DESIGN PARAMETERS FOR ENERGY EFFICIENT DWELLIGNS IN COMPOSITE CLIMATE OF INDIA

A DISSERTATION

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

MASTER OF ARCHITECTURE

By

HUMA MATLOOB

DEPARTMENT OF ARCHITECTURE AND PLANNING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE - 247 667 (INDIA)

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CANDIDATE'S DECLARATION

I hereby declare that the work, which is presented in this dissertation report, entitled **"DESIGN PARAMETERS FOR ENERGY EFFICIENT DWELLINGS IN COMPOSITE CLIMATE OF INDIA"**, being submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF ARCHITECTURE**, in the **Department of Architecture and Planning**, of Indian Institute of Technology, Roorkee is an authentic record of my own work carried out for two semesters from July'2004 to June'2005, under the guidance and supervision of **Prof. S.Y. Kulkarni.**

The matter embodied in this dissertation has not been submitted for the award of any other Degree or Diploma.

Date: 29TH JUNE'05

Place: Roorkee

HUMA MATLOOB

CERTIFICATE

This is to certify that the statement made by the candidate, **HUMA MATLOOB**, is correct to the best of my knowledge.

Date: 29TH JUNE'05

Place: Roorkee

S.Y.Kulkarni

Professor,

Department of Architecture and Planning

Indian Institute of Technology,

Roorkee.

ACKNOWLEDGEMENT

In the name of GOD, I take this opportunity to express my gratitude and sincere thanks to all the people who have helped me in the completion of my project report.

I must, first of all, acknowledge my deepest obligation and sense of gratitude to my supervisor and guide Prof.S.Y.Kulkarni, faculty of the Department of Architecture and Planning, at whose hands it was a sheer joy to listen and learn. I would long cherish this experience.

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In the end I would like to thank all those people who helped me in the preparation of the final dissertation report and its manuscripts.

Roorkee

Dated: 29TH JUNE '05 **HUMA MATLOOB**

ABSTRACT

"A penny saved is a penny earned", they said. So with joules of energy!

With recent exponential increase in energy pricing, the formerly neglected or under estimated concept of energy efficiency and conservation have swiftly assumed great significance and potential in cutting costs and promoting economic development especially in a developing country scenario.

Reckless and unrestrained urbanization, with its hap hazard buildings has bull dozed over the valuable natural resources of energy, water, air and ground cover. Thereby greatly hampering the critical process of eco-friendly habitat development.

However it's not too late to retrace our steps. The resource crunch confronting the energy supply sector can still be alleviated by designing and developing our future buildings on the sound concepts of energy efficiency and sustainability.

Energy efficiency in buildings can be achieved through a multi-pronged approach involving adoption of bio-climatic architectural principles responsive to the climate of that particular location; use of materials with low embodied energy; reduction of transportation energy; incorporation of efficient structural design; implementation of energy efficient building systems; and effective utilization of renewable energy sources to power the building.

India is quite a challenge in this sense. N.K.Bansal and Gernot Minke (1988), in their book titled "Climatic Zones and Rural Housing in India", have classified Indian climate into six zones- cold and sunny, cold and cloudy, warm and humid, hot and dry, composite, and moderate. Translation of bioclimatic architectural principles into design in the Indian context, therefore, provides a plethora of experiences and success stories to learn from. Several buildings have come up, fully or partially

adopting the above approach to design.

The study is a result of a comprehensive study of some of those dwelling units since the scope of the topic is limited to the design parameters for dwelling units in composite climate only.

In today's era of industrialized civilization, we are tending towards the highly sophisticated building. The developed technology in the field of physical comfort is leading us to the period of energy crisis, because the energy sources are not long lasting. Due to the available technology for comfort, like heating, cooling and ventilation systems etc.; architects are generally ignoring the important aspects of architectural design in buildings. This ignorance may lead the society to the grave of slum.

Spanning all the areas that come under composite climate, the projects covered here as case studies are selected on the basis of their energy efficient approach to design- be it adoption of low energy construction material and techniques, innovative use of solar passive architectural principles or use of renewable energy systems. Projects not included here are the ones that used some stand-alone renewable energy gadgets/devices without having an integrated approach to whole design.

The study will prove to be of interest and of benefit to practicing architects, building designers, scientists, engineers, urban planners, architecture students, municipal authorities, policy makers and concerned citizens.

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1. INTRODUCTION

"A penny saved is a penny earned", they said. So with joules of energy!

With recent exponential increase in energy pricing, the formerly neglected or under estimated concept of energy efficiency and conservation have swiftly assumed great significance and potential in cutting costs and promoting economic development especially in a developing country scenario. Reckless and unrestrained urbanization, with its haphazard buildings has bull dozed over the valuable natural resources of energy, water, air and ground cover. Thereby greatly hampering the critical process of eco-friendly habitat development. However it's not too late to retrace our steps. Designing and developing our future buildings on the sound concepts of energy efficiency and sustainability can still alleviate the resource crunch confronting the energy supply sector. Sustainable environment aims to create environment friendly and energy efficient buildings. This entails actively harnessing renewable natural resources like solar energy and utilizing materials that cause the least possible damage to the global commons like- air, water, forests and soil.

Developing countries situated in tropics, accounting for about half the world population but consuming only 15% energy are in bad shape. Where as the concern on account of energy crisis in developing countries are faced with problems of supply of energy, due to the following reasons:

- To sustain the working of industries for employment and production of essential goods.
- To run the transport system for supply and distribution of goods.
- For functioning of community health and other infrastructure services.

- To support minimum domestic activities etc.

These are the minimum necessities as far as the developing countries are concerned. Therefore conservation of energy for developing countries has a greater significance. India, one of the largest developing countries in tropic, should therefore consider energy conservation oriented development. In the economic development planning of a country, energy conservation through building plays a leading part, because as an architect's point of view and worldwide acceptance the buildings are the major regular energy-consuming units. Therefore, it becomes necessary to design the whole building as an energy conservation system.

The ignorance in the energy conserving designs of buildings created manifold problems. Because of the inefficient indoor environmental conditions, most of the energy in buildings is being used for physical comfort such as air-conditioning, artificial lighting, heating and cooling etc. By studying the climatic aspects for human comfort and architectural aspects of orientation, topography and microclimate of the site etc., an energy-conserving program can be established in building system. Solar energy as a long lasting energy source plays a vital role in the conservation program. The proper utilization of active and passive solar system can directly curtail the energy demand for day lighting, heating, cooling etc. of the building.

There has been a growing readiness to support the search for new energy sources and to conserve energy wherever possible. With the help of governmental programmes, considerable efforts have been undertaken to develop the utilization of renewable energy sources more rationally. There is a need for greater understanding of the qualitative concept of conservation to implement more energy conserving lifestyles.

Energy conservation can be defined as "the more efficient use of the resources of energy". This efficiency can be achieved by the reduction in the intensity of the energy use whether by doing things more efficiently, consuming in different patterns or just consuming less. Using it effectively i.e. curtailing the energy requirement at source itself can conserve the energy. The new techniques of the solar energy utilization can be introduced in the building design for further reduction in consumption. An architect plays a very important role in designing the whole system of the building. Energy efficiency in buildings can be achieved through a multi-pronged approach involving adoption of bio-climatic architectural principles responsive to the climate of that particular location; use of materials with low embodied energy; reduction of transportation energy; incorporation of efficient structural design; implementation of energy efficient building systems; and effective utilization of renewable energy sources to power the building.

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 construction can be affected by adopting an integrated approach to building design.

Thus, in brief, an energy efficient building balances all aspects of energy use in a building-lighting, space conditioning, and ventilation-by providing an optimized mix of passive solar design strategies, energy efficient equipment, and renewable sources of energy. Use of materials with low embodied energy also forms a major component in energy-efficient building designs.

1.1 THE PROBLEM...WHATS AND WHYS?

WHATS...

- The continuously and often erratically rising costs of energy headed by the price of oil led to an increasing concern about the limitations of fossil energy resources.
- 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 comfort cause severe depletion of invaluable environmental resources.
- Buildings are not designed to meet the occupants need for thermal and visual comfort at reduced levels of energy and resource consumption.
- Increased development of housing and other commercial buildings has imposed immense pressure on our dwindling energy sources and other resources like water, thus aggravating the already rampant process of environmental degradation.

WHYS...

IGNORANCE

Buildings are major energy consuming systems and the ignorance in energy conserving designs of buildings created manifold problems. The common man who forms a major chunk of the lot of users of the buildings is ignorant about the recent developments taking place in energy efficient measures to be incorporated in buildings .The research is beyond the scope of the users.

- **FEASIBILTY**

The results of researches are not feasible and practical enough to be applied at small scale. Usually, the solutions that are being derived from the researches are meant for the upper class that can afford to incorporate those steps to curtail the energy consumption of their building. But as far as the lower class is concerned these steps are not at all feasible enough to be applied because these solutions are always thought of as to being very uneconomical and complicated, which is beyond the scope of the common man.

- **LACK OF DESIGN INPUTS, EXCESS OF TECHNOLOGICAL INPUTS**

Mostly the methods of energy efficiency, which the general public is made aware of, are those, which need some mechanical inputs and devices like solar cookers. The basic architectural principles are not relied upon as far as energy efficiency is concerned.

• They do not lay stress on some basic design principles which are easy to use. Use of passive solar designs is not laid stress upon. Only active systems are being used conserve energy, which are not as useful as the passive ones.

• Increased complexity in building engineering has set a new architectural practice, which has led to wastefulness in energy use.

- **LACK OF RESOURCES**

Sometimes even when people want to incorporate energy efficiency measures in their buildings they are not able to do so because of lack of necessary resources and knowledge regarding the methods. People, usually, don't have that technical know how so as to incorporate these energy efficiency measures at small scale. We, architects, should be conscious enough to put up the solutions of the problems regarding the conservation of energy to the client in such a way that he feels at ease in incorporating them in his building. Rather, he should be made to feel that these steps would add up to his convenience in running the building in the long run.

- UNECONOMICAL

There is a general notion that mechanical methods, if adopted, will lead to incurring some additional cost and as we all know cost is the most important factor when any building is being constructed. This forms one of the most important reasons to retard the client from taking any such considerations in his building. In a developing country like India cost factor forms a major chunk of the considerations that an architect has to keep in mind while designing his building. So it is very important that the energy efficiency measures that we are coming out with, have such provisions made in them that any common man can adopt them without incurring too much of additional cost, i.e. the cost that the client has to bear for incorporating any such energy efficient design steps should be comparable to the amount the client has in mind beforehand. This will really help the architect in convincing his client for adopting such solutions, which should be the ultimate aim of the new budding architects.

1.2 ARCHITECT'S ROLE IN ENERGY-EFFICIENT BUILDINGS

Man lives in an energy intensive society as a result of depleting conventional energy resources; society must examine energy use from a total systems viewpoint.

Because buildings consume 30% of total energy resources and much of this has been wasted through traditional design techniques, thereby making they the prime target for energy conservation. The responsibility for conserving energy in buildings lies in the hands of both, the architects as well as engineers, who are engaged in the building industry. It is their responsibilities to find new and better techniques for the design of buildings, which conserve energy, while at the same time preserve the qualities of function, economics and aesthetics, which have always been valued, by designers and users alike.

As already mentioned, buildings are major energy consuming systems, so architects have a major role to play in designing energy efficient built environment.

- The architects must direct their efforts to find new and better techniques for the designing of the buildings which conserve the energy while at the same time preserve the qualities of function, aesthetics, economy etc. which have always been valued by designers and users alike.
- The increased complexity of the technology of building and of the engineering design of the mechanical services in large modern buildings has set a new architectural practice which has led to wastefulness in energy use.
- The architect, must consider from the beginning, how the overall form, details and construction must be adopted to reduce the total requirements for servicing and thus cut energy use.
- The architect himself must better understand the relationship of the building form and materials to energy consumption.

In the last two to three decades the architects were ignoring the concept of energy consumption in the buildings. The functionalism of 20's and 30's urged that the form of building and its plan should clearly reflect; express the nature of functions carried out inside the building. This same clarity of expression was to be carried in the material construction of the building. The performance of such buildings was very poor in terms of control of climate and forms of dwellings were clearly unsuited to local conditions of weather and site. The modern movement of last two decades was not concerned with the climate and site; the aesthetic interest was in rectangularity with simple geometric forms.

The increased complexity of the technology of the buildings and of the engineering design of the mechanical services in large modern building set a new architectural practice that has lead to wastefulness in energy use. Because of the complexity, the individual architect, no longer has a hold on the entire design process. So he seeks the advice of the consultants. To counter this problem, the architect must consider, from the very beginning, how the overall form, the details and the construction of the building may be adapted so as to reduce the total requirements for servicing and thus cut energy use. The architect himself must better understand the relationship of building forms and materials to energy consumption.

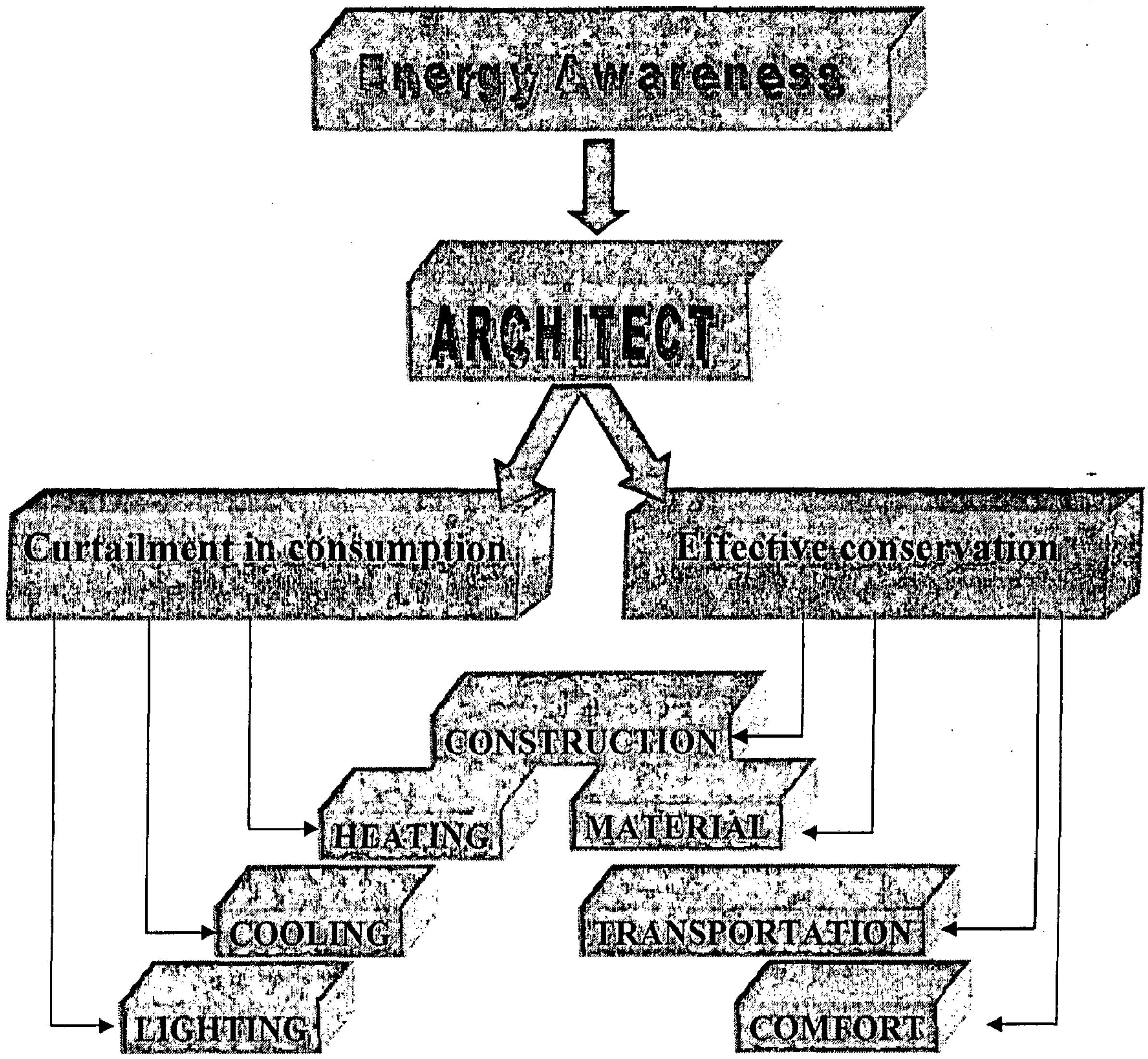


FIGURE 1.1: ARCHITECT'S ROLE IN ENERGY CONSERVATION

1.3 OBJECTIVES OF WORK

Energy conservation is vitally important to our energy future. It is a topic where opportunities and challenges deserve much more careful analysis and detailed probing than we have been able to do. The study deals with energy conservation in dwelling units and human comfort. With the emphasis on sustainable habitats as a key solution to growing urban concerns, which assume a global dimension, the study will provide a very timely insight into the context; techniques and benefits of energy efficient buildings.

This study is being done to achieve the following vital objectives: -

- Creating awareness of designing energy efficient building envelopes by taking advantage of the climatic conditions of a particular region.
- Identifying the resource efficient building practices in India.
- Advocate the application of renewable energy systems.
- Integrating active/passive solar energy system to cut the energy consumption in a dwelling unit and hence make it energy efficient.
- Guidelines to integrate the dwelling with the site conditions and microclimate of the area.
- Studying the climatic aspects for human comfort and architectural aspects of orientation, topography and microclimate of the site to establish energy efficiency program in building system.
- Studying the architectural aspects of dwelling design, orientation, topography, ventilation etc.

1.4 SCOPE OF STUDY

The scope of the study is limited to finding out solutions for achieving energy efficiency in building located in the plains of northern India having composite climatic conditions.

- Projects studied here are selected on the basis of their energy efficient approach to design –be it adoption of low energy construction material and techniques, innovative use of passive solar architectural principles or use of renewable energy systems.
- Those projects that used some stand alone renewable energy gadgets/devices without having an integrated approach to whole design fall outside the purview of this work.
- It will act as a source of inspiration to correct our building concepts and practices.
- The study will be of interest to practicing architects, designers and students.

This study will serve the dual purpose of:

- Educating the laypersons about the multiple benefits of building in tune with nature.
- Reinvigorating the zeal of professional designers, builders and planners to impart to their projects a bond with the earth far greater than any aesthetic value.

1.5 METHODOLOGY

Buildings can be designed to meet the occupant's need for thermal and visual comfort at reduced levels of energy and resource consumption. Energy resource efficiency in new construction can be affected by adopting an integral approach to building design.

The primary steps in this approach are listed below:

1. **Incorporate solar passive techniques in a building design to minimize load on conventional systems (heating, cooling, ventilation and lighting)** - Passive systems provide thermal and visual comfort by using natural energy sources like, e.g. solar radiation, outside air, sky, wet surfaces, vegetation etc. the solar passive systems vary from one climate to another.
2. **Design energy efficient lighting and HVAC (heating, ventilation and air conditioning) systems-** Once the passive solar architectural techniques are applied to design, the load on conventional systems are reduced. Further, energy conservation is possible by judicious design of artificial lighting and HVAC systems using energy efficient equipment, controls and operation strategies.
3. **Use renewable energy systems (solar photo voltaic systems or solar water heating systems) to meet a part of the building load-** The pressure on earth's non-renewable energy resources can be alleviated by judicious use of earth's renewable energy resources, i.e. solar energy.

4. **Use low energy materials and methods of construction and reduce the cost of transportation-** An architect should also aim to efficient structural design, reduced use of transportation energy and high energy building materials like steel and glass.

