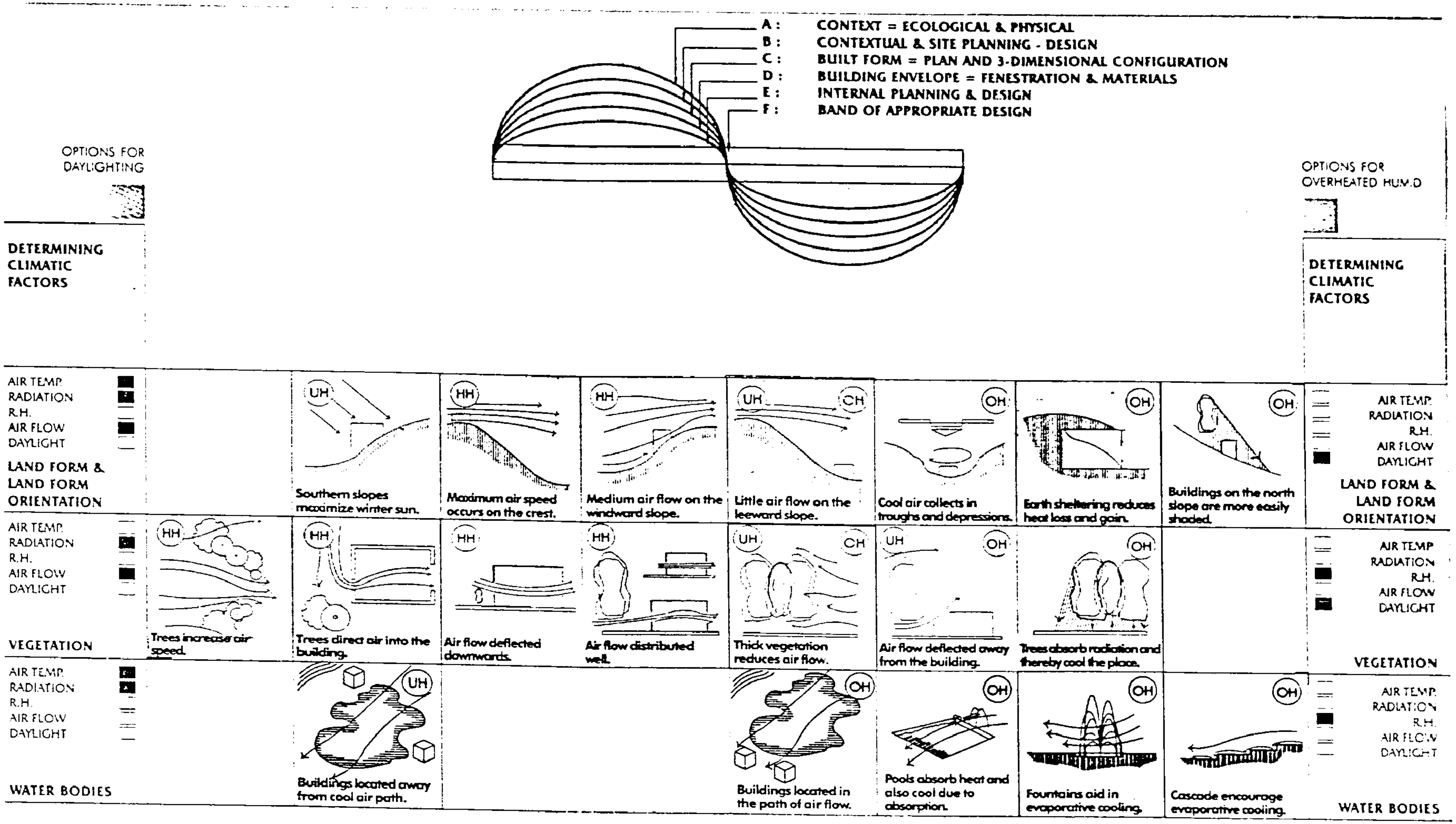
The internal finishes of a space would affect the daylight level indoors. Under certain conditions it would also affect heat loss.