A few design elements, which directly or indirectly affect thermal comfort conditions, and thereby the energy consumption of any building is listed below:

- **Landscaping**
- **Ratio of built form to open spaces**
- **Location of water bodies**
- **Orientation**
- **Plant form**
- **Building envelope and fenestration**

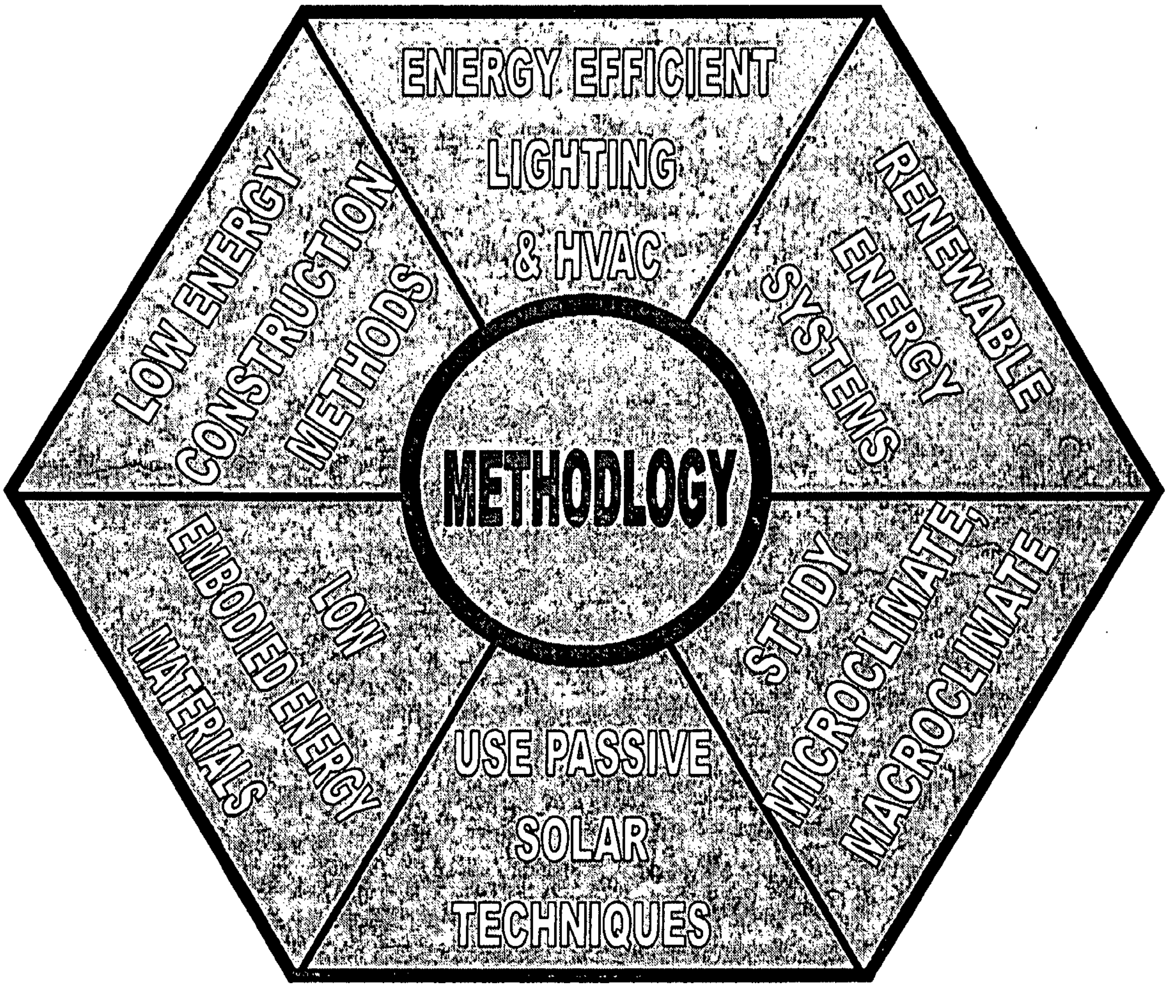


FIGURE 1.2: METHODOLOGY FOR ACHIEVING ENERGY EFFICIENT BUILDINGS

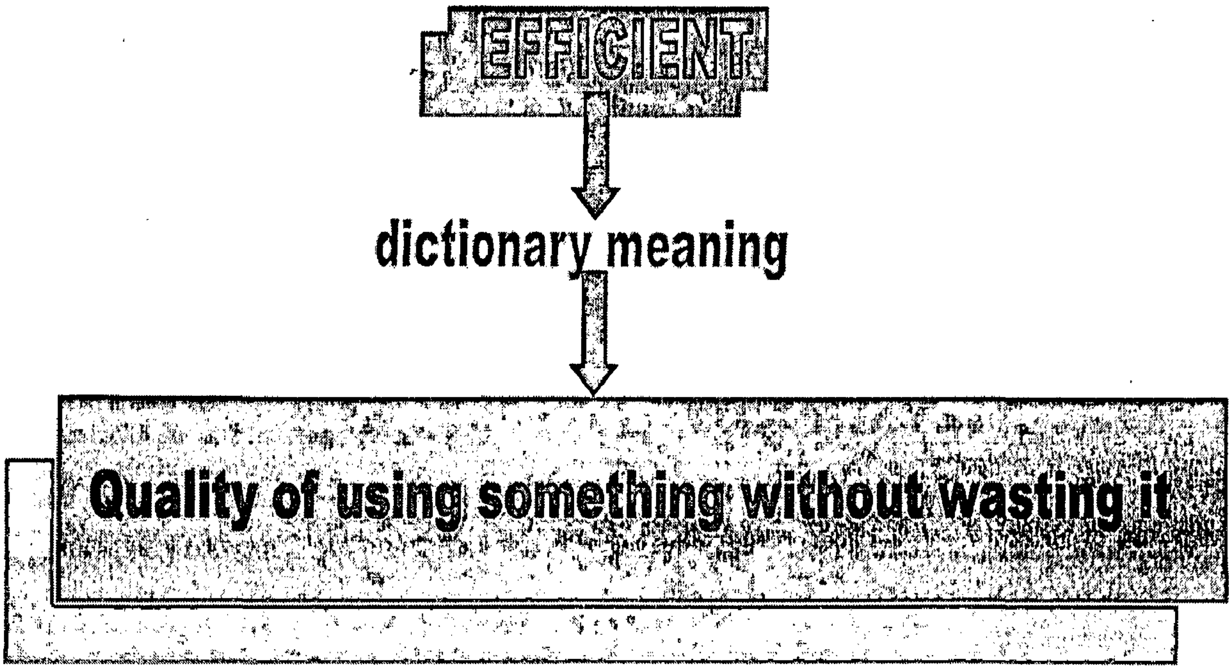
2. LITERATURE REVIEW

2.1 WHAT IS AN ENERGY EFFICIENT BUILDING

What we once called "house for all seasons" has now been christened as "energy efficient" or "climate conscious" or "sustainable architecture".

"An energy-efficient building is the one which balances all aspects of energy use in a building- lighting, space conditioning, and ventilation by providing an optimized mix of passive solar design strategies, energy efficient equipment and renewable sources of energy. Use of materials with low embodied energy also forms an important component in energy efficient building design."

WHAT IS AN ENERGY-EFFICIENT BUILDING?



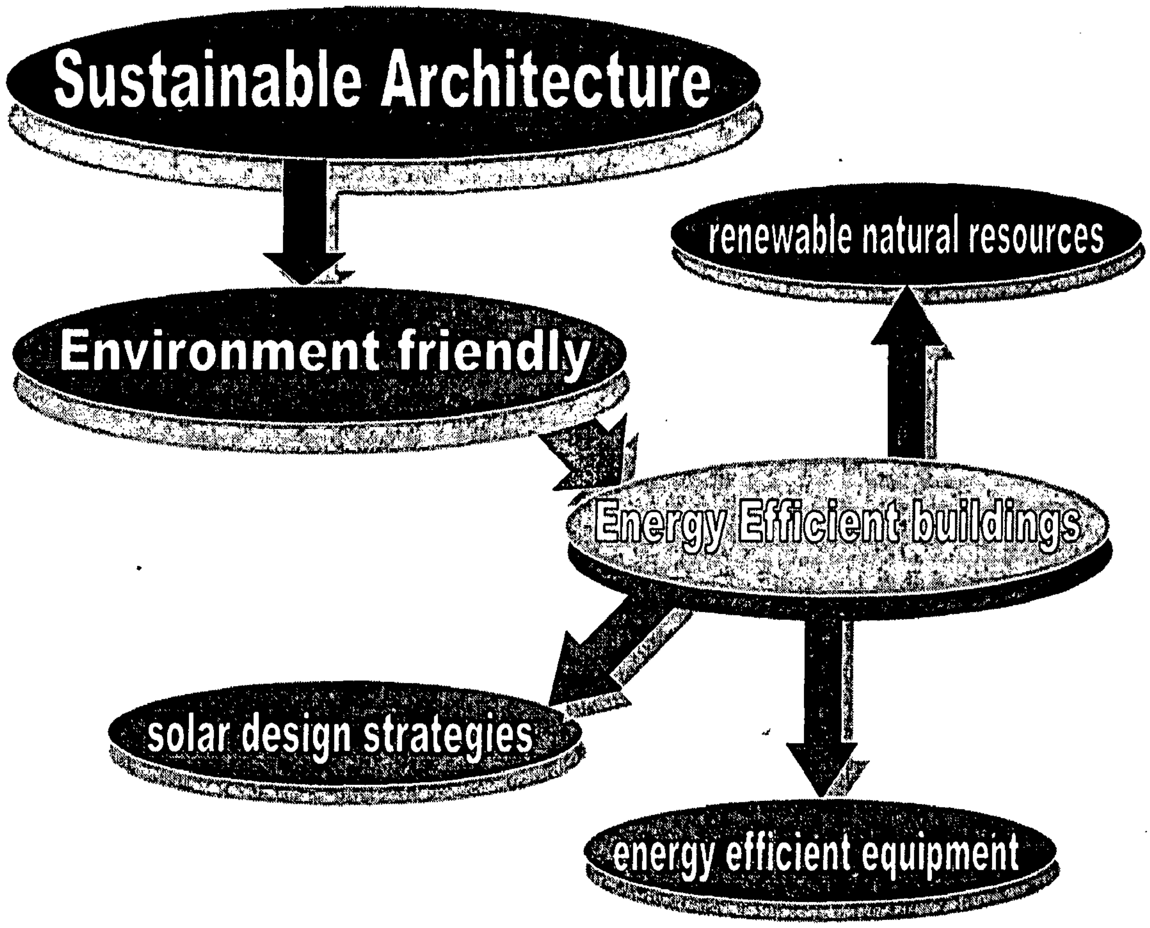


FIGURE 2.1: RELATIONSHIP OF ENERGY EFFICIENT DWELLINGS TO SUSTAINABLE ARCHITECTURE

2.2 NEED FOR ENERGY EFFICIENT BUILDINGS

The past years have shown us that energy sources and natural resources play a key role in an economic system. The intended technologies and various discoveries have lead to the rapid consumption of the energy resources. The energy crisis of 1973 draws attention to two facts, which were known earlier, but had largely been ignored. First the price of hydrocarbon fuels, and especially of oil, will increase as supplies become scarcer. Secondly, the rate of energy usage was increasing at such a rapid rate. The rate of growth is, therefore, a bigger problem than present energy consumption. Conserving energy means reducing the amount of fuel and electricity which a building and space uses every month. Therefore, conservation of energy is strongly recommended due to the following reasons, for the advantages to the nation as a whole:

a) Energy sources are not long lasting.
b) Energy conservation conserves natural resources.
c) Energy conservation can enhance economic opportunity where material and labor are required to improve building thermal characteristics.
d) Energy conservation reduces the dependency upon the external resources for the internal economic well being and security of their country.
e) Energy conservation combats inflation.

Energy conservation is also necessary for maintaining the living standard, because the rapid consumption of energy will result in the continuous price rising. Therefore, energy conservation forms an inevitable part of the total design process and it should be taken care of due to the following reasons:

I. To extend the useful life of the equipments.
II. To reduce the likelihood of shut down or curtailment of operation due to fuel or power shortage.
III. To reduce air borne pollution resulting from combustion of oil, gas or coal.
IV. To maintain the health and comfort standards.

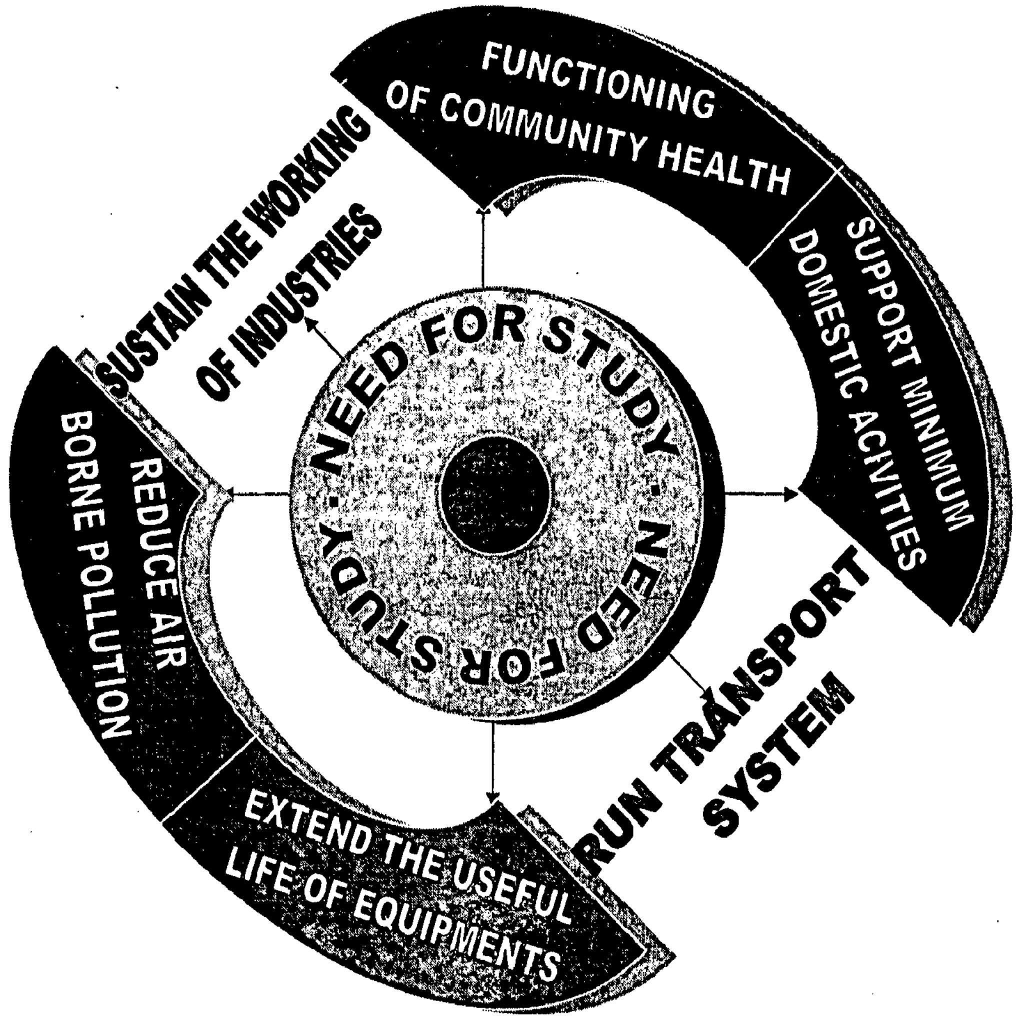


FIGURE 2.2: NEED FOR THE STUDY OF ENERGY EFFICIENT BUILDINGS

2.3 ENERGY EFFECTIVENESS

As we have seen that the energy conservation, due to lack of natural resources, became such a strong issue.

There are three basic ways to conserve energy:

- Curtailment of fuels and electric power.
- Improvement of the efficiency of utilization at the point of consumption
- Using energy alternatives to support the natural resources

Until recently, it was not widely recognized that the improvement in the efficiency utilization at the point of consumption could yield significant reductions in the natural requirements for high quality fuels without requiring sacrifices in the comfort, safety or the health of the building occupants. Effective measures for conservation will require in the curtailment and improvement of efficiency of energy consumption.

To understand the question of effectiveness of energy consumption, it is necessary to define both- consumption and effectiveness:

CONSUMPTION – it means the ultimate use of energy for a process or to provide a service.

EFFECTIVENESS – it implies same measure of the minimum energy required to operate the processes.

2.4 LOW ENERGY HOUSES

The term "low energy" stands for the low consumption of energy in the dwellings and other buildings as well. The main considerations for opting for such types of houses are as follows:

- The provision of funds for building is tending to decline in relation to the general cost of living.
- The operating cost of buildings has increased sharply, mainly due to a great increase in electricity and fuel costs.
- The usage of building by occupants is subjected to a greater change than in the past.
- The occupants of a building tend to expect a higher standard of environmental control and personal comfort.

These factors taken together impose great demand and skills on the part of the designers. The occupants of a building may be willing to accept the substitution of cheaper materials and finishes and a reduction in space in new buildings but they are less likely to accept a reduction in environmental standards and in fact may require a higher standard of visual, thermal and acoustic comfort than has been in the past. In today's trend the emphasis has been laid on the initial cost of the building not on the lifetime cost of the building.

The basic aims of low energy houses are as follows:

I. To conserve energy
II. Taking advantage of the climatic and geographical conditions for planning the building.

III. To reduce the cost of energy and this will reduce the lifetime cost of the dwelling.

IV. Introducing alternatives and recyclable energy sources in buildings.

V. Using energy effectively for essential activities like heating, cooling, lighting etc.

Energy is best used in meeting the needs of the occupants and therefore, the first requirement are that these needs should be defined. Recently, researchers have looked at our environmental preferences rather than our needs and it has been assumed that they would be met by mechanical and electrical methods. The lesson of low energy design is that we must learn again how to control the access of external environment to our buildings with man made energy reserved for use wherever it is indispensable.

This discussion shows that today there is a need of low energy housing but in this period of energy crisis one should include all other architectural aspects of design and construction for conserving energy, such as location, site, topography, climate, orientation etc.

- The main purpose of dwelling has always been to provide a comfortable environment.
- Present modern buildings are failing in their environmental performance, which is crucial to human comfort.
- It is in this recent history of new aesthetic ideas, new building types and rapidly changing building technology that the major causes of our problems can be found and we will not be able to put matters right until we understand where we went wrong.

2.5 COMFORT FACTORS

Why does man build houses? People need shelter from wind, dust and the various forms of precipitation; they require certain conditions of temperatures, humidity and air movement. This is because he wants to be physically comfortable.

"The main purpose of any dwelling has always been to provide comfortable environment. It is our success in controlling or modifying the natural environment that has enabled mankind to progress gradually from the basic necessities required for bare survival to one of ease and comfort".

Our daily life cycle compromises states of activity, fatigue, and recovery. It is essential that the mind and recovers through recreation, rest and sleep to counter balance the mental and physical fatigue. Criteria of total comfort depend upon each of the human senses. The task of the designer is to create the possible indoor climate. The occupants of a building judge the quality of the design from physical as well as emotional point of view. Thus, it is necessary to examine briefly the thermal processes of the human body.

Man's energy and health depend in large measure on the direct effects of his environment. It is a common experience to find that on some days the atmospheric conditions stimulate and invigorate our activities; while at the other time they depress the physical and mental activity effort. These observations suggest that man's physical strength and mental activity are at best within a given range of climatic conditions, and that outside this range this range efficiency lessens, while stresses and possibility of disease increase. Thus, its very necessary to understand the comfort scale and various comfort factors.

2.6 THE BODY'S HEAT PRODUCTION AND THE BODY'S HEAT LOSS

THE BODY'S HEAT PRODUCTION

The body continuously produces heat. Most of the biochemical processes involved in tissue building, energy conversion and muscular works are heat producing. All energy and materials requirement of the body are supplied from the consumption and digestion of food. The processes involved in converting food stuff into living matter and useful form of energy is known as metabolism.

The main purpose of building has always been to provide a comfortable environment. It is our success in controlling or modifying the natural environment that has enabled mankind to progress gradually from the basic necessities required for bare survival to one of ease and comfort. Present modern buildings are failing in their environmental performance that is crucial to human comfort.

THE BODY'S HEAT LOSS

The deep body temperature must remain balanced around 37^0C. In order to maintain body temperature at this steady level, all surplus heat must be dissipated to the environment. The body can release heat to its environment by convection, radiation, and evaporation and to a lesser extent by conduction.

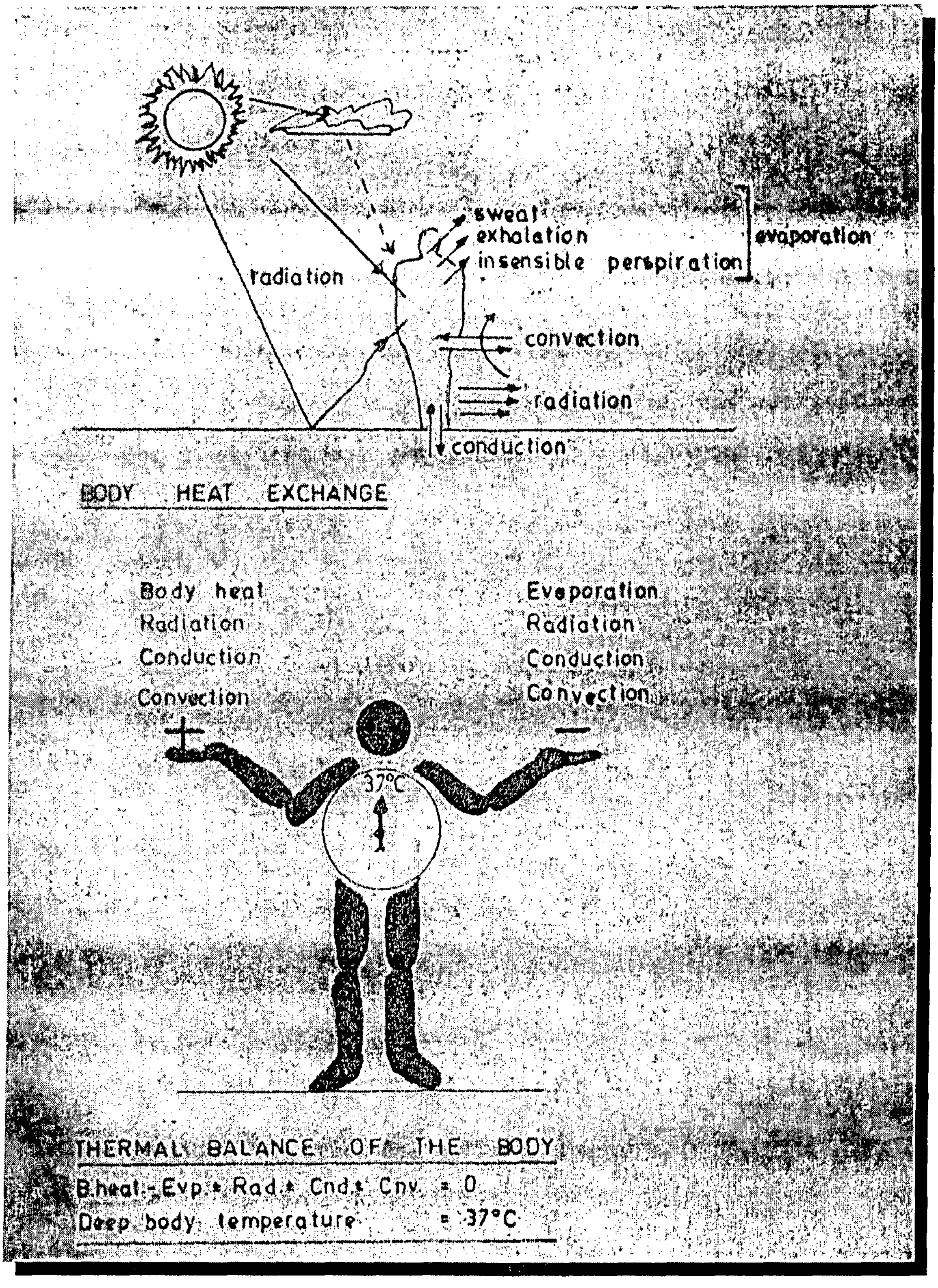


FIGURE 2.3: EXCESS HEAT PRODUCTION VARIES WITH OVERALL METABOLIC RATE AND DEPENDS ON THE ACTIVITY.

2.7 REGULATORY MECHANISMS

The thermal balance of the body can be expressed by an equation. If the heat gain and heat loss factors are:

The thermal balance of the body can be expressed by the equation:

$$M_{et} - E_{vp} \pm C_{nd} \pm C_{nv} \pm R_{ad} = 0$$

Where,

GAIN :-

$M_{et.}$=metabolism (body heat)

$C_{nd.}$=conduction (contact with warm bodies)

$C_{nv.}$=convection (if air is warmer than skin)

$R_{ad.}$=radiation (from sun, sky & hot bodies)

LOSS :-

$M_{et.}$=metabolism (body heat)

$C_{nd.}$=conduction (contact with cold bodies)

$C_{.nv}$=convection (if air is cooler than skin)

$R_{ad.}$=radiation (night sky & cold surface)

E_{vp}.=evaporation (of moisture &sweat)

2.8 THE COMFORT SCALE

When the designer wants to assess the effect of climatic conditions on the body's heat dissipation processes, he is faced with the difficulty of having to handle four independent variables simultaneously- air temperature, relative humidity, radiation and air movement. During the past fifty years many attempts have been made and many experiments have been carried out in order to devise a single scale which combines the effect of these four factors. Such scales are collectively referred as "thermal indices" or "comfort scale".

Hanghton and Yaglav produced the first such scale for comfort in 1923, working at the "American Society of Heating and Ventilation Engineers". They tried to establish a physiological measurement combining effects of temperature, humidity and air movement called the "EFFECTIVE TEMPERATURE SCALE".