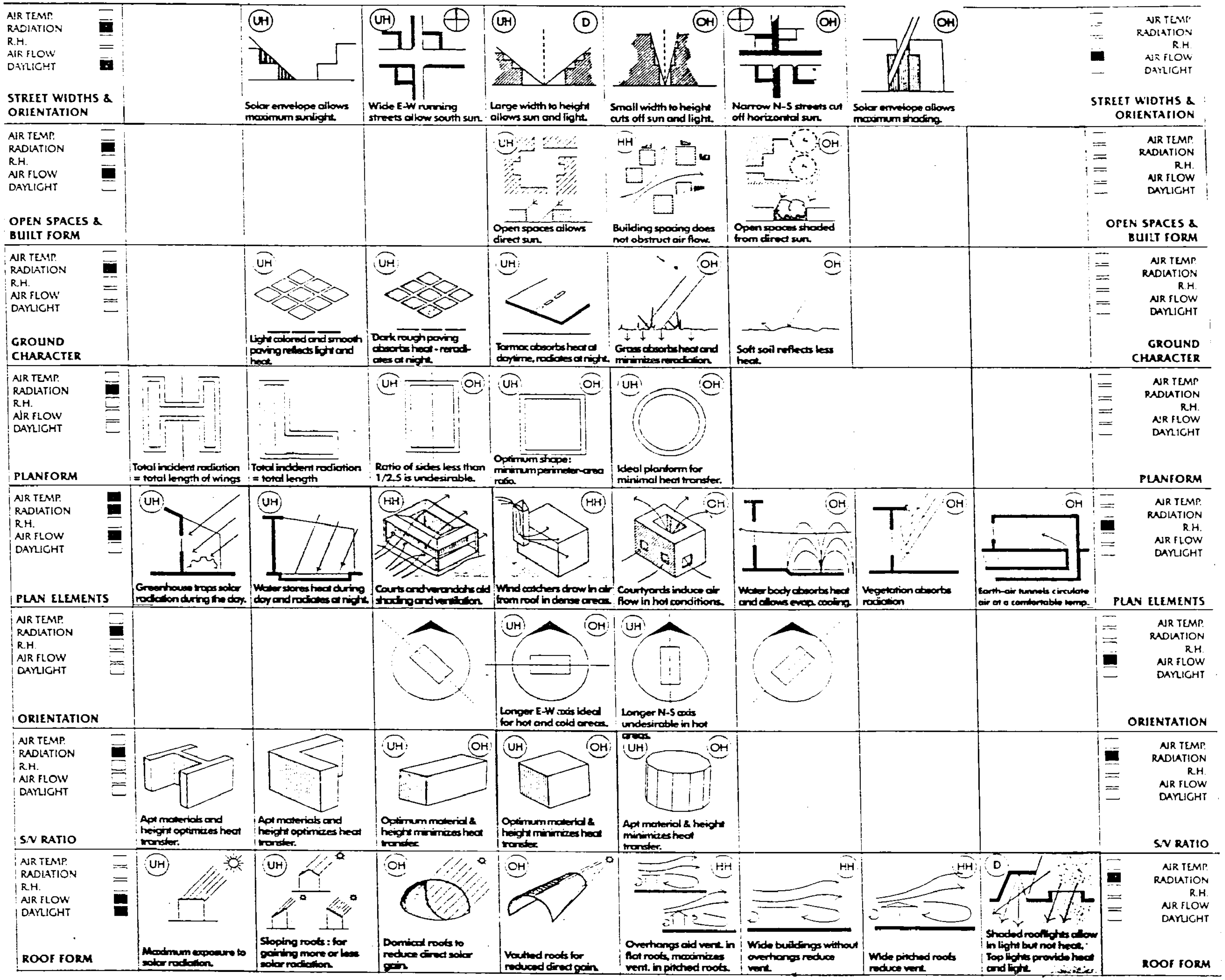
The reflectance of internal surface would affect daylight levels. Further, the reflectivity ( or emissivity) of radiation would effect heat losses when the U-value of material is low.

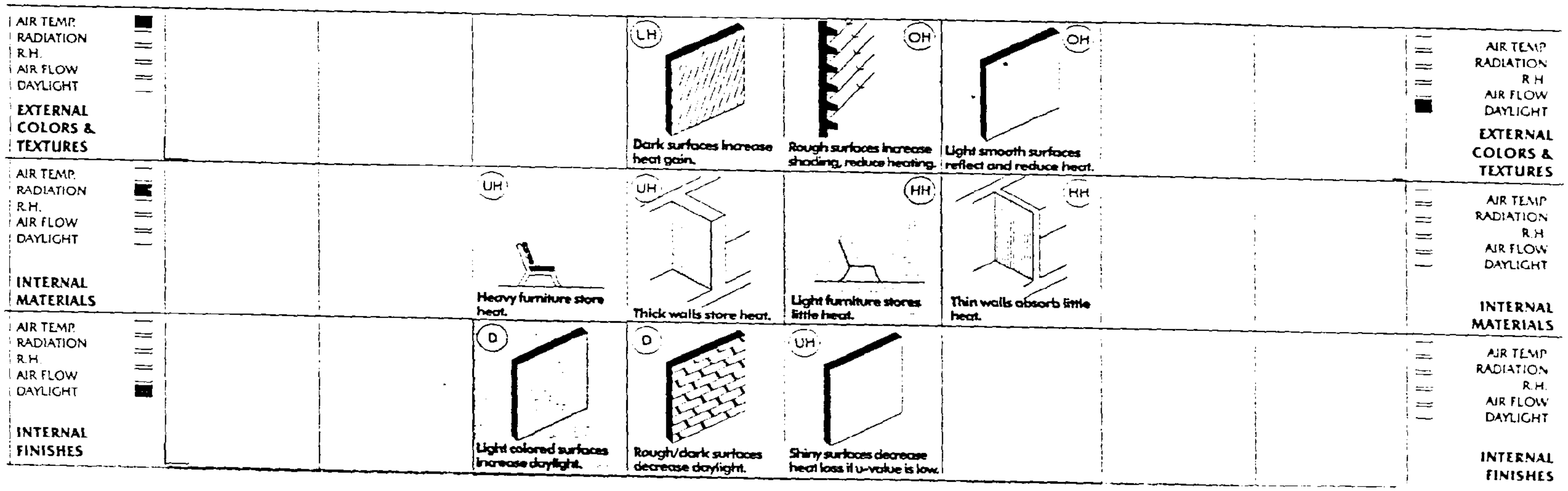
Internal reflectance's should be as per the desired daylight conditions.

# DESIGN TOOL

## Table 6.1 : Design Tool for climatically Responsive Architecture – An Integrated Approach




AIR TEMP.
RADIATION
R.H.
AIR FLOW
DAYLIGHT
STREET WIDTHS & ORIENTATION
Solar envelope allows maximum sunlight.
Wide E-W running streets allow south sun.
Large width to height allows sun and light.
Small width to height cuts off sun and light.
Narrow N-S streets cut off horizontal sun.
Solar envelope allows maximum shading.
OPEN SPACES & BUILT FORM
Open spaces allows direct sun.
Building spacing does not obstruct air flow.
Open spaces shaded from direct sun.
GROUND CHARACTER
Light colored and smooth paving reflects light and heat.
Dark rough paving absorbs heat - reradiates at night.
Tarmac absorbs heat at daytime, radiates at night.
Grass absorbs heat and minimizes reradiation.
Soft soil reflects less heat.
PLANFORM
Total incident radiation = total length of wings
Total incident radiation = total length
Ratio of sides less than 1/2.5 is undesirable.
Optimum shape: minimum perimeter-area ratio.
Ideal planform for minimal heat transfer.
PLAN ELEMENTS
Greenhouse traps solar radiation during the day.
Water stores heat during day and radiates at night.
Courts and verandahs aid shading and ventilation.
Wind catchers draw in air from roof in dense areas.
Courtyards induce air flow in hot conditions.
Water body absorbs heat and allows evap. cooling.
Vegetation absorbs radiation
Earth-air tunnels circulate air at a comfortable temp.
ORIENTATION
Longer E-W axis ideal for hot and cold areas.
Longer N-S axis undesirable in hot areas.
S/V RATIO
Apt materials and height optimizes heat transfer.
Apt materials and height optimizes heat transfer.
Optimum material & height minimizes heat transfer.
Optimum material & height minimizes heat transfer.
Apt material & height minimizes heat transfer.
ROOF FORM
Maximum exposure to solar radiation.
Sloping roofs: for gaining more or less solar radiation.
Domical roofs to reduce direct solar gain.
Vaulted roofs for reduced direct gain.
Overhangs aid vent. in flat roofs, maximizes vent. in pitched roofs.
Wide buildings without overhangs reduce vent.
Wide pitched roofs reduce vent.
Shaded rooflights allow in light but not heat. Top lights provide heat and light.
UH
HH
OH
D



AIR TEMP.
RADIATION
R.H.
AIR FLOW
DAYLIGHT
EXTERNAL COLORS & TEXTURES
LH
Dark surfaces increase heat gain.
OH
Rough surfaces increase shading, reduce heating.
OH
Light smooth surfaces reflect and reduce heat.
AIR TEMP.
RADIATION
R.H.
AIR FLOW
DAYLIGHT
INTERNAL MATERIALS
UH
Heavy furniture store heat.
UH
Thick walls store heat.
HH
Light furniture stores little heat.
HH
Thin walls absorb little heat.
AIR TEMP.
RADIATION
R.H.
AIR FLOW
DAYLIGHT
INTERNAL FINISHES
D
Light colored surfaces increase daylight.
D
Rough/dark surfaces decrease daylight.
UH
Shiny surfaces decrease heat loss if u-value is low.

## 6.2 DESIGN ANALYSIS

THE MAIN FEATURES OF DESIGN AND CONSTRUCTION FOR DWELLINGS IN HOT, DRY CLIMATES ARE SUMMARISED BELOW.

### SITE AND ORIENTATION

Avoid sun pockets and radiation glare from sky, ground paving or buildings that will intensify this zone around the house. Consider use of reflective devices on roofs and walls exposed to the sun both for sky and ground radiation. Where irrigation permits, grow grass and shade trees which will reduce the impact of the sun and temperatures. If it does not interfere with the axis of N-S winds it would be advantageous to build houses in rows or close to each other facing north and south to cut off strong radiation from the eastern and western sides in the early and late part of the day.

Grass and other types of plants will grow rapidly if they are exposed to moisture. In general, communities should be located near irrigation facilities. The best location would normally be on the leeward side of an irrigated area – the moisture produced by irrigated land tends to reduce air temperatures.

### HOUSE PLAN

An inward looking layout can benefit from microclimatic factors. It allows rapid radiation of heat and, thereby, cooling of house on summer evenings. Evaporative possibilities should be utilised. Heat producing areas should be separated from other areas of the house. Uninhabitated spaces should be placed on the west side to baffle the impact of the sun. Bedrooms should be oriented to receive cool night air.

Compact shapes are preferable, yet they should be somewhat elongated on the E-W axis. Deep room arrangements can be used for better cooling against intense outdoor heat.

## ROOF

The roof should be insulated from the sun. this can be accomplished by thick insulating materials, evaporative cooling on the exterior or a radiation screen with ventilation between it and the roof. White single roof will reduce the accumulation of heat.

The storage of heat by using thick layers thermal capacity materials has the disadvantage in summer of storing heat when night temperature do not go down low enough in the ambient air to bring internal house temperatures to a comfortable level.

## WALLS

The primary functions of walls are to control high temperature differentials and high solar radiation, to retain the moisture differential inside and to control the indraft of dust, and to exclude solar radiation and reflected radiation from hot ground surfaces around the house.