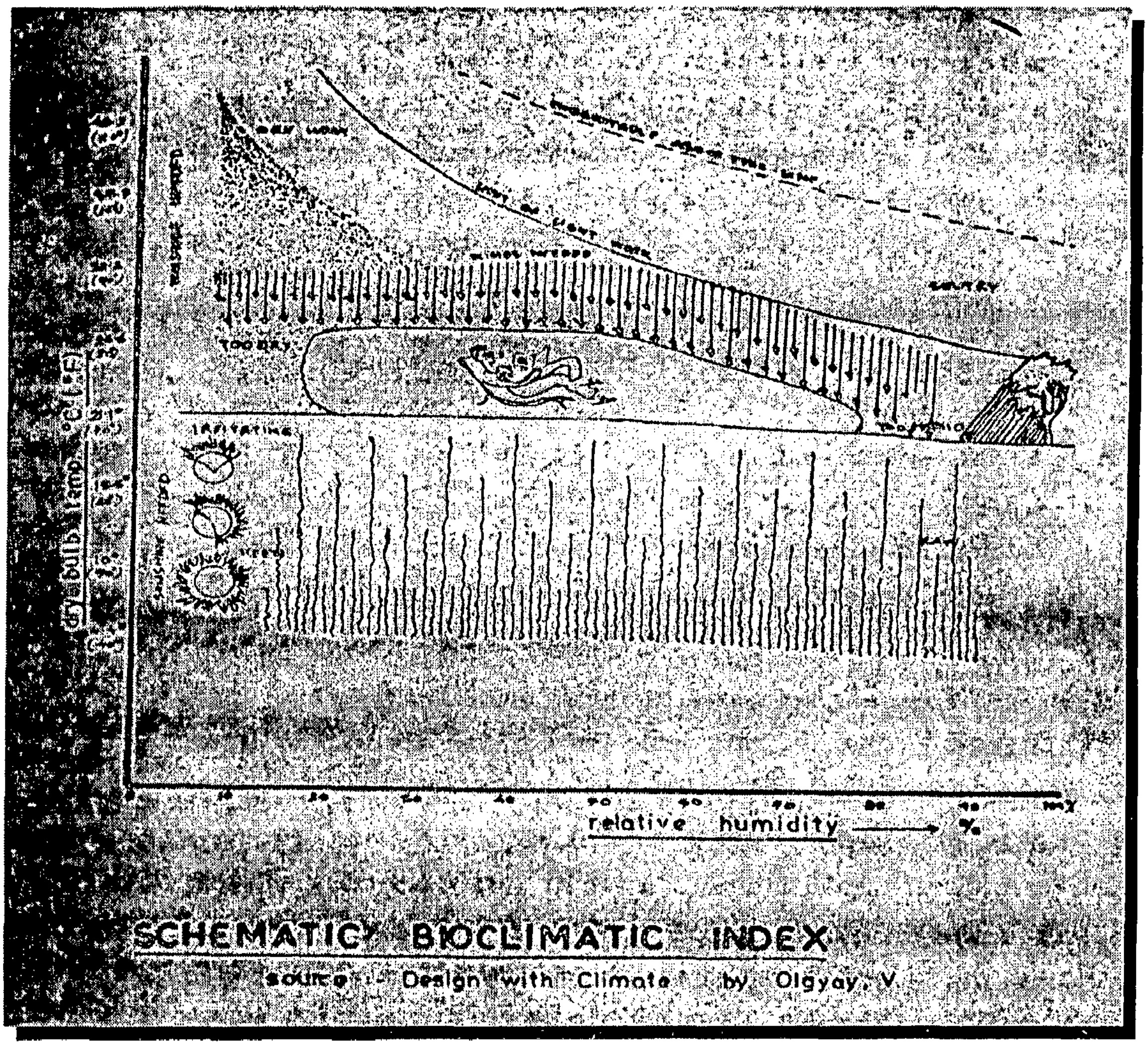


FIGURE 2.4: THE BIOCLIMATIC CHART

The effects of the climatic elements can be assembled into the single chart. This chart shows the comfort zone in the centre. The climatic elements around it are shown by means of curves, which indicate the nature of corrective measures necessary to restore the feeling of comfort at any point outside the comfort zone.

2.9 THE BIOCLIMATIC CHART

The bio-climatic chart was built up with dry bulb temperature as ordinate and relative humidity as abscissa. In the center, we can see the summer comfort zone divided into the desirable and practicable regions. The winter comfort zone lies a little lower. Any climatic condition determined by its D.B.T. and R.H. can be plotted on the chart. If the plotted point falls in the comfort zone, we feel comfortable in shade. If the point falls outside the zone corrective measures are needed.

Bio climatic evaluation is the starting point for any architectural design aiming at environmental climate balance. Prevailing climatic conditions can easily be plotted on the chary and will show the architect what corrective measures are needed to restore comfort conditions.

3. ARCHITECTURAL ASPECTS OF BUILDING DESIGN

"The objective of this massive investment is to provide shelter, security and comfortable living conditions for the occupants and to produce more than housing – homes".

MARTINE EVANS

In today's era of industrialized civilization, we are tending towards the highly sophisticated building. The developed technology in the field of physical comfort is leading us to the period of energy crisis, because the energy sources are not long lasting. Due to the available technology for comfort, like heating, cooling and ventilation systems etc.; architects are generally ignoring the important aspects of architectural design in buildings. This ignorance may lead the society to the grave of slum.

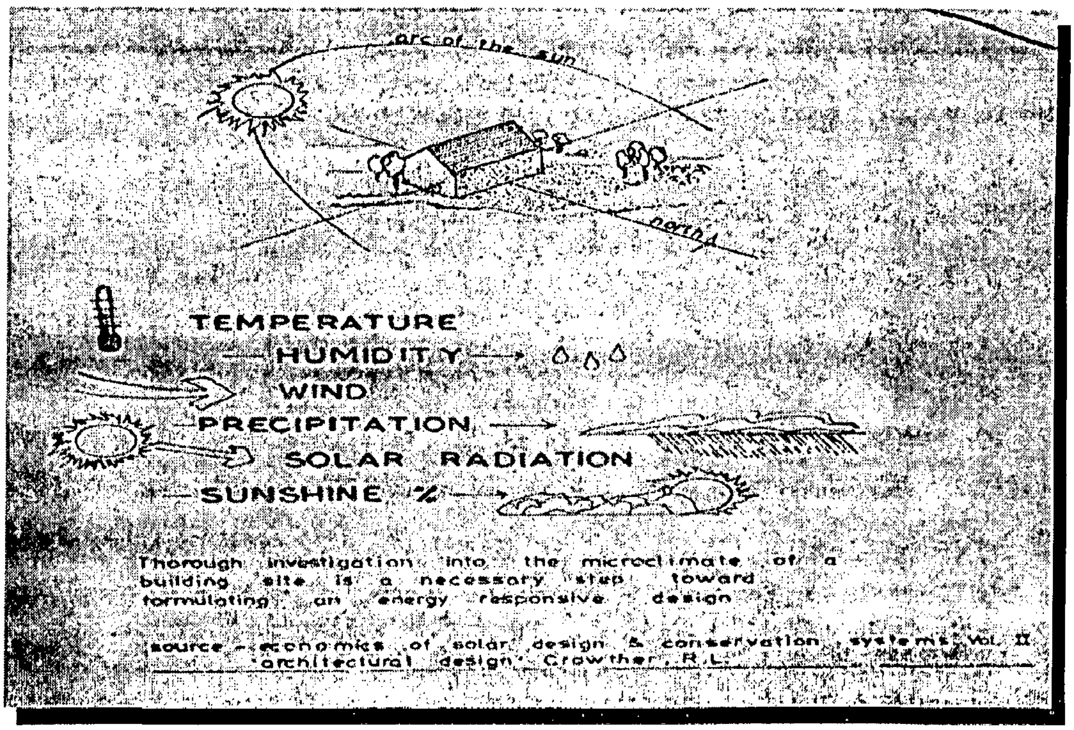


FIGURE 3.1: STUDYING THE MICROCLIMATE OF THE SITE

3.1 CLIMATE

Climate is defined as the combined processes in the annual weather cycle prevailing at any given place over a period of years. Geographical latitudes, affect climate elevation above sea level, the numerical characteristics of the physical state of the atmosphere, its temperature, humidity, winds and precipitations. Soil covering and vegetation are formed by the action of climate. Climate has a considerable influence on animal life, the life of man and his economic activity.

The effects within a large scale i.e. "macroclimate", form a small part of the "microclimate". Deviation in climate plays an important role in architectural land utilization. The nature and extent of climatic deviations also the likely effects of the intended building should be assessed early in the design stage, before one is committed to a certain solution which may later prove difficult to be rectified.

Man made environments can create microclimates of their own, deviating from the macroclimate of the region to a degree depending on the extent of man's intervention. Such intervention is the greatest in large towns or cities.

Man made environments can cause deviation in macroclimate of any region. These factors are:

a.) Changed surface quality: pavements in front of buildings increase absorbance of solar radiation and reduce absorption.

b.) Buildings: casting a shadow and acting as barriers to winds, but also channelizing winds possibly with localized increase in velocity or by storing absorbed heat in their mass and slowly releasing at night.

c.) Energy seepage: through alls and ventilation of heated buildings, the output of refrigeration plants and air conditioning (removing heat from a controlled space to the outside air): heat output of internal combustion engines and electrical appliances, heat loss from industry especially furnaces and large factories.

d.) Atmospheric pollution: waste products of boilers and domestic and industrial chimneys exhaust from motor cars, fumes and vapors which both tend to reduce direct solar radiation but increase the diffuse radiation and provide a barrier to outgoing radiation. The presence of solid particles in urban atmosphere may assist in the formation of fog and induce rainfall under favorable conditions.

e.) Air temperature: in a city, it can be 8^0C higher than in the surrounding countryside and a difference of 11^0C has been reported.

f.) Relative humidity: it is reduced by 8 to 10% due to the quick run off of rain water from the paved areas, due to the absence of vegetation and due to higher temperature.

g.) Wind velocity: it can be reduced to less than half of that in the adjoining open country through the funneling effect along a closely built up street or through gaps between tall slab blocks can be more than double the velocity. Strong turbulences and eddies can also be set up at the leeward corners of obstructions.

3.2 EFFECTS OF TOPOGRAPHY

Topography of land affects the microclimate in various ways. Therefore, it has its own importance in the designing of the dwelling units. Topography of the site may affect the microclimate in all aspects of comfort – air movement, temperature, humidity and radiation.

Temperature in the atmosphere decreases with altitude, this is important in tropical land where temperature becomes more favorable at higher altitudes. As mountains affect the macroclimate, small differences in terrain can create remarkably large modifications in the microclimate. Cool air is heavier than warm air, so cold air behaves somewhat like flowing water towards the lowest points. Accordingly, the elevations that impede the flow of air affect the distribution of the nocturnal temperatures by dam action and concave terrain formation becomes cold air lake at night. On the valley slopes a series of smaller circulations mix with the neighboring warm air, causing intermediate temperature conditions. Accordingly, the temperatures at the plateau will be cold, the valley floor very cold, but the higher sides of the slopes will remain warm, this area, often indicated by vegetation, is referred to as the warm slope (thermal belt). In the temperate zone the thermal belt is most advantageous for placing a dwelling.

On a hilly site, funneling the parallel winds. The affect of long tall slabs or rows of buildings may be similar to this.

3.3 FORMS OF DWELLINGS

Before designing for a climatic zone the form of the dwelling should be studied. Various aspects, which affect, the form of a dwelling are as follows:

- Air movement
- Humidity
- Solar radiation

- Temperature

The form should be adjusted to take the advantage of those climatic factors. The design of dwelling form shall not only be related to improvement of the internal environment, but also to the creation of comfortable conditions in the external spaces in and around the buildings. This is particularly important in hot climates where outdoor spaces can function as living rooms, kitchen, play spaces and laundry spaces or even sleeping spaces.

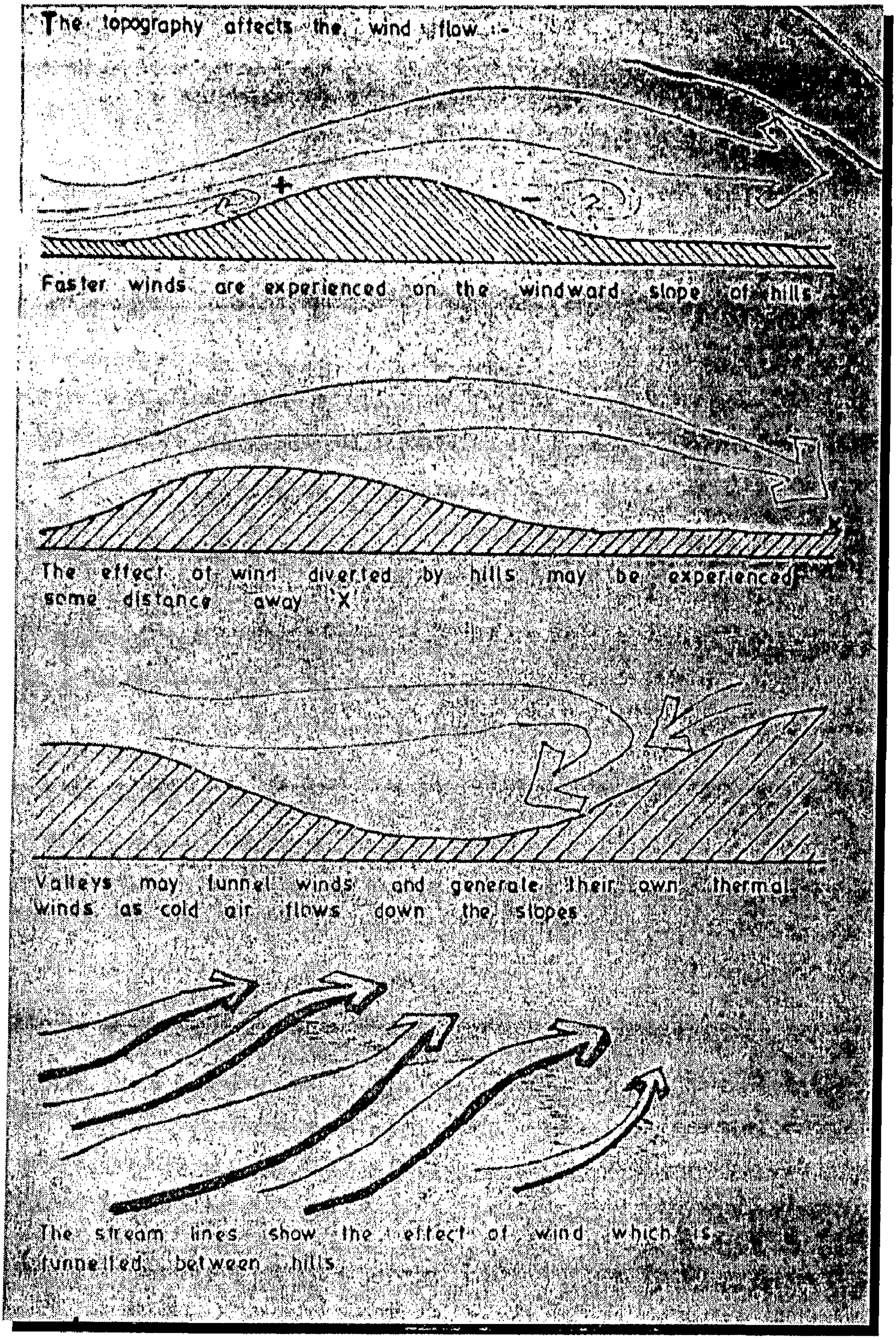


FIGURE 3.2: EFFECTS OF TOPOGRAPHY

The factors, which govern the form of dwelling, are discussed thereafter:

1. **PROPORTION AND DEPTH:**

The volume of the building is very approximately related to its thermal capacity, whereas the surface area is related to the rate at which the building gains and loses energy. The ratio of volume to surface area is therefore an important indicator of speed at which the building will heat up during the day and cool down at night. If the temperature is high and it is desirable that the building heats up slowly, a high volume to surface area ratio is preferable.

2. **SPACING:**

The proportion of the space between the buildings will determine the quantity and the quality of the light falling onto the facades as well as the availability of breeze, with wider spaces permitting increased illumination and better air movement. The proportion will also affect the amount of light falling on the facades.

3. **CEILING HEIGHT:**

One of the features traditionally associated with housing in hot climates is high ceiling. This is expected to create cooler conditions at the body level.

High ceilings cost both in terms of the construction cost and indirectly in terms of reduced density, construction speed and maintenance costs. The supposed benefits of high ceilings in hot climates have therefore been studied in a number of countries. The conclusion that can be drawn from these studies is that rooms with high ceilings are not significantly more comfortable than rooms with ceiling heights of 2.5 to 2.7 m.

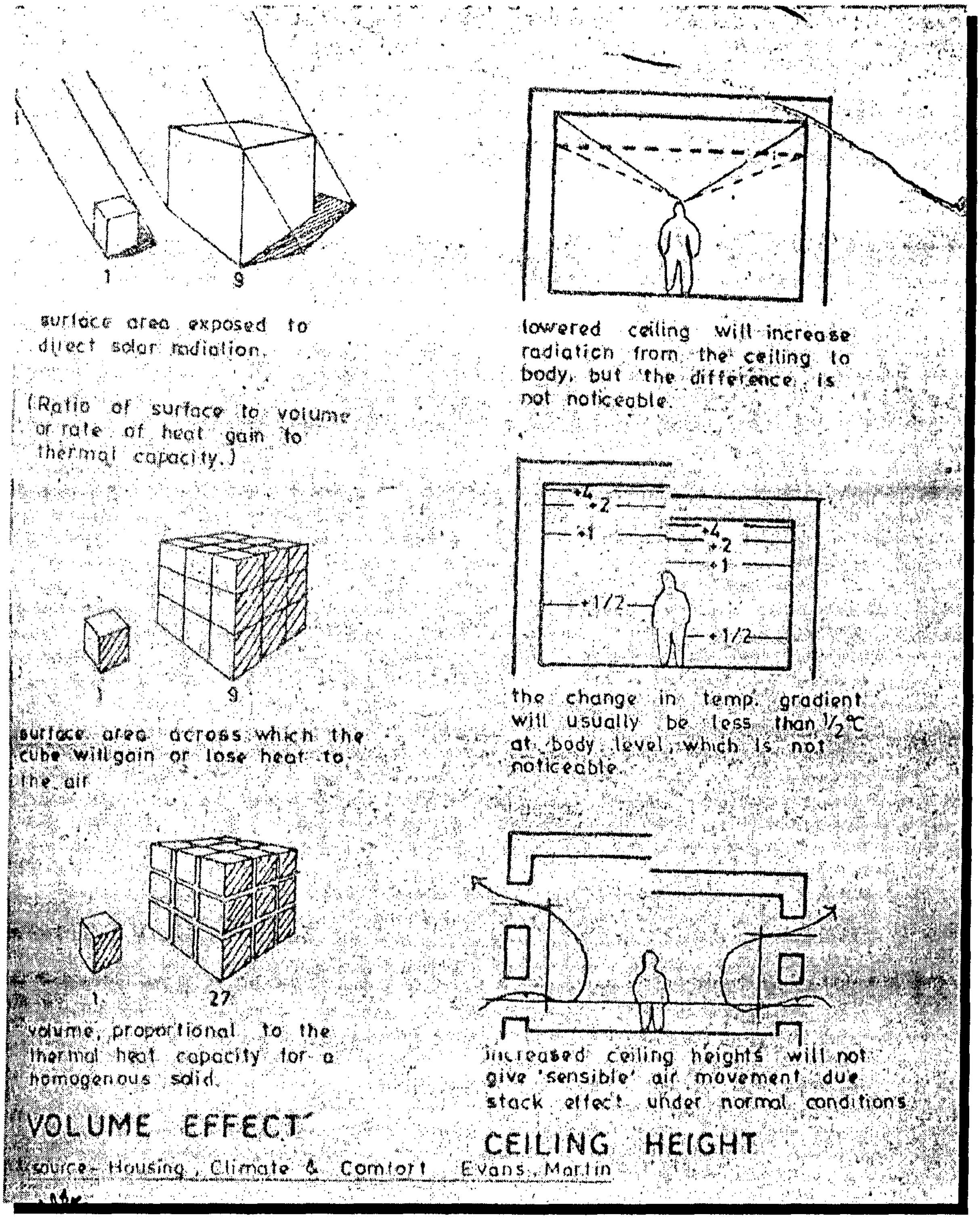


FIGURE 3.3: EFFECTS OF CEILING HEIGHT AND VOLUME ON THE INDOOR ENVIRONMENT

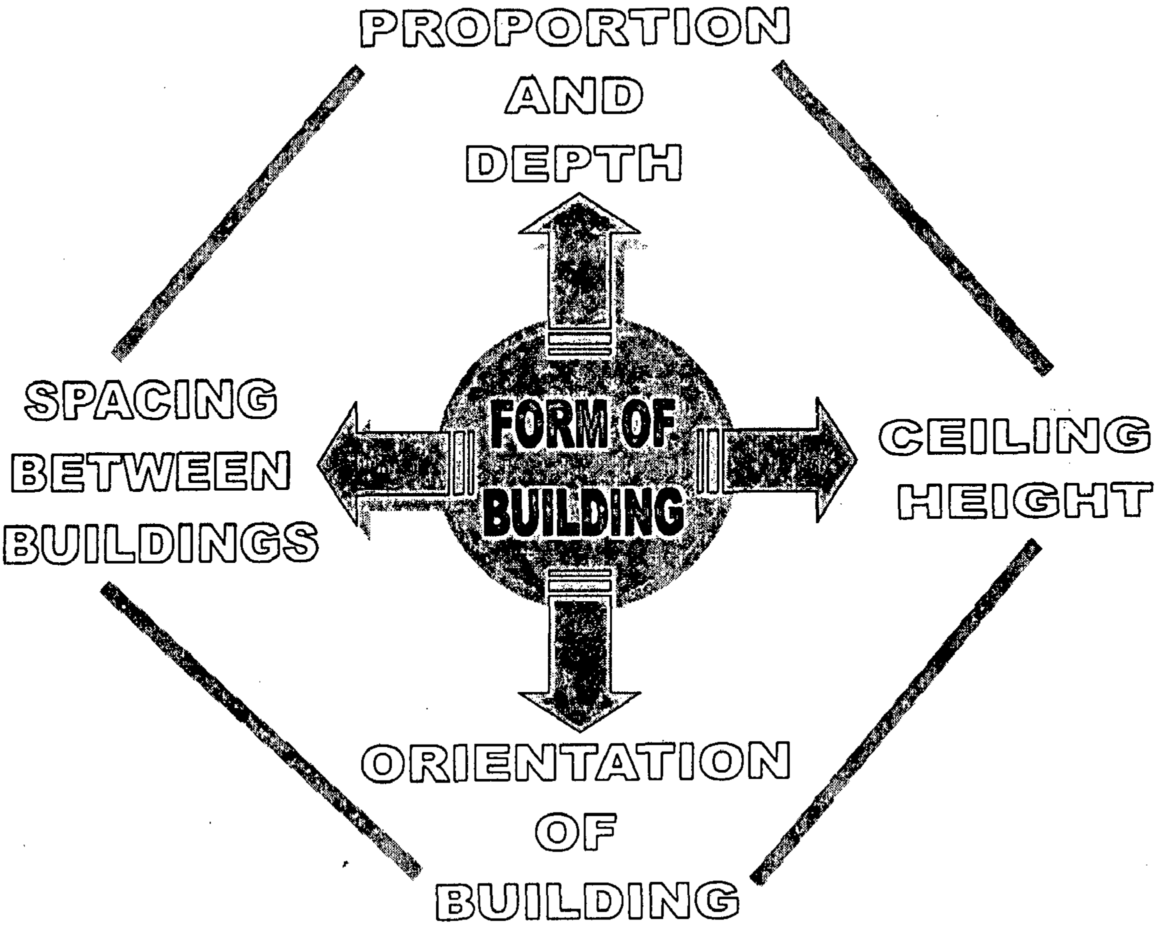


FIGURE 3.4: FACTORS EFFECTING FORM OF THE BUILDING

3.4 THEORIES ON ORIENTATION

The orientation of a building is the direction faced by the facades i.e. the direction perpendicular to the axis of the block. The choice of orientation is subject to many considerations:

- Local topography
- Requirements of privacy
- Pleasures of view
- Reduction of noise
- Climatic factors

Building orientation affects the indoor climate in two respects by its regulation of the influence of two distinct climate factors:

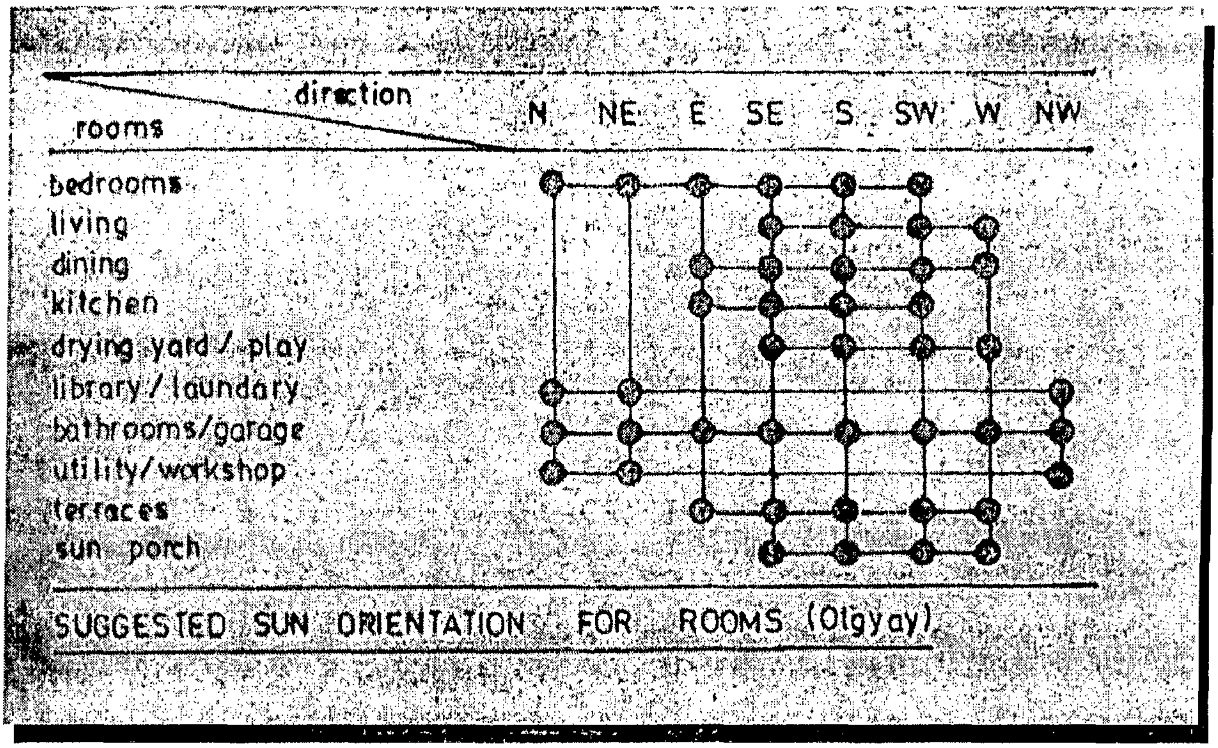
I. Solar radiation and its heating affect on walls and rooms facing different directions.

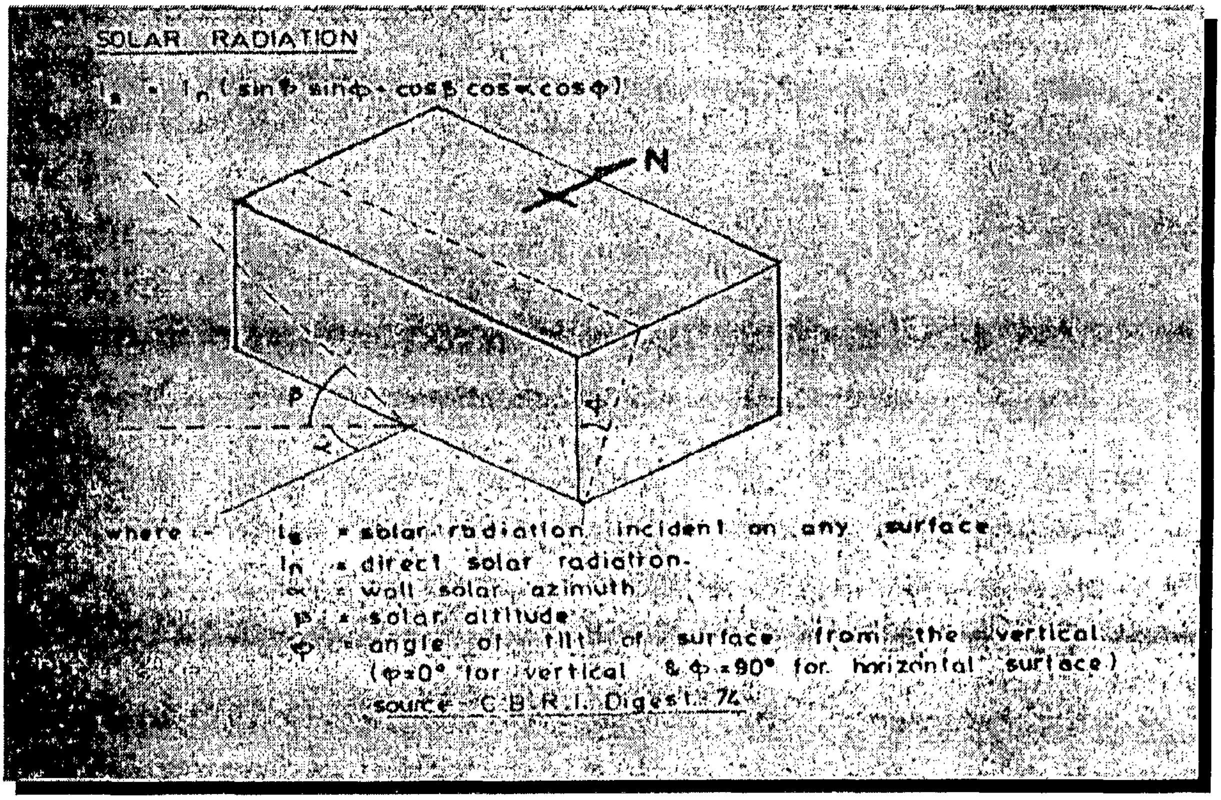
II. Ventilation problems associated with the relation between the direction of the prevailing winds and the orientation of the building.

Ludwig Hilberscimer concludes that:

- East and west orientation is least advantageous.
- Southeast and southwest are reasonably satisfactory.
- South is most advantageous.

A number of recent theories relating to solar houses have preferred true south orientation. This undoubtedly does yield the greatest amount of radiation at the summer solstice, but these theories do not consider daily temperature variations,





FIGUR 3.6: SOLAR RADIATION

3.5 SOL-AIR APPROACH

The "sol air approach", to orientation recognizes that air temperature and solar radiation act together to one sensation of heat in human body. Thus, to utilize the sun's rays fully their thermal impacts must be considered in conjunction with the heat convection and the total affect measured by its ability to maintain temperature levels near the "comfort zone".

The importance of the sun's heat will then vary according to regions and seasons. Under cold conditions its additional radiations should be welcomed and a building should be positioned to receive as much radiation as possible, while under conditions of excessive heat the orientation of the same building should decrease undesirable solar impacts.

The variation in orientation produced by regional requirements is diagrammatically presented. In northern latitudes, the air is generally cool and there is great need for sun's heat. Consequently, the buildings should be oriented in so as to receive the maximum amount of radiation throughout the year. However, the same building in the south, where the air is heavy with heat, should turn its axis to avoid the sun's unwanted radiation and pick up cool breeze instead.

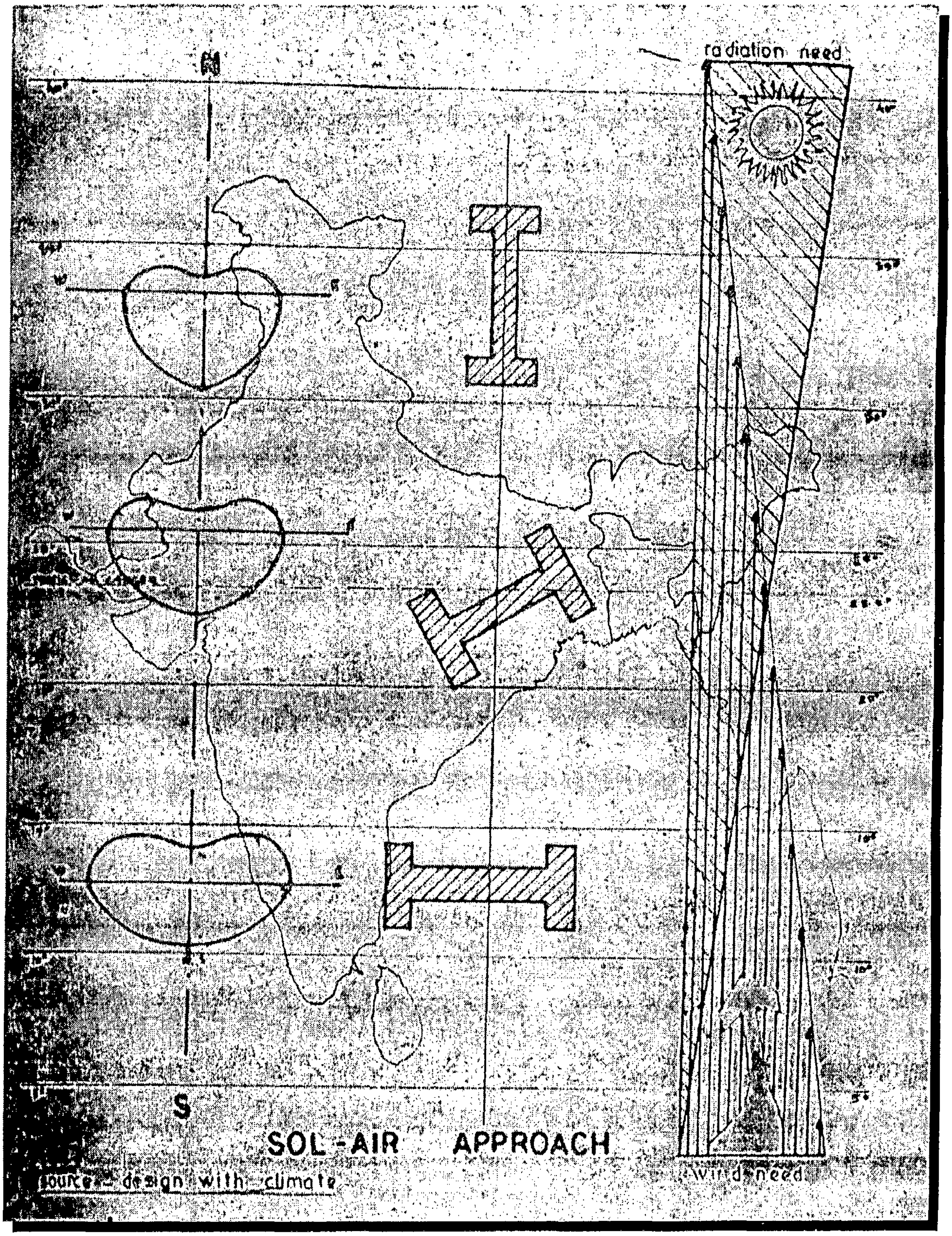


FIGURE 3.7: SOL-AIR APPROACH

3.6 DAY LIGHTING

"If the building envelope is thought of as a barrier between the internal controlled environment and external, perhaps undesirable conditions, it must be realized that it should be a selective barrier, or rather a filter, which excludes the unwanted influence whilst amidst those which are desirable. One such desirable effect is daylight".

-Alan Mayhew

The most important communication channel of man with his environment is vision. The eye is stimulated by light reflected from objects, thus light is a prerequisite for seeing anything. The ultimate source of daylight is the sun, from which we receive a large amount of thermal radiation together with the light. When in bright sunshine the illumination is around 100 klux. The intensity of thermal radiation is likely to be around 1kw/M^2. Therefore, in the climates where heating is required this daylight with thermal radiation is welcomed. But, in the tropics, situation is not simple since the light with excessive heat is not desired. Thus, the filter function of the envelope becomes important.

The steps for designing a building for daylight are as follows:

- From an appropriate lighting code select the recommended illumination level for the type of building and visual task.
- Determine a value for the designing in terms of the total external illumination available for same percentage of working hour.
- Determine the resulting required daylight factor.

- After making allowance for dirt on glass, obstruction by window framing etc., selection and arrangement of window or roof lights which will produce the required daylight factor.

With the appropriate design, considerable savings can be made in electrical energy used for lighting. When the daylight becomes inadequate, artificial lights can supplement it. Control over the switches and by other electronic devices and appropriate level of lighting can be maintained which will offer great opportunities for energy savings.

3.7 VENTILATION FACTOR

Ventilation may be simply defined as a process of removing or supplying air by natural or mechanical means to and from an air source or any space. Good ventilation is an important factor in providing comfort in buildings.

The necessity of ventilation may arise due to the following reasons:

I. To prevent undue concentration of body odors, fumes, dust etc.
II. To prevent undue concentration of bacteria carrying particles.
III. To remove products of combustion and in some cases to remove body heat and heat liberated by the operation of the electrical and mechanical equipments.
IV. To create air movement so as to remove the vitiated air and its replacement by the fresh air.
V. To create healthy living conditions by preventing the undue accumulation of carbon-di-oxide and moisture, and depletion of oxygen content of the air. For

comfortable working conditions, the content of CO_2 should be limited to 0.6% of the total volume.

VI. To maintain conditions suitable to the contents of the space.

With these aspects of the necessity of ventilation there are several other different functions, which can be performed by the exchange of inside air by fresh external air. Therefore, it is very important to determine which functions are required before deciding how they are to be achieved.

The first function of ventilation is to replace the used up internal air by fresh external air and a minimum level of ventilation for this purpose is required in all occupied dwellings.

The second function of ventilation is to cool the body by encouraging evaporation of moisture from the skin and increasing heat loss from the skin by forced convection. The air velocity required to attain comfort increases with air temperature and relative humidity because the same cooling effect must be obtained through a smaller temperature difference between body and environment. The relationship holds until the air and skin temperatures are equal i.e. $35^{O}C$, regardless of humidity, clothing and working conditions, although these factors determine the magnitude for the required velocity. Above $35^{0}C$, the increase in air velocity elevates the convective heat gain, but the ultimate effect depends on the level of humidity, metabolic rate and clothing conditions.

The third function of ventilation is to heat or cool the building structure. Air has very low heat capacity and therefore when a building is not ventilated the temperature of the indoor air attains that of the surrounding internal surfaces and fluctuates about the external surface temperature. This depends mainly on the external wall color, the indoor level being higher as the color is darkened. When the building is ventilated, the air entering the indoor space has its original outdoor temperature, but in traversing the internal spaces, it mixes with indoor air and heat is exchanged with the internal surfaces according to indoor-outdoor difference.

In buildings during hours when the indoor temperature is above the outdoor level, ventilation lowers the indoor level and in reversed conditions the effect is also reversed. The relation between the indoor and outdoor temperature also depends on the design of the building and in particular of the external wall color and on the size and shading of the windows.

In general, the building with white or nearly white external wall color, medium to high thermal resistant and heat capacity and relatively small and shaded windows have daytime indoor temperature lower than outdoor. Thus the direction and magnitude of the ventilation effect on indoor temperature and the desirable pattern of ventilation depends on the external wall color and the size and shading of windows.

3.8 THE SUN AND SHADING DEVICES

THE SUN

The sun is a hydrogen fusion, nuclear furnace that is powered by sheer gravitational crush. To fuel this furnace, matter is consumed at the rate of 4million tones per second. As this fuel is consumed some of this matter is converted into light energy and is radiated and is radiated away from the sun.

Not all areas on the surface of the earth receive the same amount of sunshine. The earth is tilted in it s plane of rotation about the sun, or ecliptic which causes seasonal weather variation. This tilt is 23.47^0, as shown in the figure.

After studying the various aspects of architectural design, we can conclude that the main environmental feature affecting the building design is the sun. The sun plays a vital role in the design process of buildings.

The earth's climate is dependent on solar energy. The important aspect of building orientation is totally dependent on the sun's position and radiation. The winds, tides, rivers and ocean currents all rely on the daily heat of the sun for their motion.

SUN PATH

An important aspect of climatic analysis is the determination of the path of the sun across the sky, and the direction from which solar radiation will be received. This will have an important on the form and orientation should also relate to the path of the sun across the sky. In noon the sun will be at the highest point of it across the sky. At the equinox in March and September, the sun at noon will be at overhead locations on the equator. For locations north of the equator, the midday sun will be further south in the sky and sun will be correspondingly further north in the sky for southern locations. The angular difference being equal to the latitude.

The following are the factors, which determine the amount of sun's radiation received at any point of the earth:

I. The position of the sun according to the day of the year.
II. The position of the sun according to the season.
III. Clouds and other atmospheric obstructions.
IV. The direction of the slope of the station.
V. The angle of slope of station.
VI. The height of station.
VII. The situation of the station with regard to its surroundings.

The position of the sun at any particular point is determined by the angles of azimuth and the altitude. The latitude determines these angles, date and hour. Azimuth is the horizontal angle measured from the north meridian.

The different presentations of the sun's path are used for different scales of design. The first is the equiangular projection in which the hemisphere of the sky is projected onto the horizontal circle, the centre of which represents the zenith, a point directly overhead; and the circumference of which represents the horizon. This projection can be visualized as the approximate field of vision of an observer lying on his back viewing the sky. It is convenient for analyzing the path of the sun across the sky in relation to orientation and building form.

For windows, vertical surfaces and the normal field of human vision, it is more convenient to consider a projection of the sky onto the vertical surface. The second projection used is therefore of equiangular projection of the sky hemisphere onto the vertical cylinder, which is subsequently flattened out into a strip. These are a convenient form of analyzing glare, solar radiation and diffuse light from the sky.

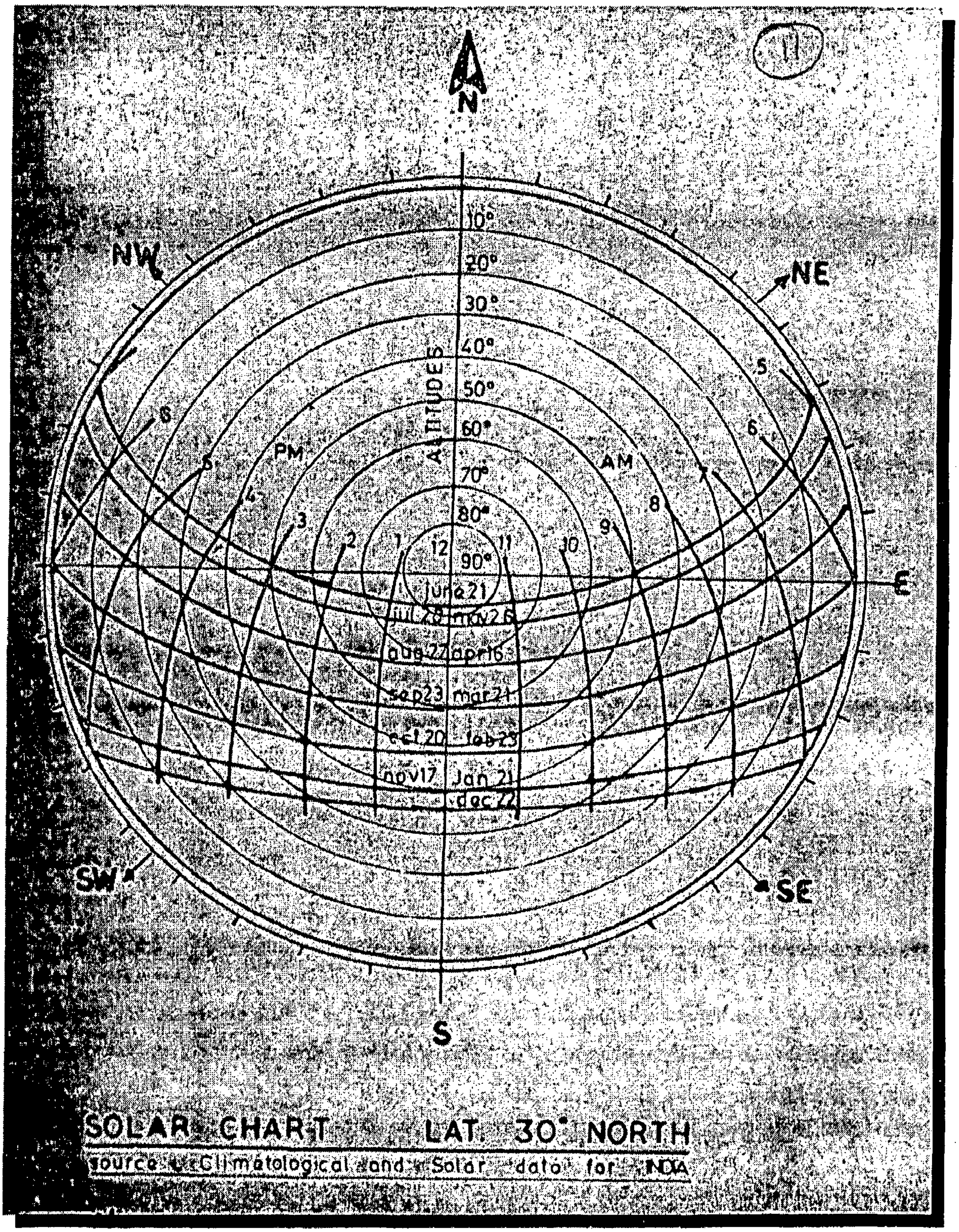


FIGURE 3.12: SOLAR CHART

SHADING DEVICES

Most efficient way of maximizing management of influx of solar heat gain through the building envelope is to:

-protect the glazing against both the direct and diffused components of the solar heat gain in the summer.