The walls of daytime living areas should be made of heat-storing materials, while walls of night rooms of materials with light heat capacity. East and west should preferably be shaded. Heavy masonry walls are desirable on the west and should be shaded by trees if possible. Double walls construction with proper air ventilation should be constructed on western side. Cavity wall with insulation on outer wall is preferable.

## OPENINGS

Openings should be tight-closing as protection against high heat. Low solar angles may bring radiation deep into the house from windows placed on either the eastern or western sides. Windows, particularly those facing the direction of the sun, should be small. Deep reveals are advantageous. Avoid large glass areas. All windows, except those on the north, must be shielded from the high summer sun. windows should be broad rather than high. Exterior sunshades are essential on east windows during summer. If possible, avoid west windows altogether. Shading devices should be separate from structures.

## INTERIORS

White paint has a high reflection ratio on sun-exposed surfaces. Dark absorptive colours are adaptable where reflection towards the interiors is expected. The sue of low emissivity 'cool' colours reduces heat reflection on interior surfaces. Connection with patio areas has a cooling effect on adjacent spaces.

## 6.3 PRINCIPLES FOR HOT DRY CLIMATE AND IMPORTANT APPLICATIONS

| Principles | Important Applications |
|---|---|
| Reducing human heat production | |
| * Convenience of arrangement | * Convenient storage space convenient plan and conservation of floor space convenient facilities |
| * Ease of cleaning | * Easily cleaned surfaces |
| Reducing gain & promoting losses from Body by radiation | |
| * External shade | * shade trees where possible, |
| * reduced ground reflection | especially to roof |
| * Attached shade | * shade bushes where possible, |
| * water cooling of exterior | especial to east and west |
| * minimal solar project | exposures |
| * High reflectivity & remission of exterior | * contiguous building in east-west rows or consolidated |
| * convection over surfaces exposed to radiation | * Non-inhabited wings to east and west exposure to provide shade |
| * Insulation (capacity type) | * Vegetation over ground where |
| * convection over inner surfaces | Possible |

| Principles | Important Applications |
|---|---|
| * Low emissivity of inner surface | * dark color for ground exposed to sun |
| | * Vertical projections beside window openings on equatorial exposures |
| | * water layer on flat roof |
| | * North-facing slab or tall square shape for inhabited building |
| | * Light color for surfaces exposed to solar radiation |
| | * wood, earth, stone, or other materials of low diffusivity for roof |
| | * Ceiling height generally over 8 feet |
| Reducing gain and promoting losses from Body by conduction | |
| * Insulation | * Continuous walls, with capacity |
| * Controlled ventilation | Insulation where exposed to |
| * Ventilation of roof spaced | radiant load |
| * Ground cooling | * Doors, windows, etc., fashioned |

| Principles | Important Applications |
|---|---|
| * Evaporative cooling | * for both tight closing and easy opening |
| * Refrigerant cooling | * Ventilation of roof space and spaces between successive roof layers |
| Reducing heat liberation in building | |
| * Minimize heat liberation | * Capacity insulation around and firebox oven |
| * Remove liberated heat | * Narrow air space lined with aluminum foil in oven wall |
| | * Liquid or gas fuel, or power where economically feasible |
| | * Vent to outside over stove |
| | * Vents and infrared screens for lamp |
| | * Installation of solar power |
| | * cavity wall construction |

## 6.4 FLY-ASH AS A BUILDING MATERIAL

The fly-ash is a fine powder thrown out as a waste material in large quantities at the modern thermal power stations in our country. It resembles a pozzolana i.e. a substance which although not cementitious itself contains constituents which combine with the lime to form a material having cementing properties. Normally, the fly-ash contains some unburnt carbon. It is acidic in nature and its main constituents are silica, aluminium oxide and oxide.

There are a present more than 70 thermal power plants in our country and to cope with the increasing demand of electricity, more thermal power plants may be set up in near future. It is expected that by the turn of century, the quantity of fly-ash available will touch the figure of 1000 million kN per annum. The disposal of such large quantities of fly-ash is certainly a gigantic problem and a matter of national concern.

At present, the fly-ash driven away from the boilers by flue gases is extracted by mechanical collectors or electrostatic precipitators or combination of both. The existing system of disposal of fly-ash is causing the followed problems:

(1) The costly land in the vicinity of the thermal power station is wastes because of the dumping of fly-ash.

(2) The ecology of the region is disturbed.

(3) The disposal of fly-ash involves heavy expenditure.

(4) There are chances of health hazard for the people living near the power stations because the inhalation of fly-ash over a long period causes silicosis, fibrosis of lungs affecting the heart, bronchitis, pneumonitis, etc.

(5) There is non-utilization of a by-product which can be recycled or used for other profitable purpose.

(6) There is risk of pollution to the surrounding environment including soil, vegetation and underground water resources.

The research conducted in India and abroad indicates that the fly-ash can be used in many profitable applications and out of the possible general uses, the following three practical applications are briefly discussed:

(1) Addition to mass concrete

(2) Cellular concrete blocks

(3) Fly-ash building bricks.

(1) ***Addition to mass concrete:*** The addition of fly-ash to the mass concrete work or ready-mixed concrete plants works as an admixture for concrete aggregate reaction.

(i) Aggregate reaction: The addition of fly-ash reduces the cement aggregate reaction.