-Admit both indirect and diffused components in winter.

This can be achieved with greater efficiencies by providing the adequate sun shading devices over the openings such as windows, ventilators, fixed sashes etc. the function of the shading devices is to intercept the sun rays before they reach the building envelop, when it is not required i.e. in hot weather.

A shading device can be designed with the following steps:

- The temperature at different times of the day must be found to establish when the shading is required i.e. overheated period.
- These times can then be located on a chart showing the paths of the sun (sun path chart across the sky to find out where the sun is at that time).
- Finally, the proportions of the shading device should be chosen using and overlay (shading angle protractor) which shows here the sun can be shaded.

The sun shading devices are of three types:

{Their construction and characteristics are shown in the figure on next page}

a) HORIZONTAL DEVICE

b) VERTICAL DEVICE

c) EGG CRATE DEVICE

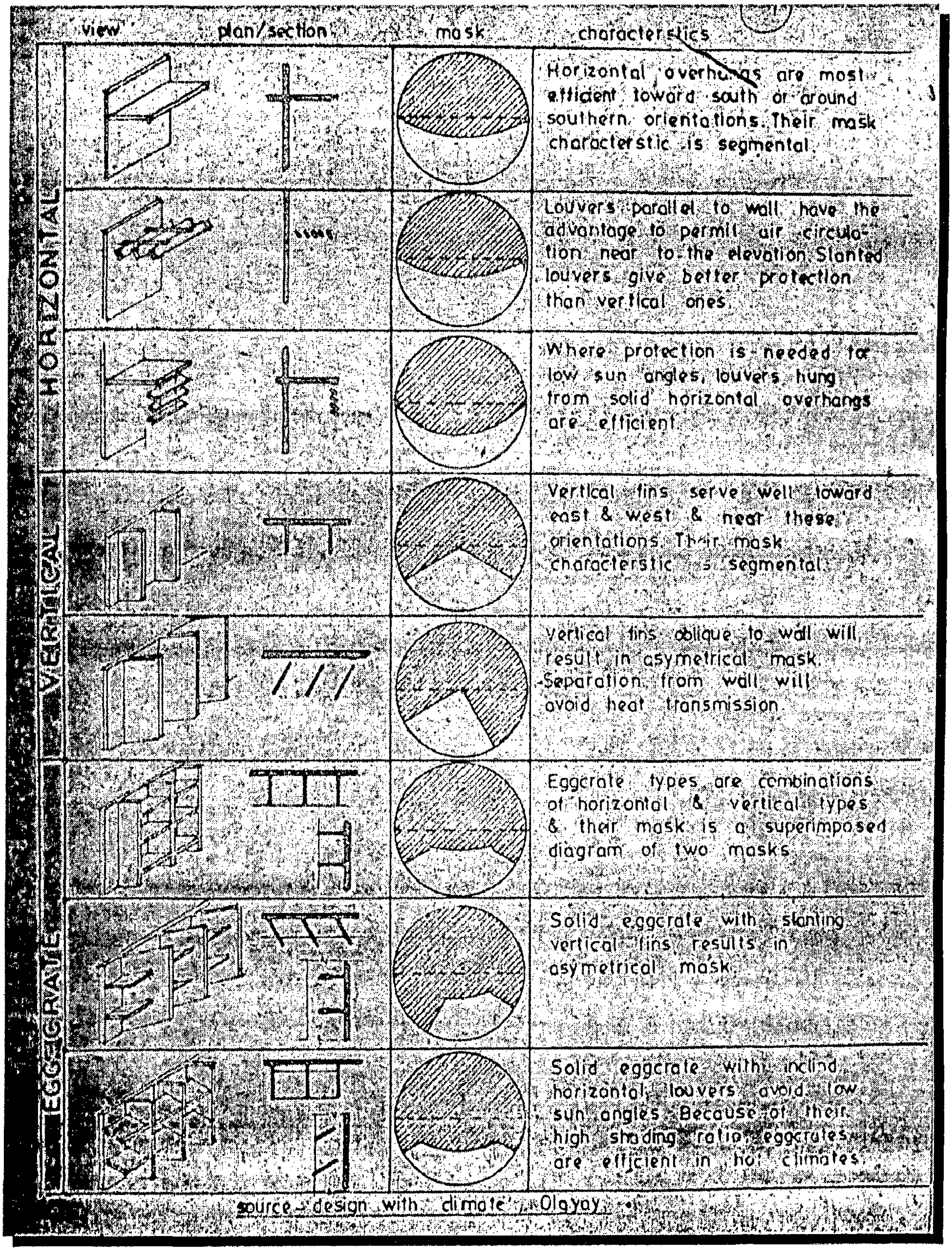


FIGURE 3.13: SHADING DEVICES - HORIZONTAL, VERTICAL AND EGG CRATE

3.9 HEAT EXCHANGE OF DWELLING

A dwelling is the controlling variable, which can be modified in numerous ways to reconcile the demands of climate and comfort. A dwelling gains or losses heat jus by convection, conduction, evaporation, radiation and internal heat sources and mechanical systems. The flow of heat by conduction through walls, floors and ceilings may occur in either direction. The material composition of the walls, floors and ceiling of dwelling determines the rate of conduction.

Heat exchange by convection can occur through building surfaces by the movement of air between areas of different temperatures. The heat exchange between the interior of a dwelling and the outdoor air may be unintentional air infiltration "leakage", or deliberate air regulation "ventilation".

Radiation of heat through glass or other transparent surfaces can add considerable heat to a dwelling. Window area, dwelling orientation and shading influence the amount of radiant or solar heat gain.

Internal heat sources such as human bodies, lamps, motors and appliances can provide as much as 25% of the dwelling's heating load.

Mechanical equipment may introduce or remove heat from a building by utilizing one form of outside energy such as natural gas, oil, electricity or solar radiation.

A dwelling designer and building share the responsibility of properly selecting building materials, determining its size, volume and orientation and sizing and orientation windows, doors, overhangs and other thermal controls to assure occupant comfort.

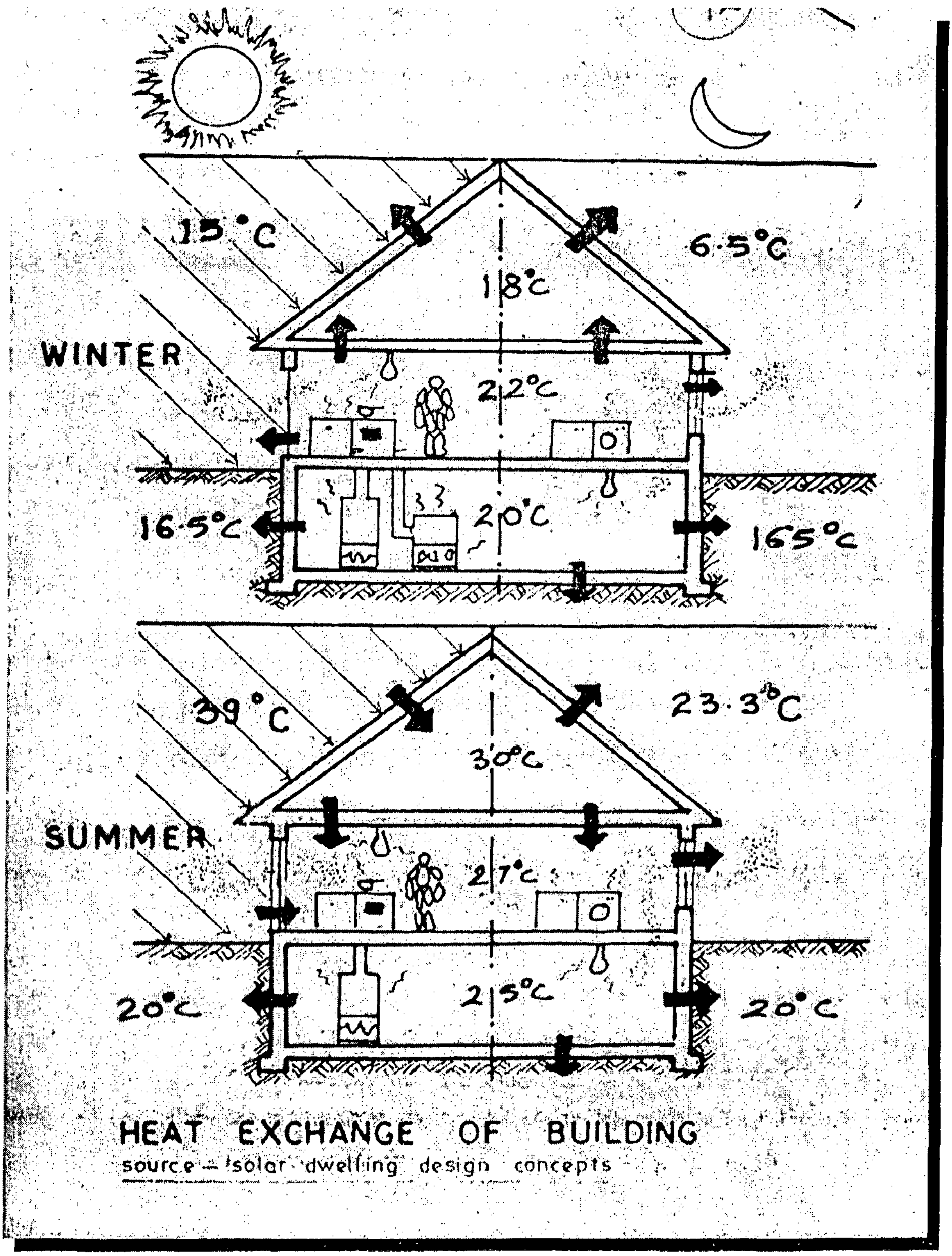


FIGURE 3.14: HEAT EXCHANGE OF DWELLING

3.10 BUILDING DESIGN ASPECTS

Architects can achieve energy efficiency in the buildings they design by studying the macroclimate and microclimate of the site, applying bioclimatic architectural principles to combat the adverse conditions, and taking advantage of the desirable conditions.

A few common design elements that directly or indirectly affect thermal comfort conditions and thereby the energy consumption in a building are listed below:

- ***Landscaping***
- ***Ratio of built form to open spaces***
- ***Location of water bodies***
- ***Orientation***
- ***Plan form***
- ***Building envelope and fenestration***

However in extreme climatic conditions, one cannot achieve comfortable indoor conditions by these design considerations alone. There are certain tested and established concepts, which, if applied to any design in such climatic conditions, are able to largely satisfy the thermal comfort criterion. These are classified as advanced passive solar techniques.

The two broad categories of advanced concepts are:

I. Passive heating concepts (direct gain system, indirect gain system, sunspaces, etc.)

II. ***Passive cooling concepts (evaporative cooling, ventilation, wind tower, earth-air tunnel, etc.***

3.10.1 LANDSCAPING

Landscaping is an important element in altering the microclimate of any place. Proper landscaping reduces direct sun from striking and heating up building surfaces. It prevents reflected light carrying heat into a building from the ground or other surfaces. Landscaping creates different air flow 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 temperature adjoining the building and provide evaporative cooling. Properly designed roof gardens help to reduce heat loads in a building. A study shows that the ambient air under a tree adjacent to the wall is about 2^0C to 2.5^0C lower than that for unshaded areas (Bansal, Hauser, and Minke, 1994).

Trees are the primary elements of an energy conserving landscape. Climatic requirements govern the type of trees to be planted. Planting deciduous trees on the southern side of a building is beneficial in a composite climate. Deciduous plants such as mulberry or champa cut off direct sun during summer, and as these trees shed their leaves in winter, they allow the sun to heat the buildings in winter. This landscaping strategy has been adopted to shade the southern side of the "RETREAT" building (Resource Efficient TERI Retreat for Environmental Awareness and Training) of TERI.

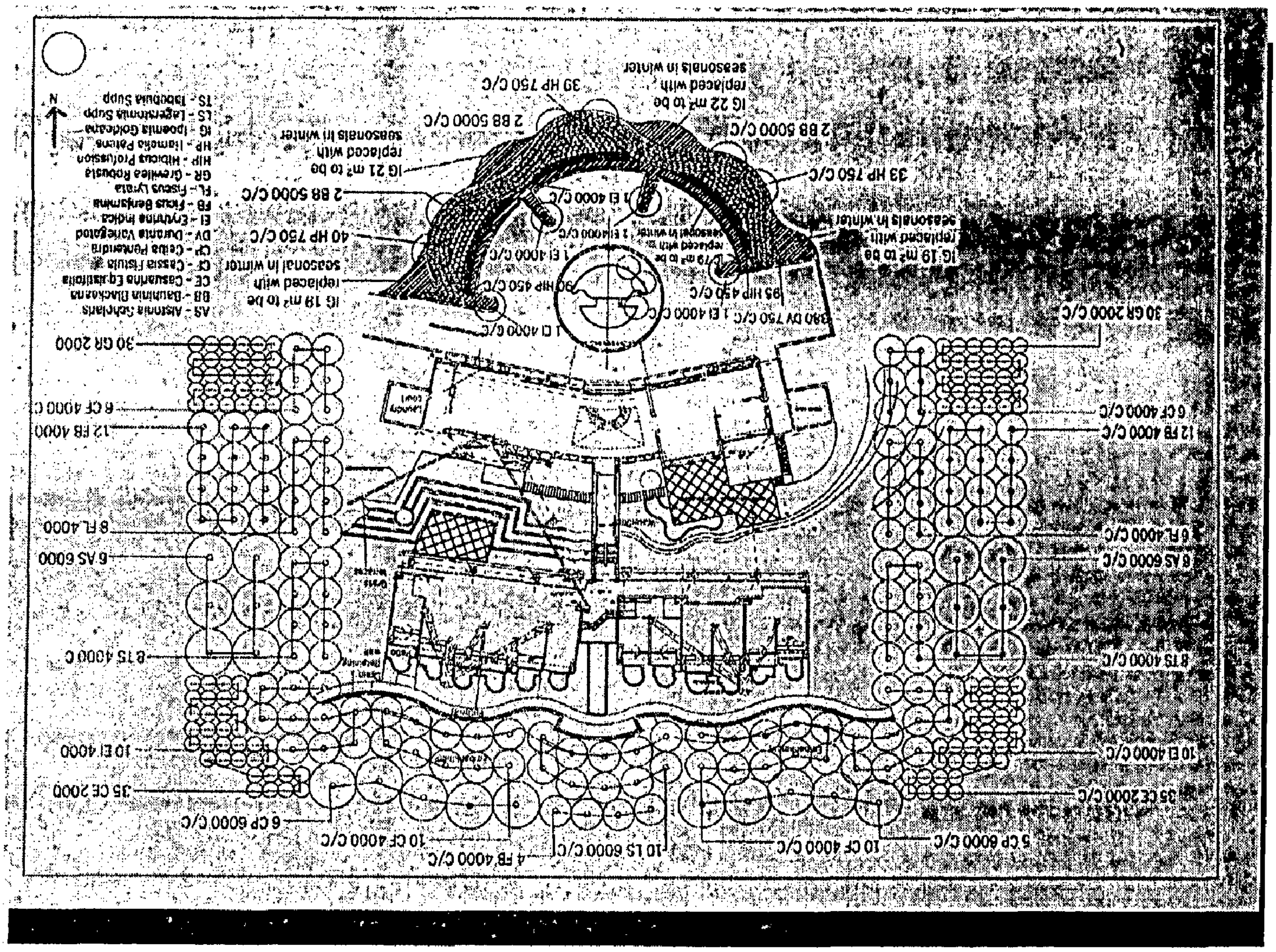


FIGURE 3.15: ***The retreat building has deciduous trees on the south side to cut off summer gains. These trees shed their leaves during winter so that winter solar heat gains are not cut-off. Windbreaks are provided in the north and northeast to protect from the winter winds.***

3.10.2 RATIO OF BUILT FORM TO OPEN SPACES

This means the ratio of the building form to surface-to-volume. The volume of space inside a building that needs to be heated or cooled and its relationship with the area of the envelope enclosing the volume affect the thermal performance of the building. The building form determines the parameter, known as the "surface-to-volume ratio". For any given building volume, the more compact the shapes, the less wasteful it is in gaining and losing heat.

Thus, hot and dry regions and cold climates, the buildings are compact in form with a low S/V ratio to reduce heat gain and losses respectively. The building form determines the airflow pattern around the building, directly affecting its ventilation. The depth of the building also determines the requirements of artificial lighting-greater the depth, higher the need for artificial lighting.

3.10.3 LOCATION OF WATER BODIES

Water is a good modifier of the microclimate. It takes up a large amount of heat in evaporation and causes significant cooling especially in a hot and dry climate. In humid climates, water should be avoided as it adds to humidity. Water has been used effectively as a modifier of microclimate in WALMI (Water and Land Management Institute) building complex in Bhopal.

3.10.4 ORIENTATION

Building orientation is a significant design consideration, mainly with regard to solar radiation and wind. In predominantly cold regions, building should be oriented to maximize solar gain; the reverse is advisable for hot regions. In regions where seasonal changes are very pronounced, both the situations may arise periodically. For a cold climate, an orientation slightly east of south is favored (especially 15degrees east of south), as this exposes the unit to more morning than afternoon sun and enables the house to begin to heat during the day. This has been demonstrated in the MLA Hostel building at Shimla. Similarly, wind can be desirable or undesirable. Quite often, a compromise is required between sun and wind orientations.

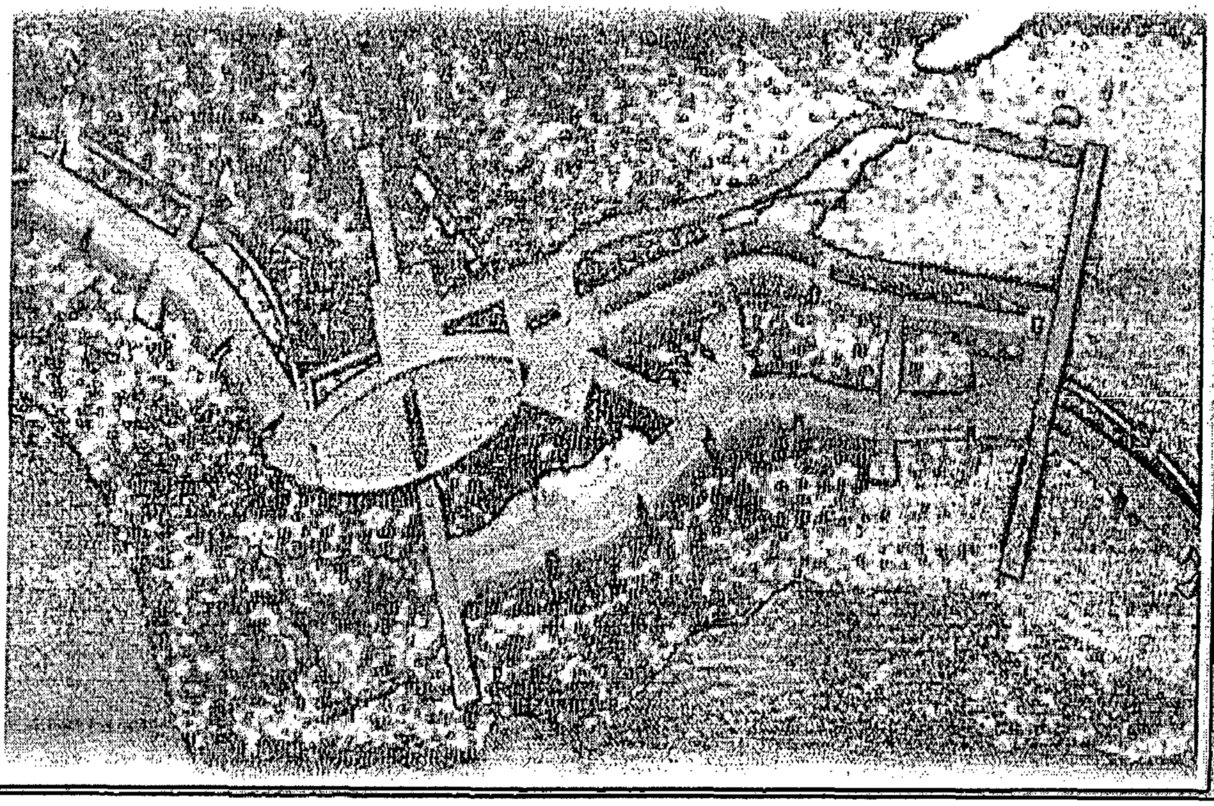


FIGURE 3.16: *A view of the WALMI building. The flowing form overlooks a water body which has been used to advantage for modification of the microclimate.*

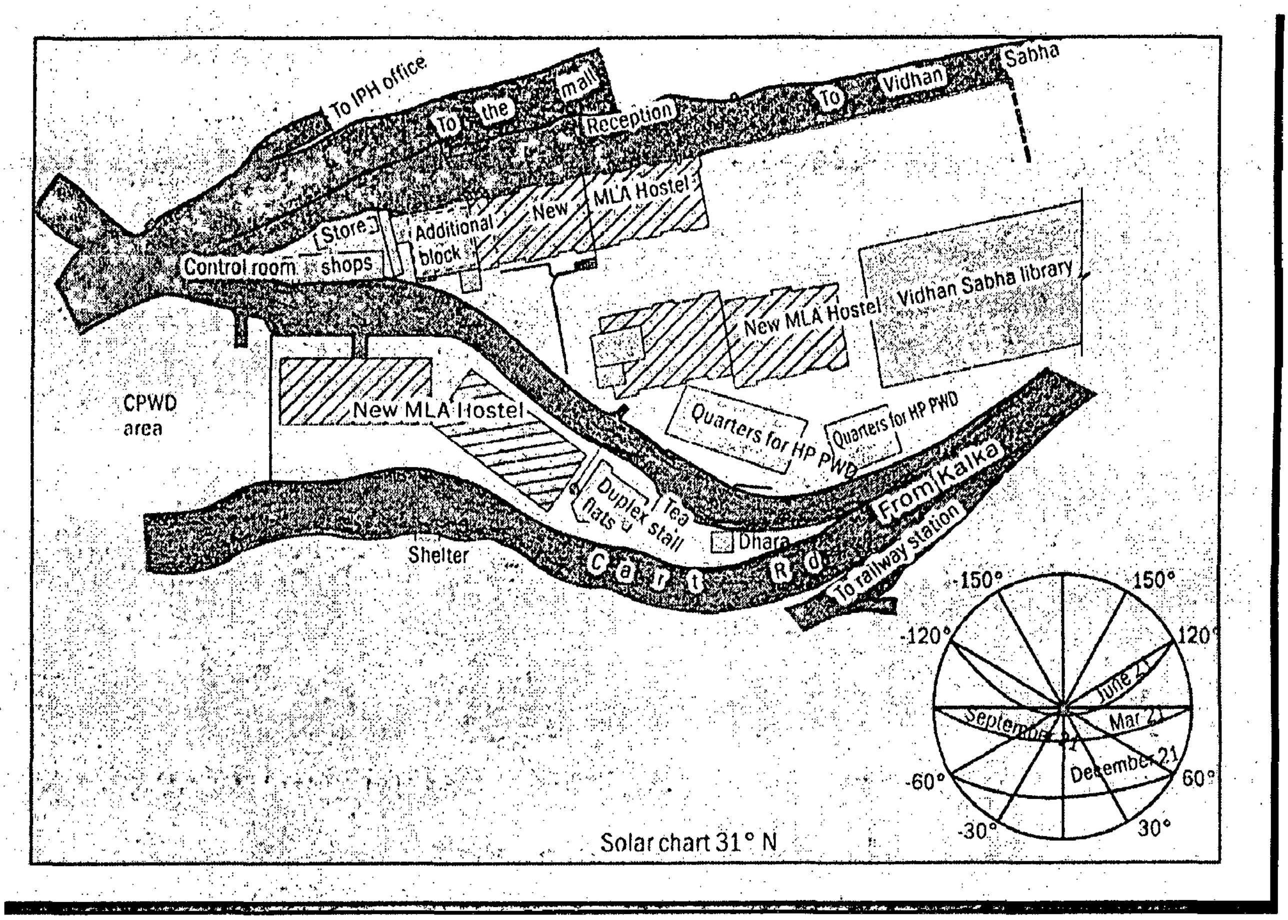
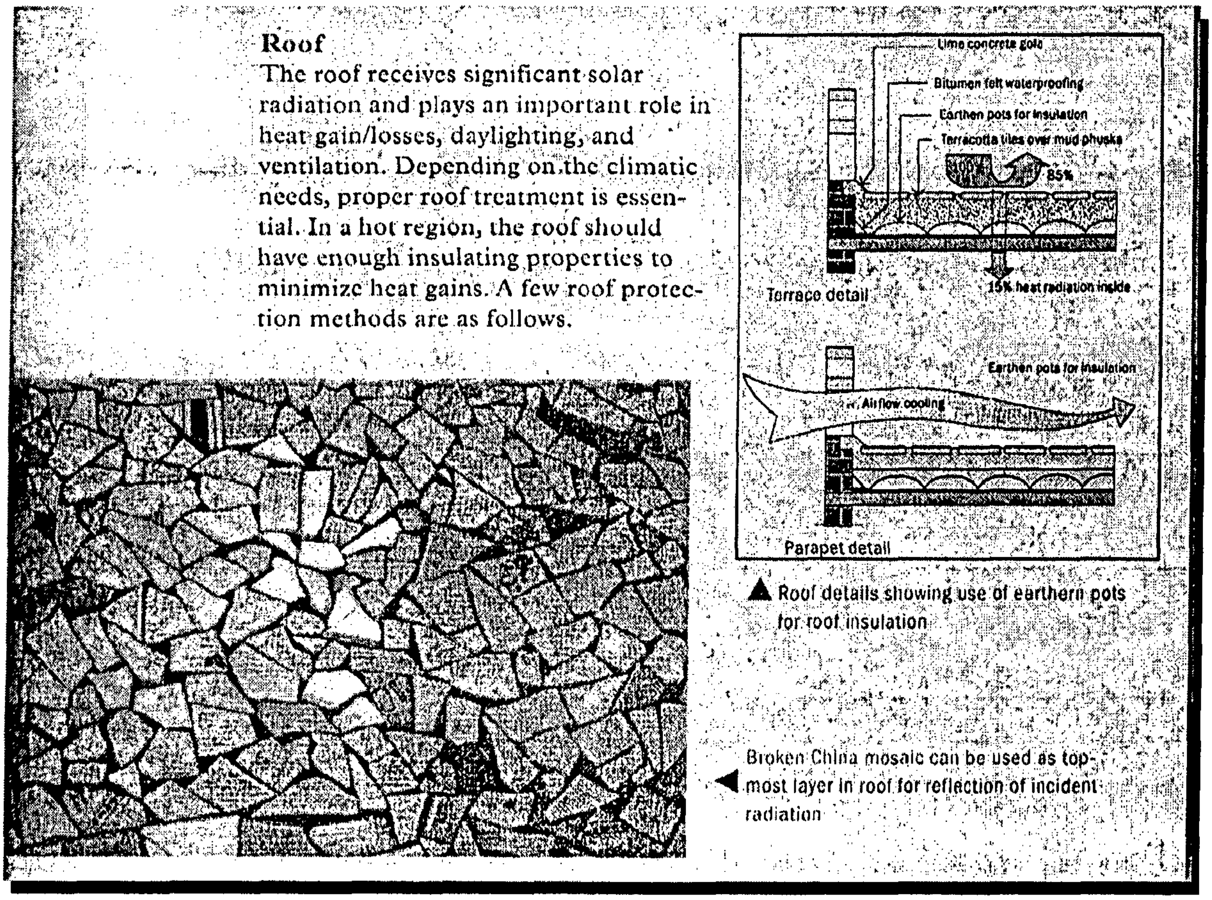


FIGURE 3.17: *The building blocks in MLA hostel, Shimla, located in the cold and cloudy zone, are oriented due south (+_15degrees) for direct solar gain. They are spaced apart so as to eliminate shadows of one building over the other, even for the longer winter shadows. it was proposed that all bedrooms be south facing to avail the benefit of south exposure.*

3.10.5 BUILDING ENVELOPE AND FENESTRATION

The building envelope and its components are key determinants of the amount of heat gain and loss and wind that enters inside. The primary elements affecting the performance of a building envelope are:

- Materials and construction techniques
- Roof
- Walls
- Fenestration and shading
- Finishes



Roof

The roof receives significant solar radiation and plays an important role in heat gain/losses, daylighting, and ventilation. Depending on the climatic needs, proper roof treatment is essential. In a hot region, the roof should have enough insulating properties to minimize heat gains. A few roof protection methods are as follows.

▲ Roof details showing use of earthern pots for roof insulation

◀ Broken China mosaic can be used as top-most layer in roof for reflection of incident radiation

FIGURE 3.18: THE DETAILS OF ROOF FINISHES

4. CASE STUDIES

The concept...

Energy efficiency is a concept that should be applied in totality. The projects covered here as case studies are selected on the basis of their energy efficient approach to design- be it adoption of low energy construction material and techniques, innovative use of solar passive architectural principles or use of renewable energy systems. Projects not included here are the ones that used some stand-alone renewable energy gadgets/devices without having an integrated approach to whole design.

All the case studies are located in composite climate zone. Since the study deals with "the design parameters for energy efficient dwellings", so only dwellings have been covered except for an additional study of the *TERI RETREAT BUILDING, GURGAON.*

In all these dwellings, the architect has given due consideration to all the parameters starting from the minutest detail and to the building on the whole. The architects have adopted a "part to whole" approach while designing all these buildings. This has proved to be very useful to the people residing in the houses in both the ways- first of all they have got all energy efficient parameters in their houses without incurring any additional costs and secondly the houses are proving to be most comfortable in the extreme climatic conditions that the composite zone experiences throughout the year.

The dwellings covered as case studies, so as to study the energy efficiency measures that can be adopted in the dwellings are as follows:

1) *RESIDENCE FOR MADHU AND ANIRUDH, PANCHKULA*
2) *BIDANI HOUSE, FARIDABAD*
3) *RESIDENCE FOR SUDHA AND ATAM KUMAR, DELHI*
4) *RESIDENCE OF ASHOK AND NEELAM SAIGAL, GURGAON*
5) *DILWARA BAGH, COUNTRY HOUSE FOR REENA AND RAVI NATH, GURGAON.*

4.1 RESIDENCE FOR MADHU AND ANIRUDH, PANCHKULA

Architects- Anant Mann and Siddhartha Wig

A small residential house in the composite zone that uses simple and economically viable solutions to respond to the climatic needs. The city of Panchkula lies in the plains at the foot of the lower Himalayas, within a composite climatic context.

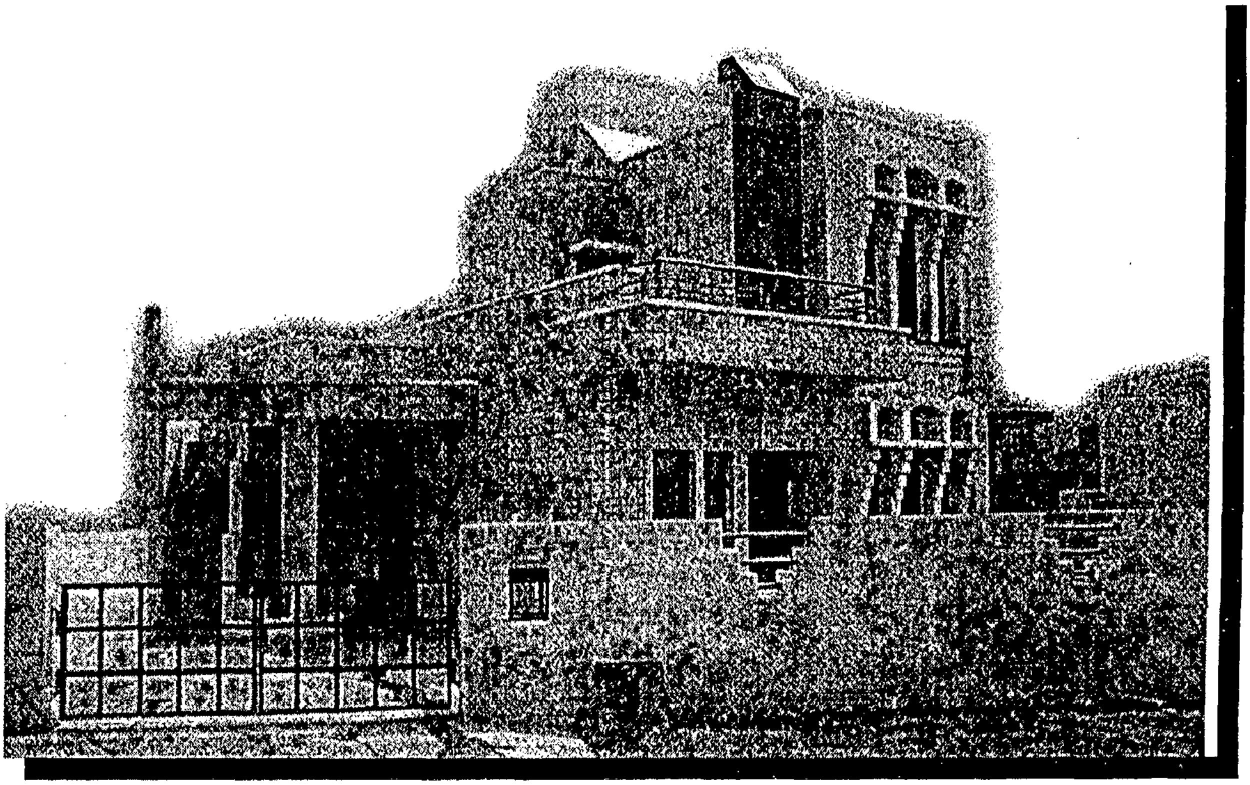


FIGURE 4.1.1: THE BUILDING IS ORIENTED DUE SOUTH. THE INSULATED WEST WALL CLAD IN SLATE CAN BE SEEN. THE BLACK SOLAR CHIMNEY AND LIGHT SHELVES ON THE SOUTH WINDOWS ARE ALSO VISIBLE.

Panchkula experiences wide climatic swings over the year, i.e. very hot and dry period for almost two-and-half months (maximum DBT [dry bulb temperature] 44^{0}C) and quite cold period for a shorter duration (minimum DBT 3^{0}C). The hot dry period is followed by a hot and humid monsoon period of about two months (maximum DBT 38^{0}C and maximum relative humidity 90%), with intervening periods of milder climate.

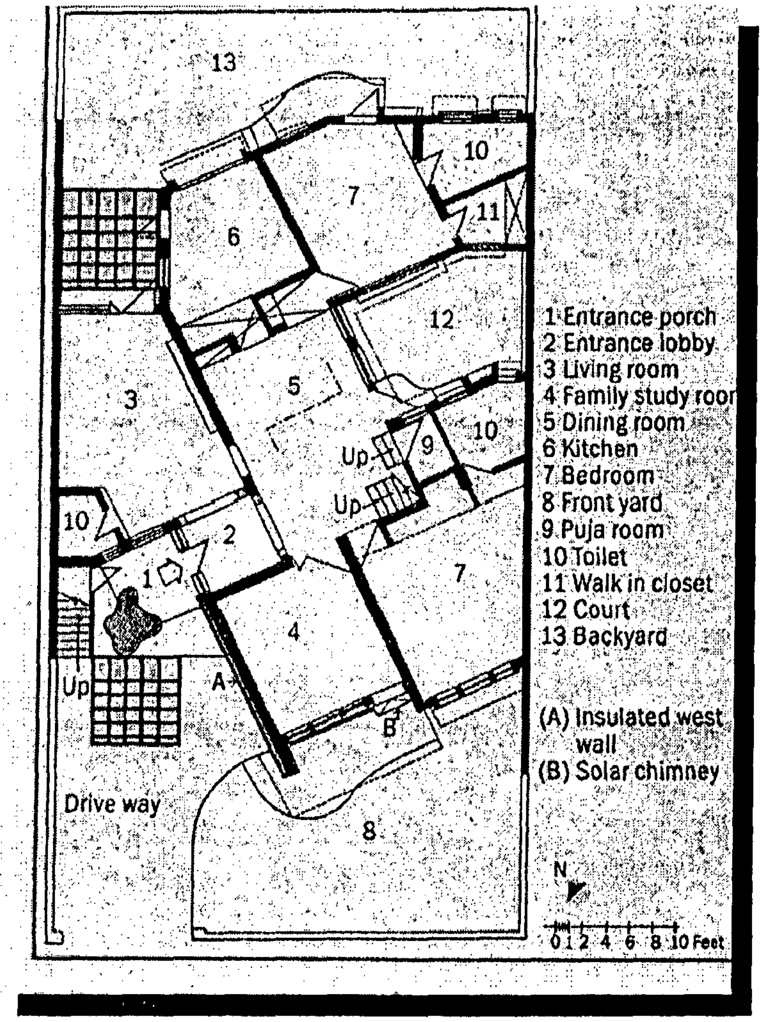


FIGURE 4.1.2: BUILDING PLAN SHOWING ANGULAR DESIGN OF THE HOUSE IN ORDER TO GIVE SOUTHERN EXPOSURE TO MOST OF THE ROOMS.

The demand on building design, is to respond to the extremes; eliminate (minimize) heat gain in hot and dry period, maximize ventilation in hot and humid period from zones or areas designed as sinks, and maximize heat gain in cold period. **This is a small residential building on a rectangular plot measuring 245m^2 and opening on to the south west.** The rooms are placed around a courtyard with the master bedroom and the study/family room facing the south.

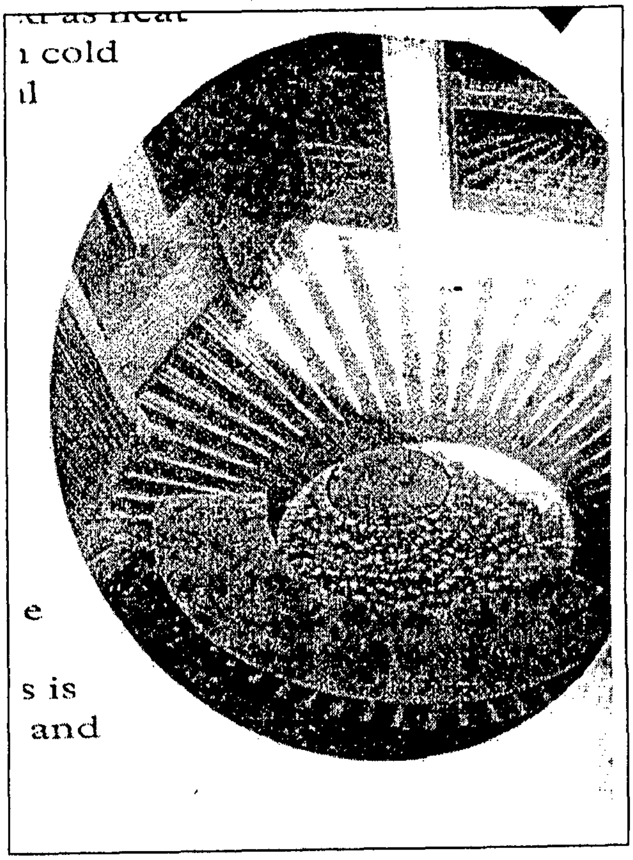
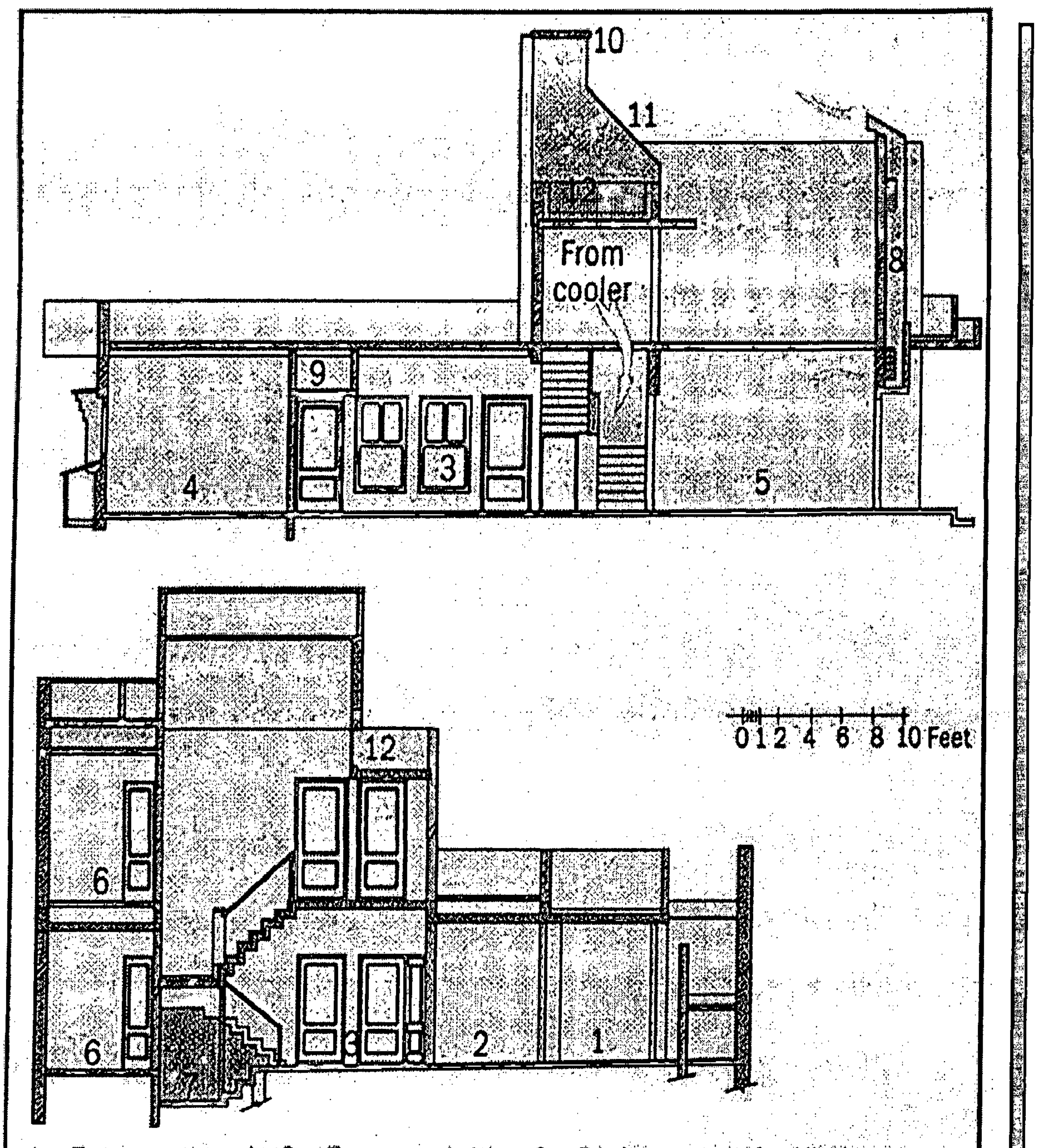


FIGURE 4.1.3

The living room faces north while the second bedroom on the ground floor opens on the north and gets direct sunlight from the court. The dining room is also adjacent to the courtyard. The structure is load-bearing brick with RCC slab. The woodwork in doors and windows is in sheesham wood and the floors are brick and polished stone.



1 - Entrance porch; 2 - Entrance lobby; 3 - Dining room; 4 - Kitchen;
5 - Family room; 6 - Toilet; 7 - Puja room; 8 - Solar chimney; 9 - Loft;
10 - Cool water tank; 11 - Solar panels; 12 - Opening for cooler

FIGURE 4.1.4: THE CHIMNEY ASSISTS SECTION OF THE BUILDING SHOWING CENTRALIZED EVAPORATIVE COOLING SYSTEM FOR THE ROOMS.THE AIR MOVEMENT.