(ii) Heat evolution: There is low heat evolution when fly-ash is used for the preparation of concrete.

(iii) Permeability: The use of fly-ash greatly improves the water tightness of the concrete.

(iv) Placing and finishing: The fly-ash permits easier placing of concrete and finishing because of the improvement in plasticity and cohesiveness of the mixture.

(v) Strength: The addition of fly-ash improves the strength of concrete. The fly-ash usually replaces 20 to 25% of cement by weight or volume. The strength of such mixture equals or exceeds at a later stage than the strength of non-fly-ash mixture because of the pozzolanic action of the fly-ash.

(vi) Water requirement: It is found that the use of fly-ash results either in small reduction or no change in the quantity of mixing water required per $m^3$ of concrete for a given consistency or slump.

(2) **Cellular Concrete Blocks**: This is a light weight building material produced by autoclaving a set mix of a fine siliceous material such as fly-ash and binder in the form of lime. The cellular concrete blocks possess many technical advantages such as better strength to weight ratio, better sound insulation, stability to variations in temperature and humidity, resistance to fire, low thermal conductivity, resistance to water seepage, etc.

As these blocks are machine finished and uniform in size. The units required comparatively less quantity of cement mortar and plaster can be completely avoided as the blocks are smooth and uniformly coloured.

(3) **Fly-ash Building Bricks:** The process involves the use of fly-ash lime, and a small quantity of magnesium chloride as chemical accelerator. The fly-ash, sand and lime are mixed approximately in the ratio of 80:13:7. The hydraulic press is used for making these bricks and ultimately, the semi-dried are cured in a steam chamber at appropriate pressure and temperature.

The fly-ash building bricks are superior to the conventional burnt bricks in shape, technical specifications, compressive strength and impermeability. They are also about 20% light in weight and about 10 to 15% cheap as compared to the conventional bricks.

In addition to the above applications, the fly-ash can also be used for miscellaneous purposes such as:

(1) Aggregate: It can be used in the form of fine aggregate for concrete and mortar.

(2) Filler: The fly-ash varieties which are otherwise not found suitable could be used as a filling material.

The proportion of fly-ash used in considerable in Japan, Germany, France and U.K. In our country, the use of fly-ash has been restricted to a maximum of about 4% of total production because of various reasons which may be grouped in the following three categories:

(1) Administrative such as absence of fiscal incentives and subsides to the prospective entrepreneurs, existence of conventional bye-laws, contract systems which are not suitable for adoption of new techniques and materials based on fly-ash, etc.;

(2) Economical such as limitations in terms of the distance over which the fly-ash can be commercially transported, absence of appropriate cost-effective technologies, etc.; and

(3) Technical such as non-availability of adequate data regarding the quality of fly-ash, heterogeneity of fly-ash which

### 6.4.1 HEAT RESISTANCE OF PORTLAND FLY ASH CEMENT

Hydrated Portland cement contains a large amount of calcium hydroxide [$C_a$ $(OH)_2$], which gets dehydrated to calcium oxide (CaO) between 500-600°C. on cooling and exposure to moist air or wetting, the CaO rehydrates to Ca $(OH)_{21}$ with a volume expansion of 97 percent. This leads to the formulation of cracks or total disruption of the set cement which has with-stood high temperature without actual disintegration.

The heat resistance of portland cement is thus very poor. Addition of finely divided materials such as dehydrated aluminium silicate (fire-clay), natural hydrated aluminium silicate (clay), chromite, sintered magnesite, slag, silica, diatomaceous earth, etc. in portland cement is known to stabilise and increase heat resistance by combining with free CaO.

The heat resistance of portland fly-ash cement vis-à-vis ordinary portland cement was evaluated by studying the effect of (I) heat up to 1200°C on compressive strength and free CaO content and (ii) alternative heating and exposure to high humidity.

The study shows that portland fly ahs cement containing 20 to 30 percent fly ash, by weight, possesses good heat resistance and volume stability at high temperatures vis-à-vis portland cement which develops cracks due to rehydration of CaO on exposure to high humidity. It can, therefore, be used to produce heat-resistant mortars and concretes which are likely to be exposed to a temperature of 900-1000°C.

**PROCESS**

A process for the manufacture of clay fly-ash bricks has been developed which involves:

- Addition of 10 to 40 per cent fly ahs on the dry weight of the red, black and alluvial soils, depending on the physico-chemical and ceramic characteristics of the soil.
- Mechanical or manual mixing and processing of clay fly ash admixture.
- Manual moulding of bricks or shaping by extrusion process.
- Firing of bricks in continuous type Bull's kiln, High draught kiln or intermittent type of kilns, conventionally adopted in the country

  Firing temperature range, 950 to `1050°C.

## NOVEL FEATURES

(1) In most of the flyahses, the associated unburnt carbon varies in the range of 5 to 8 percent. Addition of flyash in optimum proportion to the soil, therefore, results in:

(a) Production of better burnt bricks, besides an appreciable economy in fuel consumption.

(b) Fuel saving in the range of 15 to 25 percent or coal saving upto 5 tons per lakh bricks.

(2) Flyash addition to the plastic red and black soils reduces excessive linear drying shrinkage in the brick body.

(3) Drying and firing losses during brick production are checked.

(4) Strength of bricks in case of red and black soils is largely increased.