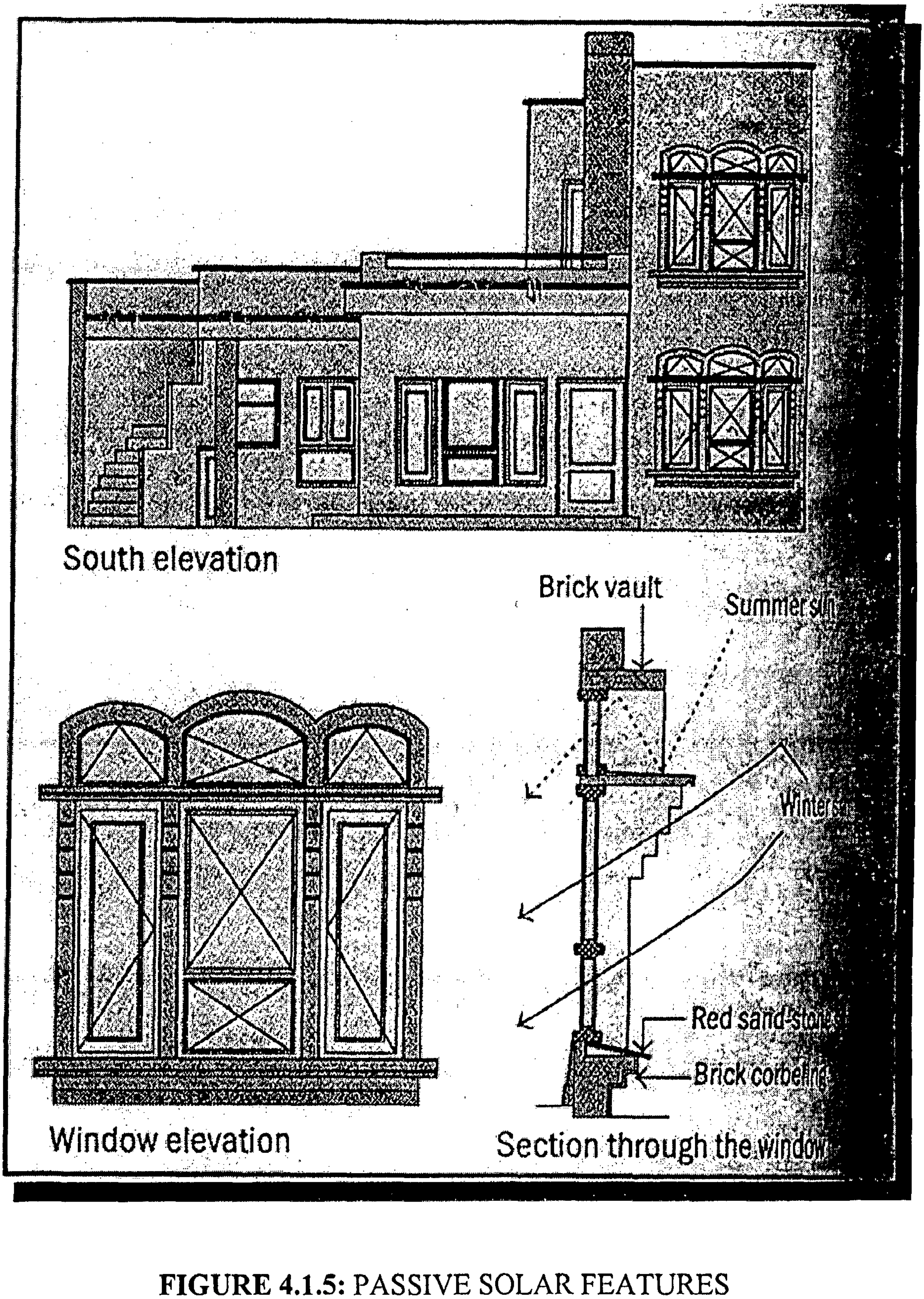


FIGURE 4.1.5: PASSIVE SOLAR FEATURES

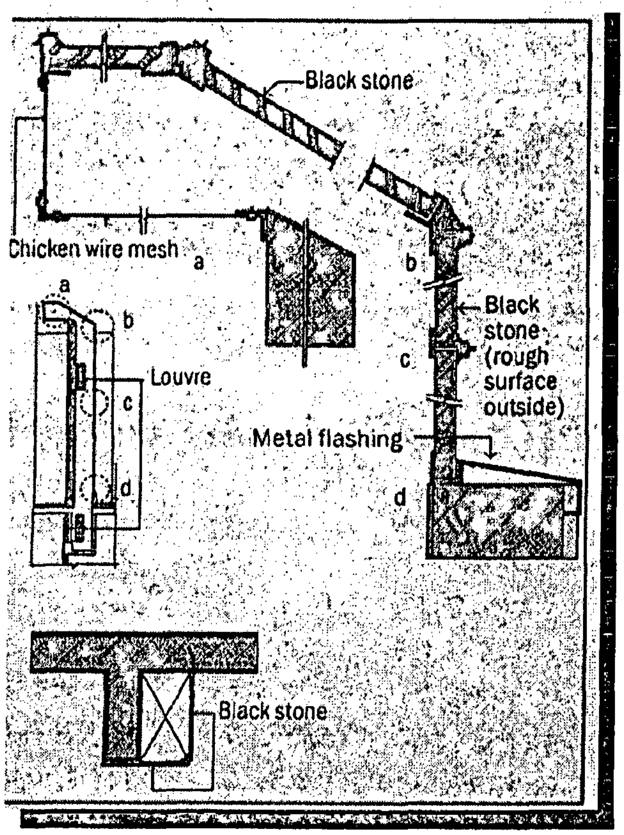


FIGURE 4.1.6: SECTION OF THE SOLAR CHIMNEY FOR VENTILATION

The main building was oriented due south to have better control of the sun. Properly designed south shades coupled with light shelves determine the south façade. The orientation ensured winter sun (while keeping the summer sun out) and adequate daylight in the rooms. The adjacent building keeps the east sun out while the west wall is insulated with 50mm polystyrene. Light shelves and white ceiling sin the rooms allow for enough day lighting in the rooms. There is a central evaporative cooler above the staircase well. A solar chimney that extracts air from the front room augments this air current. Louvers in the doors ensure air circulation even if the doors are closed. The sloping slab above the stairs allows for architectural integration of solar water heating panels or solar photovoltaic panels as the case may be. The north face of this well catches more light and carries it down the stairs.

4.2 BIDANI HOUSE, FARIDABAD

Architects Arvind Krishnan and Kunal Jain

A residential building that responds to climatic needs to provide comfort.

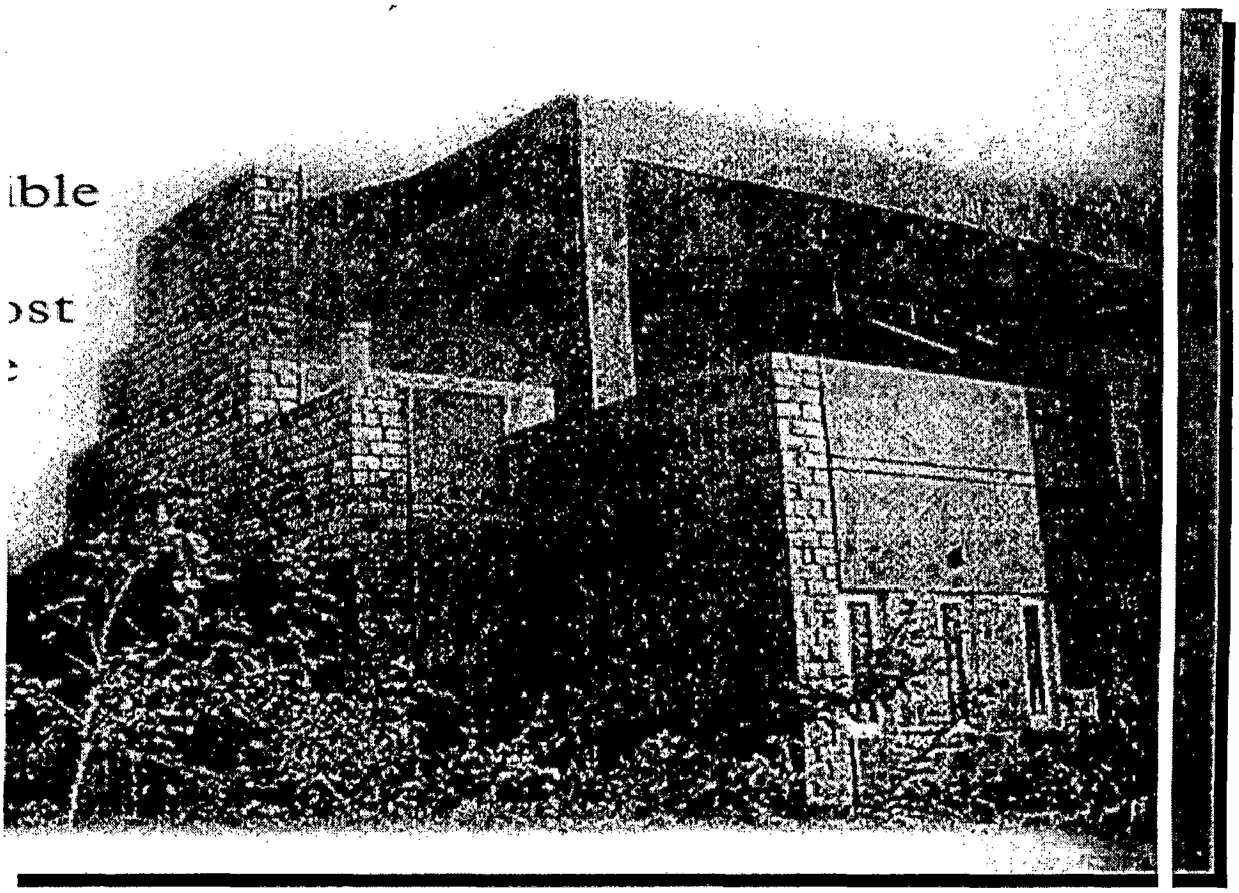


FIGURE 4.2.1: CLIMATE RESPONSIVE FORM TO MAXIMIZE HEAT LOSS IN SUMMER AND HEAT GAIN IN WINTER.

Very often it is stated that it is possible to design climatically responsive buildings on a larger site, but in most urban situations where the sites are constrained by their small size and fixed orientation, it is not possible to develop such a design.

The Bidani House is a project that demonstrates a situation where a climatic responsive form and design was achieved in an existing urban situation with a fixed site size and orientation.

Faridabad, located in the "composite climatic zone", has large climatic swings over the year, i.e. very hot and dry period of almost two and a half months and a colder period of shorter duration. The hot dry period is followed by a hot humid, monsoon period of about two months with intervening periods of milder climate.

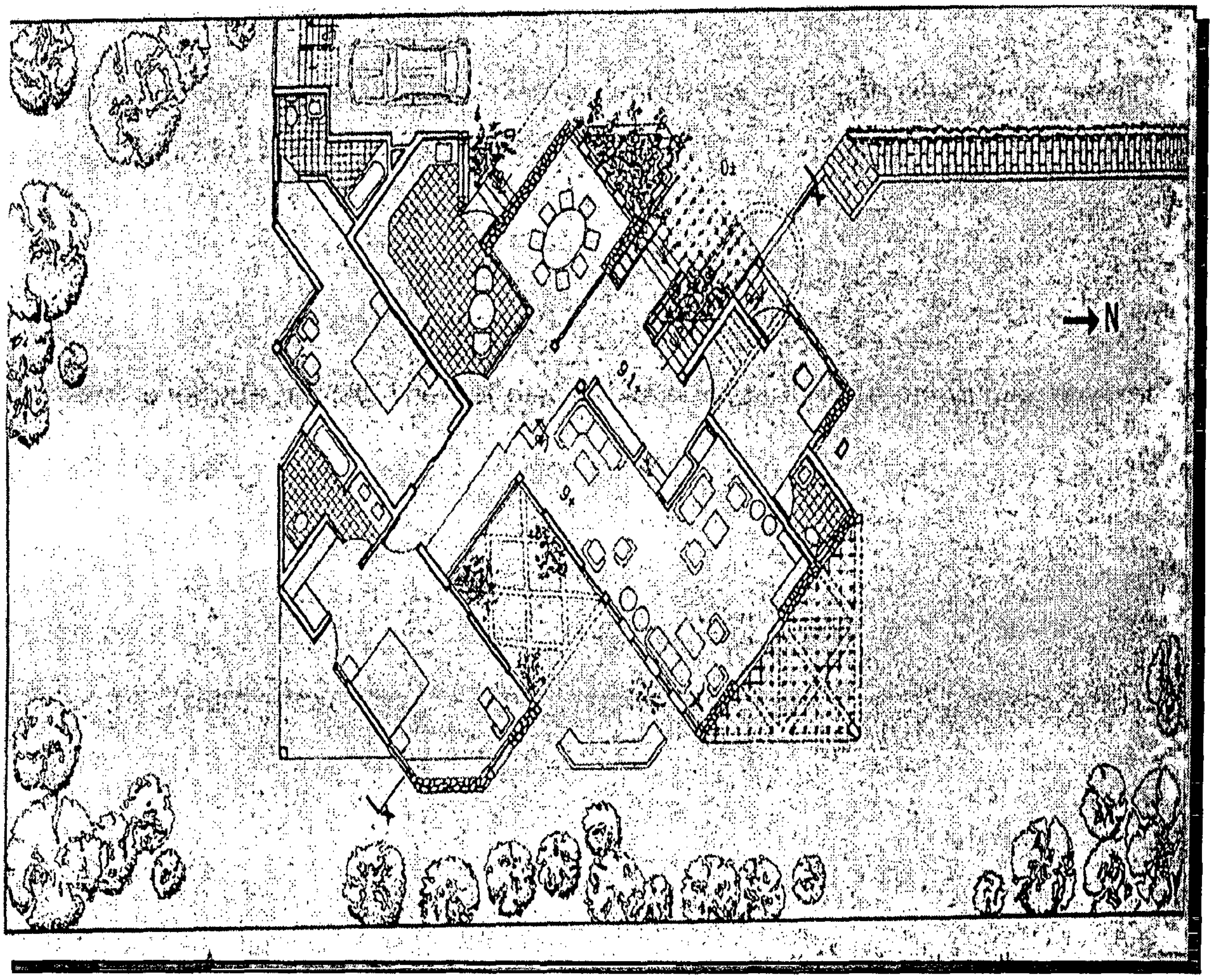


FIGURE 4.2.2: MAXIMUM EXPOSURE TO SOUTHEAST FOR LIVING SPACES AND BUFFER SPACES ON THE SOUTH WEST TO ELIMINATE HEAT GAINS DURING SUMMER.

PLANNING IN RESPONSE TO CLIMATE

The demand on building design was to respond to the extremes: eliminate (minimize) heat gain in hot dry period, maximize ventilation in hot humid period from zones/ areas designed as heat sinks and maximize heat gain in the cold period. This has been achieved in this house entirely through the form and fabric of the building. A courtyard facing and opening onto northeast has been designed as a heat sink. The entire house form has been developed around a courtyard with all the main living spaces wrapping around it and having maximum southeast orientation that is the ideal exposure for this context. A large volume living space designed as a double height space is wrapped around the courtyard. Buffer spaces like the toilets and stores are located on the overheated south western exposure to eliminate heat gain in summers.

THE SITE

Located in Faridabad, near New Delhi, this house has been designed and built in the 'composite climate context'. The site of about 1000 m^2had a plan area in the ratio of 1:3 with the shorter side facing the road and oriented towards north.

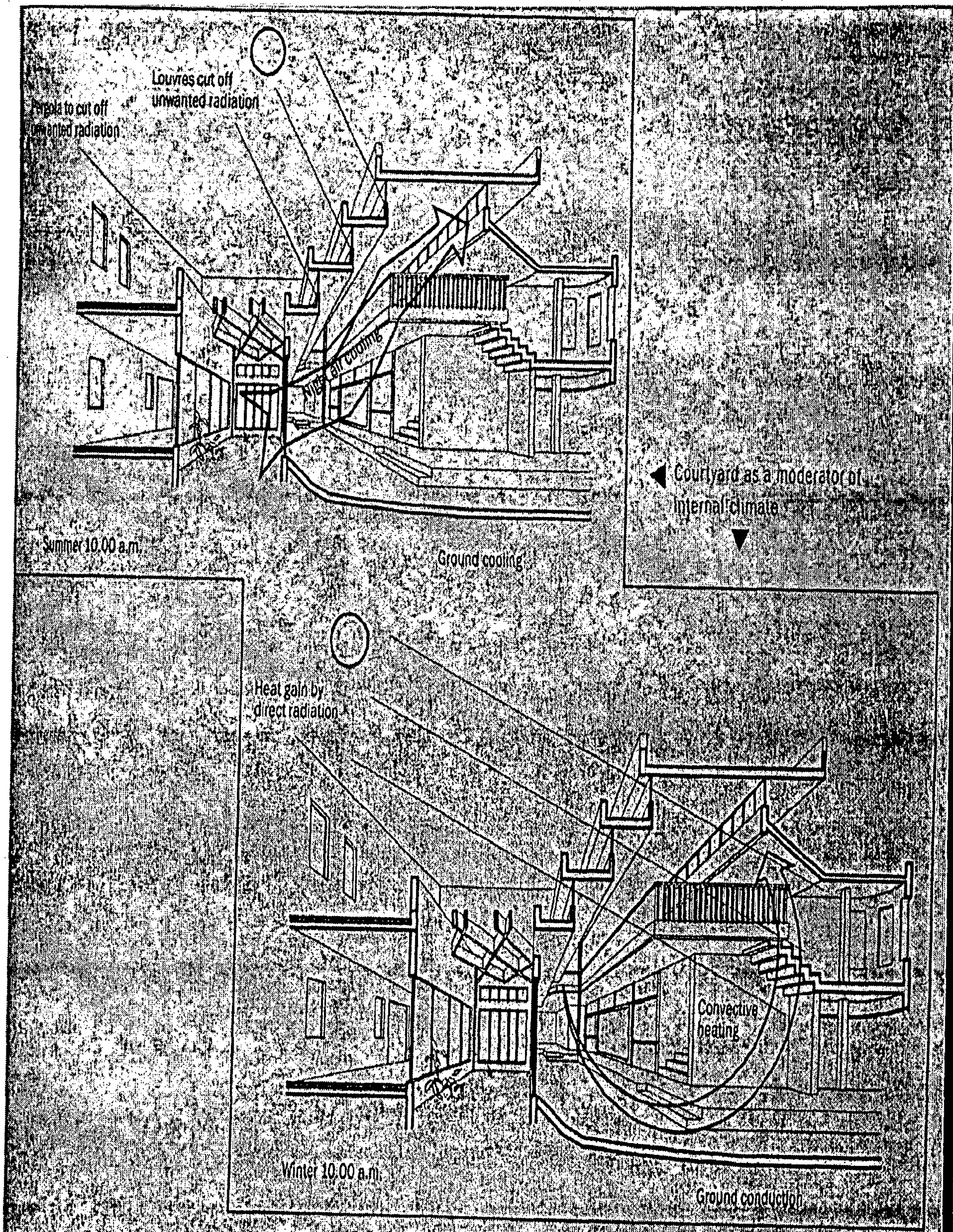


FIGURE 4.2.3: THE COURTYARD ACTS AS A MODERATOR OF THE INTERNAL CLIMATE.

The three-dimensional form of the building is generated to eliminate or allow solar penetration according to seasonal changes. Large volume spaces and their coupling with the courtyard also allow good ventilation from the courtyard that acts as a heat sink. The plan and three-dimensional form of the building have, therefore, been developed entirely in response to solar geometry.

Diurnal swings in temperature are attenuated by judicious design and placement of thermal mass, utilizing local stone as the major material for construction.

The resultant building provides a comfortable environment with temperatures, humidity and air flow levels remaining in the comfort zone during all seasons of the year.

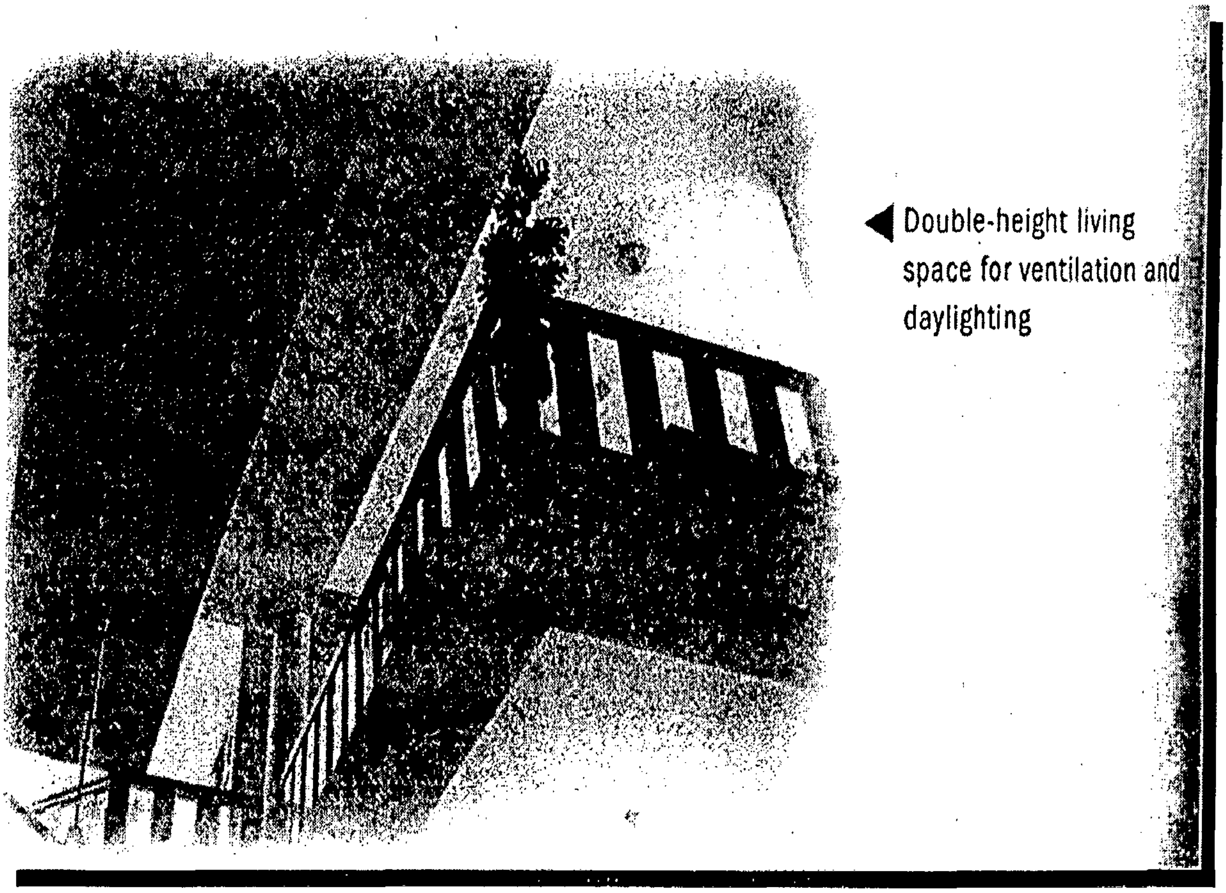
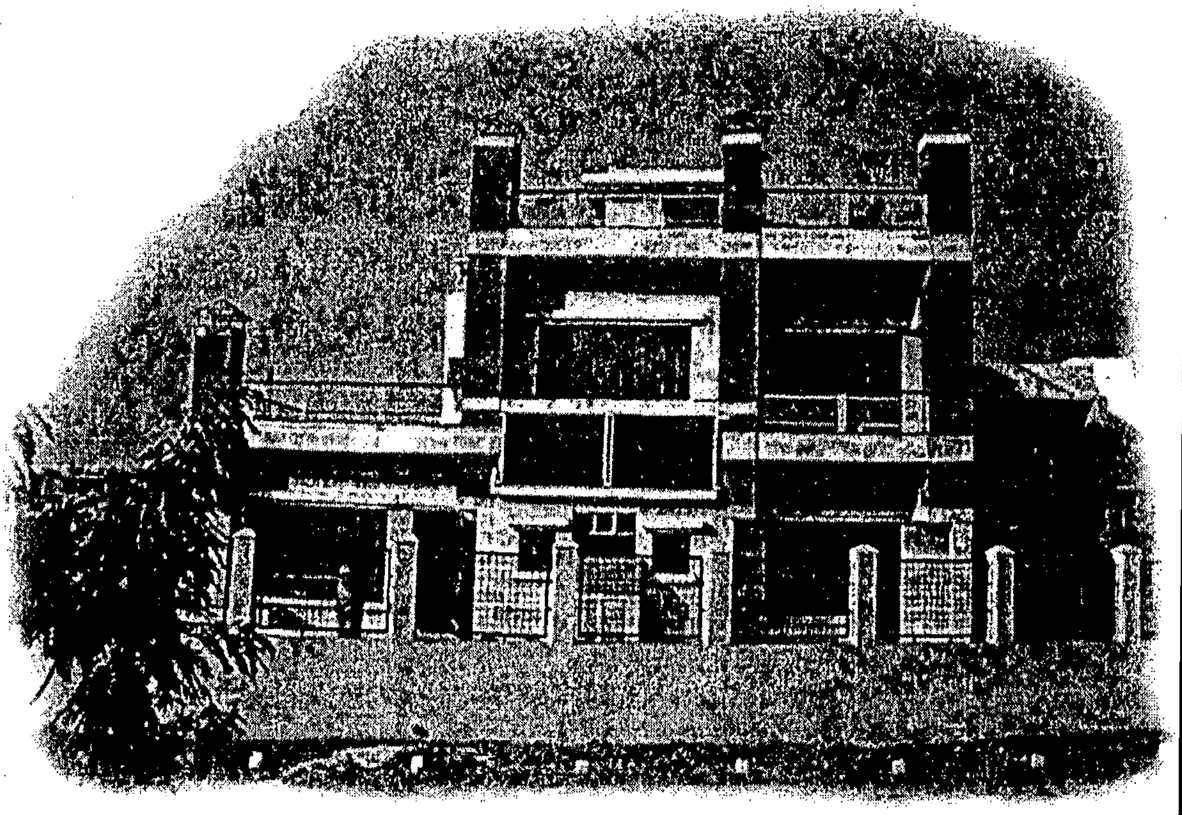


FIGURE 4.2.4: DOUBLE HEIGHT LIVING SPACE FOR VENTILATION AND DAY LIGHTING.