(5) By the addition of fly-ash to the soil, greater number of bricks (upto 40 percent) can be produced from the same quantity of the soil.

(6) The bulk density of clay fly-ash bricks is reduced, which provides better thermal insulation property to the masonry walls and reduces dead load on the brick masonry structure.

(7) Waste fly-ash upto 30 to 40 tons per lakh bricks incase of alluvial soils and100 and 125 tons per lakh bricks in case of red and black soils can be utilised.

(8) Bricks conforming to grades 50 to 300 (IS:13757-1993) can be manufactured. These bricks can be used for all type of brick masonry, paving and soiling purposes.

## 6.4.2 ADVANTAGES IN THE PRODUCTION OF CLAY FLY ASH BRICKS

Numerous advantages in mixing fly ash have been achieved during commercial production of bricks as :

1. Fuel saving varying in the range of 15 to 25 percent (coal consumption) of coal saving upto 3 to 5 tonnes per lakh bricks. The use of fly as is more economical where coal including its transportation is costly.
2. Drying losses are checked in the case of plastic black and red soils. Excessive linear drying shrinkage is reduced
3. Brick strength in the case of black and red soils is almost one and half times increased (30 to 50 percent).
4. Waste material is utilised, 30 to 40 tonnes/lakh bricks in case of alluvial soils and 100 to 125 tonnes/lakh bricks in case of red and black soils.
5. Clay saving in brick manufacture 10 to 40 percent by weight of the soil.

## 6.4.3 USE OF FLY-ASH IN MASONRY MORTARS

Investigations on the use of fly ash in structural concrete were reported earlier (1). Its similar use in masonry mortars of mix proportions 1:3, 1:4, 1:5, 1:6 and 1:8 cement-sand was studied. It was noticed that a direct replacement of a part of cement with fly ash adversely affected the strength and other properties of the mortar. Since a weaker mortar would not be acceptable to engineers, efforts were directed towards producing fly ahs mortars of equivalent strength and quality. It was observed that the strength and workability of some lean cement mortars increased when instead of cement, 20 percent of the sand in the mortar mixes was replaced by weight with fly ahs. For the same strength and workability, there fore, still learner mortar mixes could be used. On the basis of this observation, fly ahs mortar mix proportions corresponding to 1:3, 1:4, 1:5, 1:6 and 1:8 cement-sand mortars were determined by replacing 20 percent. sand by weight with fly ash in cement sand mortar of mix proportions of 1:4, 1:5, 1:6, 1:8 and 1:10 respectively.

It came to know that the fly ash can be used in masonry mortars with advantages of enhanced strength, better water retentively and savings in cost. The fly ash mortars of mix proportions corresponding to the plain cement mortars of 1:6 or leaner mix proportions and prepared using sand of F.M. not less than 1.45 are recommended to be used for plastering.

**Table 6.2 : Orientation of the rooms in the residential buildings in hot-dry climate**

| Sl. No. | Name of the Rooms | North | South | East | West | North- West | North-East | South-West | South-East |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Garage | | ● | | ● | | | | |
| 2. | Entrance | | | ● | ● | | | | |
| 3. | Varandah | | | ● | ● | | | | |
| 4. | Living Room | | | | | | | | |
| 5. | Bed Room | | | | | | | ● | |
| 6. | Study Room | | ● | | | | | | |
| 7. | Kitchen | | | | | ● | | ● | ● |
| 8. | Dining | | ● | | | | | ● | |
| 9. | Pooja | | | ● | | | ● | | |
| 10. | Store | | | | ● | | | | |
| 11. | Toilet | | | | ● | | | | |
| 12. | Bath | | | | ● | | | | |
| 13. | Water closet | | ● | | ● | | | | |
| 14. | Guest Room | ● | | | | | | | |

# CONCLUSIONS AND RECOMMENDATIONS

## 7.1 CONCLUSIONS

Buildings, as environmental controller, consume a lot of energy which is primarily used for heating/cooling, ventilation and lighting. This ever alarming cost of consumptive use of energy in buildings, morally enforce a statutory demand of evolving climate responsive design. The challenge is to design a single building that responds in an equally appropriate manner to each of the different seasons in a given climate, thus achieving maximum comfort at minimum cost of doing it. This is possible only through climate design.

In this industrial age architecture that is developed is free from environmental control and is governed by mechanical controls which results in high level of energy consumption. Such level of energy consumption was not consumption. Such level of energy consumption was not available in the past. The traditional buildings give us many examples of a sensitive approach to thermal comfort designs. It has now become essential to develop alternative technologies associated with primitive aspects for thermal comfort. So the techniques used in traditional buildings should be re-discovered and all that is suitable to our requirements should be extracted and minimized in cooling contemporary Architecture.

After going through the climatic data, and study of traditional building in hot-dry climate which have been followed, knowingly or unknowingly, in the traditional buildings, following conclusions can be made

1. To minimize energy demand and provide better degree of natural conditioning, it is essential to give climatic considerations for designing. For a building to function in co-ordination with the environment, there should be a relation between the interior and the exterior environment, orientation, building form, fenestration , materials and bioclimatic needs of the users.

2. Space : Overall planning of a building should be centrifugal and compact. Provision of a central courtyard is preferable which helps in achieving shaded spaces, natural light in most of the spaces and better circulation of air without providing much openings on the exterior surfaces. This helps in reducing heat gain through the envelope. Planning should be such that it allows excess heat from the interior spaces to be transferred to the perimeter spaces. Individual spaces should be arranged in such a way that more natural light reaches the interiors. Appropriate planning of individual spaces and the overall form of the building affect the thermal comfort.

3. Location or orientation of an individual room may depend on the type of occupancy and the time of use. Orientation of the overall built form should be in co-ordination with the orientation of the sun and the prevailing wind direction. The shape should be such that it resists unwanted heat gain or losses.

4. When buffer spaces are provided between exterior and interior spaces, heat from outside dissipates here before entering the interiors.

   As the position of a window goes higher, light penetration increases with lesser heat gain.

5. Ventilation : Air movement is required in the interiors mainly in the rainy seasons to bring high humidities to a lower the level. Stack effect, suction effect, venturi effect etc., created due to the size and location of the

openings, help in enhancing the movement of air in the interiors. Height of the building can be increased to improve ventilation by providing circulation of air near the top.

6. Thermal Comfort : Two major objectives of climate responsive design are

   (i) avoiding heat storage, (ii) promoting ventilation

   The most important factor for thermal comfort conditions in the interiors of a building is to minimize heat gain through roof, walls and openings. Comparatively there is not much effect due to exposed surfaces on heat load but the major heat gain is through roof therefore, roof shading is essential.

7. Thick walls provided in the historical buildings create thermal time-lag thus creating comfortable conditions.

8. Heat removal can be affected by natural or induced ventilation, evaporation of water and the use of heat sinks.

9. Courtyard is an effective means of attenuating internal thermal conditions. It provides shaded spaces but it is effective only when it has a plan area and volume relationship proportional to built-up area and its volume.

10. Landscaping : Landscaping is a passive energy saving technique. It controls wind, solar radiations and temperatures extremes of climate.

## 7.2 RECOMMENDATIONS

Following recommendations can be made corresponding to the conclusions drawn from the study with proposed modification to suit the present day architecture:

1. Climatic aspect should be considered and all the effects of microclimate should be evaluated while designing a building.
2. Plan should be centrifugal and compact. Best alternative is to provide a central courtyard that fulfils the requirement of natural light and induced ventilation in the surrounding spaces, maintaining comfort condition.

   In the present day buildings, presence of a non-functional duct is mostly found for the purpose of lighting and ventilating a few spaces. Instead of such provisions, building can be planned in such a way that a multifunctional open-to-sky space is provided at one place which fulfils the requirements of light and ventilation. If the conditions permit, courtyard planning can be done.
3. Rectangular form of the building should be elongated along East-West direction. This means that the orientation of the building should be North-South. Non-habitable rooms should be provided as heat barries in the worst orientations on the outer periphery of the building.
4. Planning should be done in terms of semi-open and enclosed spaces. Verandahs, balconies, galleries, toilets, stores and even overhangs can be provided as buffer spaces between the exterior and the interior spaces. Covered verandah on the West side and pergola covered with creepers can be provided on the South side.
5. The configuration of building and the openings should be adjusted in such a way that cross ventilation is allowed through occupied spaces.

6. The size and location of the ventilators must though about in such a way that it helps to take the hot air out and improves the cross ventilation vertically.

7. In a two-storied house through proper design, the staircase tower can be efficiently used as a ventilator shaft to take the hot air out.

8. Roof, walls, openings and outdoor spaces should be shaded as per requirement.

9. Terrace exposed roof. Roof slab when overhanged shades a part of wall area below.

10. To provide sun shading, projected eaves and balconies should be provided. Verandahs should be provided on the Western and the Southern sides along with certain offsets in the plan depending upon the activities, on the East and West sides to provide self-shading taking the advantage of the direction of movement of sun.

    Minimum glass area should be provided on the Western side or the windows should be made deeply recessed because even curtains or internal blinds cannot prevent heat to accumulate inside the room due to green-house effect.

    External surfaces of the walls should be light coloured or made reflective with use of some other material.

11. Always encourage white washing of external walls, even if it is only brick pointed, to help to reflect heat and so to reduce heat from going into the rooms through walls.

12. Temperature differential should be created between outer and inner surfaces of an exposed wall to achieve thermal time-lag. Now a days we can not afford to provide thick walls as it was done in the past but we can create

time-lag by providing cavity/air gap or insulation within the wall. This is not required on the North side.

13. Since the rat-trap bond, Joshi bond wall and filler slab roof adds insulation against heat, its use is highly recommended.

14. If the ceiling height is increased the material used for wall should possess better thermal insulation and the ceiling should be well ventilated.

15. Shape of the roof should be designed such a way that it receives oblique radiations from the sun which have low intensity or some provisions can be made for the flat roof to fulfil this requirement. Roof surface can also be made reflective with the use of material of such quality.

16. Size of the courtyard in proportion to the height of the building should be such that it provides shaded spaces.

17. As far as possible local and indigenous materials should be used with cost saving construction techniques.

18. Landscape should be planned in such a way that it creates environmental buffer spaces to reduce heat gain and environmental corridors to enhance air movement in the interiors of the building.

    Excessive vegetation should be provided in the surroundings of a building to maintain comfortable conditions due to evaporative cooling.

    Ground surface should also be covered with vegetation to avoid reflection of solar radiations onto the building.

19. Trees with high canopies and good spared should be planted on South West. Deciduous trees should be planted as sun and wind block for summers and coniferous trees for summers as well as winters. Deciduous trees or creepers should be provided for shading South and West Wall.

Water bodies should be planted in the wind direction to provide maximum comfort indoors.

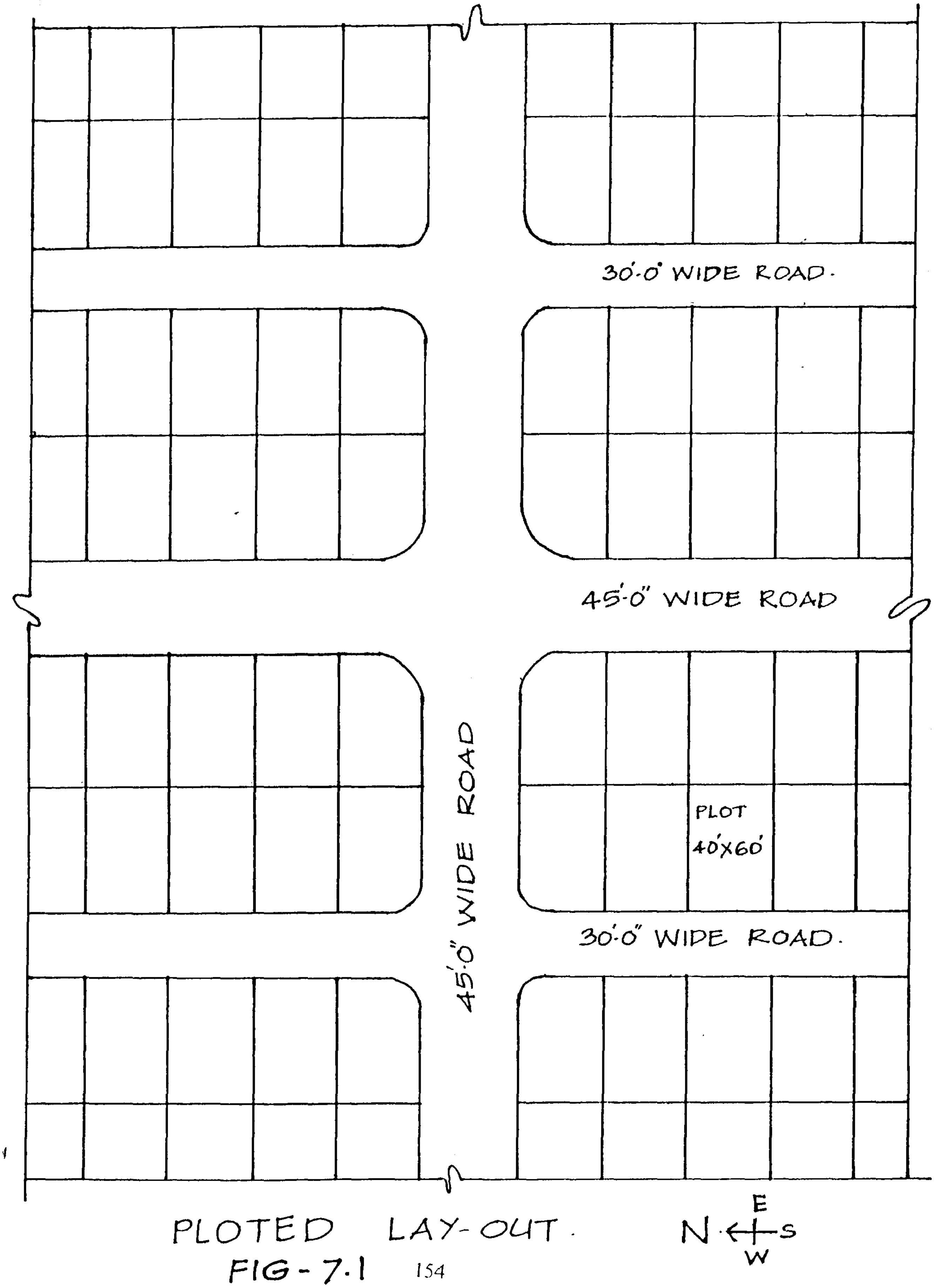
20. The layout of the plot is such a way that the shorter side facing east and west direction and longer side of the plot must be facing North and South direction to create a Building shadow on the street in morning as well as in the evening. This will also reduce a glare and dust (Refer. Fig. 7.1).

21. Use insulative material for roof and South and West wall. To minimize the transfer of heat.

22. Adopt newly developed passive downdraft cooling in building to achieve thermal comfort.

23. In hot-dry climate maximum solar radiation. So installation of solar energy is recommended. For domestic purpose, for a lighting and hot water. This will save maximum electrical energy and reduced load on production of electrical energy.

24. Use of fly-ash as a building material waste dumped fly-ash from thermal power plant can be used. The ecology of the region is improved. The environment is improved by clearing fly-ash dumps. It saves fuel by manufacturing bricks. The strength of the brick is increased by 1.5 times the normal bricks. It saves 10 to 40% of clay for manufacturing of brick. It is not much more affected by thermal variation, for developing the minor cracks in walls.




PLOTED LAY-OUT.

FIG-7.1

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