4.3 RESIDENCE FOR SUDHA AND ATAM KUMAR, DELHI

Architect Sanjay Prakash

A residential house in a composite climate responding to various seasonal needs and maintaining comfort levels without any energy intensive systems.



▲ South elevation of the building with large shaded openings and solar chimneys as predominant architectural feature. Solar water heating collectors are integrated with the south facade

FIGURE 4.3.1: SOUTH ELEVATION WITH LARGE SHADED OPENINGS AND SOLAR CHIMNEYS AS PREDOMINANT ARCHITECTURAL FEATURE. SOLAR WATER HEATING COLLECTORS ARE INTEGRATED WITH THE SOUTH FAÇADE.

This is the inaugural project in a series of EASE (Environmentally Appealing and Energy Saving) houses. EASE is a concept promoted by Cdr. C.P.Sharma (Retd.) as a commercially viable method to propagate energy efficient houses. This particular project was sold to a solar energy device manufacturer and consultant, who, interestingly, was also the energy consultant for the building.

The house is a duplex structure with a living room, kitchen, three bedrooms and a study. There is an outhouse with a servants unit and the office.

MATERIALS, TECHNIQUES AND METHODS

SITE SELECTION

From within the overall development, the site selected had a road to its south and west. The longer side of the plot faced south. The road on the south was a wider one, reducing possibilities of shadows from the south in the future.

PLANNING OF BUILT VOLUMES

The house was planned as a duplex to further reduce its footprint on the plot and was shifted as far north within the site, to an extent feasible, to allow for a large south open area.

SOUTH ORIENTATION

The house was oriented south in the sense that every habitable room ahs a liberal south exposure. Only entries, toilets, and staircases are without direct south orientation. The three bedrooms and the living room all have large south glazing for winter sun heat gain with proper overhang protection for prevention of summer heat gain. The south overhang soffit level is higher than the window lintel level so as to ensure that even a part of the windows is not shaded in winter. All winter heating needs can be met by the south glazing.

INSULATION AND MASS

Expanded polystyrene (25-mm thick) insulation is provided near the outer surface of the walls so as to retain the mass of the wall acting in tandem with the internal space. Likewise, asbestos powder (40-80 mm thick) insulation is provided over the roof slab. Both these provide for a highly inert house with a high thermal mass and high insulation

REFLECTIVE FINISH

The walls are clad in white sandstone providing a textured and reflective finish. The roofs are finished in white terrazzo making for good terraces to sit out on as well as excellent reflection characteristics.

RECESSED JAMBS

All windows have an indented lintel, sill, and jambs, creating space for hanging the curtains while at the same time ensuring that when the curtains are drawn, they fall in a way that creates a reasonably dead air gap between the curtain and the glass improving the insulation characteristics.

EVAPORATIVE WIND TOWER

A multi directional wind tower fitted with evaporative cooling pads tops the stairwell. Outside air, cooled by flowing past the pads kept wet by circulation pump, falls down this well and enters the rooms through permanent ventilation openings above the doors. These openings may be closed with shutters if required.

SOLAR CHIMNEYS

South-facing thin-walled and dark-colored shafts assist air exhaust in the summer days. The shafts are topped with fiberglass chimneys. Internal shutters cut out this exhaust when required (in the winter).

RENEWABLE ENERGY SYSTEMS

ARCHITECTURALLY INTEGRATED SOLAR HOT WATER

A 200 liters-per-day hot water system is architecturally integrated with the house. A solar water heater panel is mounted vertically on the south wall above the kitchen. This non standard mounting angle reduces the problems of dust accumulation, endemic to Delhi. It reduces the chances of breakage due to hail or cats etc. It also frees up terrace space and is a technique that can also be used in multistory buildings to provide individual hot water systems without using the roof. A roof top insulated hot water tank collects the solar heated water, which is then available to all the toilets and kitchen. A sensitive thermostat activates the back-up low-wattage electrical element on the evening of cloudy days, but only if manually activated by the residents. An independent 100 litre-per-day vertically mounted solar hot water system is provided for the outhouse.

BUILT-IN SOLAR COOKING

A sliding solar cooker is built in to the south wall of the kitchen. The pans can be accessed from inside the kitchen and come out at counter level for ease of use. Balance cooking is done with conventional fuel.

4.4 RESIDENCE FOR ASHOK AND NEELAM SAIGAL, GURGAON

Architect Sanjay Prakash

A small residence in the composite climate of Gurgaon uses cost effective passive techniques for achieving thermal and visual comfort.

FIGURE 4.4.1: FRONT VIEW OF THE SAIGAL HOUSE; BEDROOMS HAVE ADJOINING GARDEN COURTS.

This house seeks to translate the traditional courtyard house of inner cities to an updated lifestyle of today. While remaining within the legal framework, which is based on the model of the semi detached house for plots such as these, the design seeks water heating. Using a careful selection of devices, 15 A circuits can be eliminated from the house altogether.

INVERTER AND FUTURE PROVISION OF PHOTOVOLATIC CHARGING

The house has a central inverter and a battery bank that can provide for 8 hours of emergency usage. It is planned that as soon as affordable, the house shall be put on photovoltaic charging and progressively made less dependent on the grid.

PERFORMANCE

The thermal systems generally worked very well in winter, eliminating the requirement of heavy quilts altogether. The dry summer season performance was good except for slight droplets of water spilling from the wet pads of the cooling tower into the staircase area. Monsoon comfort is dependent on strategically closing or opening the windows.

Renewable energy systems have worked well. Electrical systems are satisfactory, but highly stressed due to erratic power supply and extreme voltage fluctuations in the area.

WASTE RECYCLING AND WATER CONSERVATION

COMPOST PIT

Two pits in the garden can ensure the composting of kitchen wastes. The kitchen, in turn, is provided with ample space below the counters to ensure separation of paper, organics, and other waste and recycling of the first two types.

LOW WATER FLUSHES

The house is fitted with flush valves and without any cisterns.

ENERGY EFFICIENT LIGHTING

DAYLIGHT

All spaces in the house are properly lighted with natural light in the day.

LOW ENERGY LIGHTS

All lamps and luminaries are based on warm color CFL's (compact fluorescent lamps) so as to reduce the electrical loads to the maximum.

OVERALL RATIONALIZATION OF LOADS

Including fans, lights, refrigerator, and a water circulation pump for the cooling tower, the running loads of the house work out to be about 400 W. adding a TV/ computer or water boosting pump (not running simultaneously), the running load of the house is about 800 W. if one heavy electric appliance (electric iron, washing machine, etc., not running simultaneously) is added, the house can be run under 2000 W peak all the time. There is no need to use electricity for space heating and cooling, nor for to convert the small patio often given for light into a proud centerpiece of the house, a status that it once commanded in the traditional house. The house is a ground floor unit with a living and dining room, kitchen and three bedrooms.

The central dining area is built like a roofed courtyard and can allow the next floor to be made in the future without compromising the privacy or working of the space below.

MATERIALS, TECHNIQUES AND METHODS

PLANNING OF BUILT VOLUMES AND SOUTH ORIENTATION

The footprint of the house was shifted as far north as possible. The two important bedrooms were placed towards the front, south side, with the largest possible open area on the south, even though it would have been normally frowned upon since it is usually expected that the living rooms get an attached garden.

DAYLIGHT

The house is entered past the controlling kitchen window and almost from the rear due to planning of the built volumes. It is entered from a multifaceted space where the future staircase can be. No rooms require artificial light even during the cloudiest of periods. The focus of the living areas is the central dining space, which ordinarily would have been the darkest room of the house, but is converted by the use of the 'tropical skylight' into the brightest space.

COURTYARD AND COVERED COURTYARD

The design pattern for this house is based on a pattern of nine squares. Taking inspiration from the traditional courtyard, the central space was designated the "courtyard", despite the paradox that the house is a semi- detached quasi-bungalow. The plan that finally developed, in fact, contained two courtyards: the central (covered with the 'tropical skylight') court forming a permanent dining area and the next area a true temperate-weather patio.

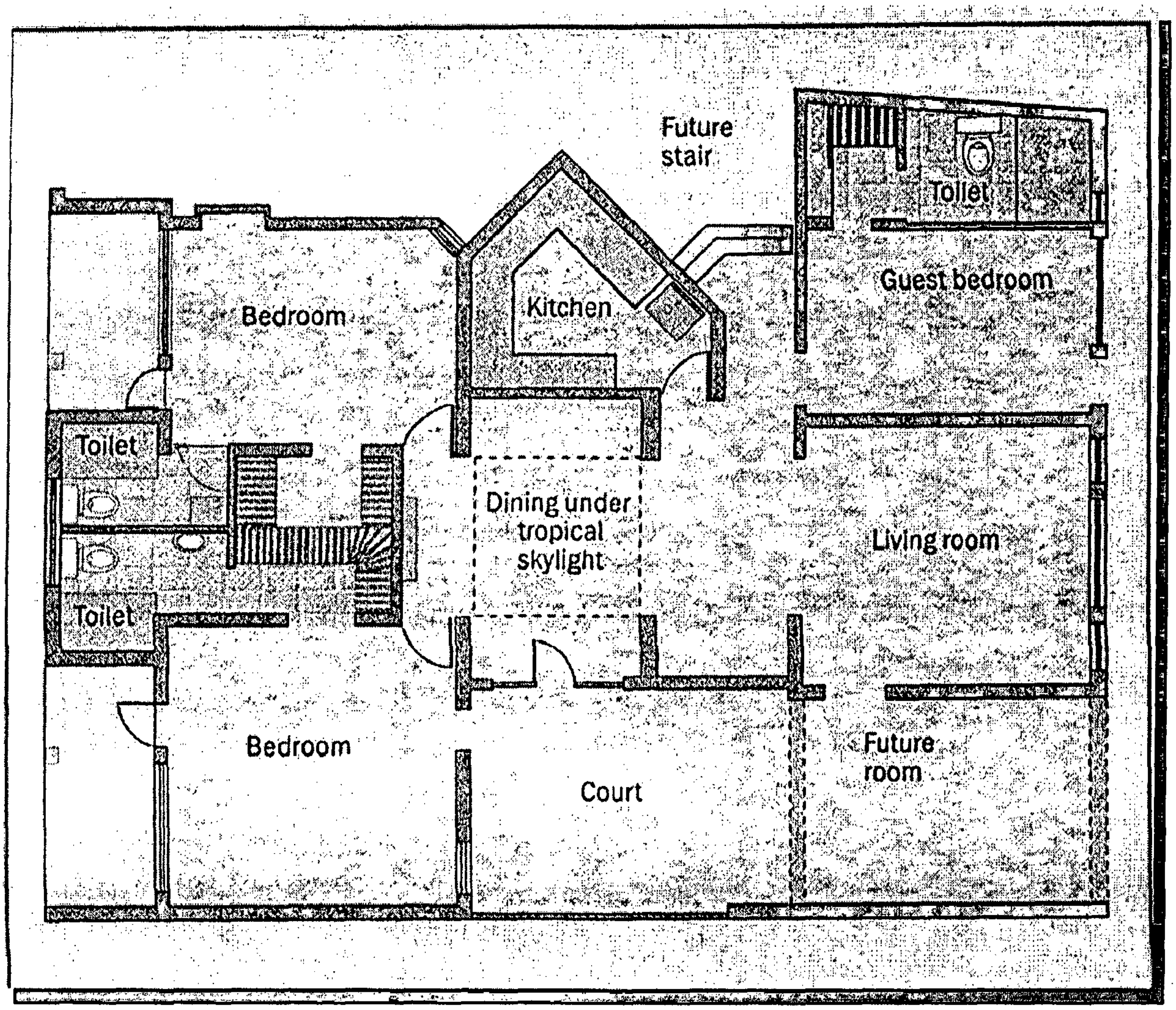


FIGURE 4.4.2: THE PLAN OF SAIGAL HOUSE. INTROVERT PLANNING WITH SPACES ORGANIZED AROUND THE CENTRAL ATRIUM, COVERED WITH A TROPICAL SKYLIGHT.

TROPICAL SKYLIGHT

The central dining space was notionally thought of as a courtyard. However, neither insects nor rain nor modern lifestyle would have allowed this feature to be used from traditional models. Therefore, it was roofed over with what has come out to be called as 'tropical skylight'. This is a skylight suitable for atria in tropical climates. It consists of a glazing being placed vertically, facing north and south, and covering the roof so that direct summer solar gain is avoided while winter sun streams into the space. The proper design of the overhangs and glazing allows this geometry to be adapted to all tropical climates, and can be recommended instead of the horizontally glazed skylights which are an attractive but an unsuitable design feature for our climate. The advantage of the skylight is that the construction on first floor would not deter day lighting construction on first floor would not deter day lighting.

CENTRAL EVAPORATIVE COOLING

Along the rim of the tropical skylight are plenums to reach cooled air from an adapted desert cooler to every room in the house. It is an extremely simple affair, with two evaporating pads, a downward facing fan, and a pump.

FIXED MESHES

Fixed netting was installed inside the window and the glass windows opening outwards, operated by a winch-pulley type of arrangement. The hardware failed miserably, but potentially is a real space and cost saver.

REFLECTIVE ROOF AND INSULATION

The roof is a reflective white (and mixed color) broken china mosaic over 50mm thick expanded polystyrene insulation. This makes the otherwise meager cooling system very effective.

FIGURE 4.4.3: THE DINING AREA WITH THE TROPICAL SKYLIGHT

OPTIMIZATION OF STRUCTURE

In order to achieve cost savings as well as to reduce embodied energy, the concentration was on structural design of roof slabs. The spans were limited to about 4 m and the planning allowed a layout without a single beam or column. The total amount of reinforcing steel was reduced to as little as less than $9kg/m^2$ (less than half of usual) while the reinforced concrete volume was restricted to under $0.12m^3/m^2$ total.

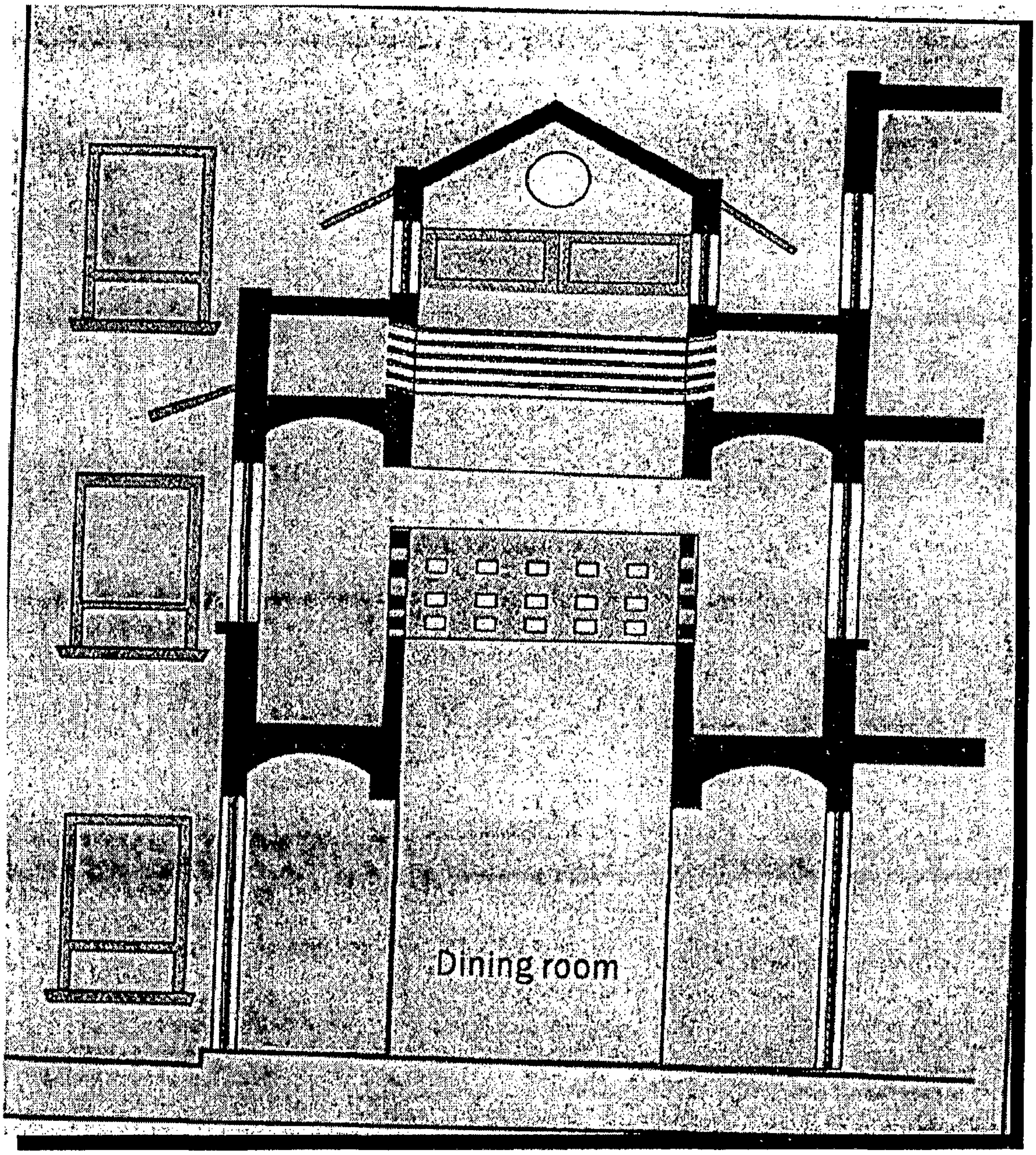


FIGURE 4.4.4: SECTION THROUGH THE TROPICAL SKYLIGHT

PERFORMANCE

The thermal systems generally work well in winter, eliminating the requirement of all artificial lighting, barring the occasional use of the fireplace. The performance during the summer season is also good. Monsoon comfort is dependent on strategically closing or opening the windows, but is still sufficiently uncomfortable so that window air conditioner was placed in the master bedroom for this season, with the children and parents using the room together at that time. Central cooling system is satisfactory, but requires maintenance a bit more often than usual window coolers.

ECONOMICS

The initial cost of the project was same as conventional. In fact, the use of self managed construction and optimization of structural design and spans led to cost savings so the house was made for about 10% lower than the prevailing rates in that area at that time. The running cost is now in the form of electricity for the cooler and air-conditioner, and LPG in the kitchen.

4.5 DILWARA BAGH, COUNTRY HOUSE FOR REENA AND RAVI NATH, GURGAON

Architects Gernot Minke and Sanjay Prakash

A country house in the vicinity of Delhi uses the traditional architectural principles and methods of construction to provide updated requirements of an international lifestyle.

FIGURE 4.5.1: A SOUTH VIEW OF THE HOUSE WITH WINDOWS FOR WINTER GAINS. THE ROOF OVERHANGS PROVIDE SHADING FOR OVERCOMING SUMMER GAINS.

The Dilwara Bagh (the country house) merges the traditional Indian courtyard house with the western "prairie house", to meet the updated requirements of an international style. The house is a ground floor unit with a living room, dinning room, kitchen and three bedrooms, with ample verandahs and gazebos. The dinning area is a small courtyard with pool. There is an outhouse for guests and garages, four huts for servants and services.

MATERIALS, TECHNOQUES AND METHODS

THE LAKE

The flat agricultural land was transformed into an undulating garden. The earth for edge berms and other mounds was taken by forming a lake. This lake acts as a central visual element of the landscape design as well as a microclimate modifier. It stores the water of the monsoon and is topped up in dry season with a tubewell, which was required in the first instance for irrigation. The lake is sealed with a clayey soil. The bank is designed and planted to allow the water level to fluctuate within a range of 0.6 m.

THE VEGETATION

The drive up to the house takes the visitor through a playful series of views of the house and lake contrasted with closed spaces with dense vegetation. A few major other trees accentuate some of the other shady trees where one can rest. The selection of the tree and shrub species is made keeping in view the practical requirement for obtaining a variety of fruits and getting natural compost.

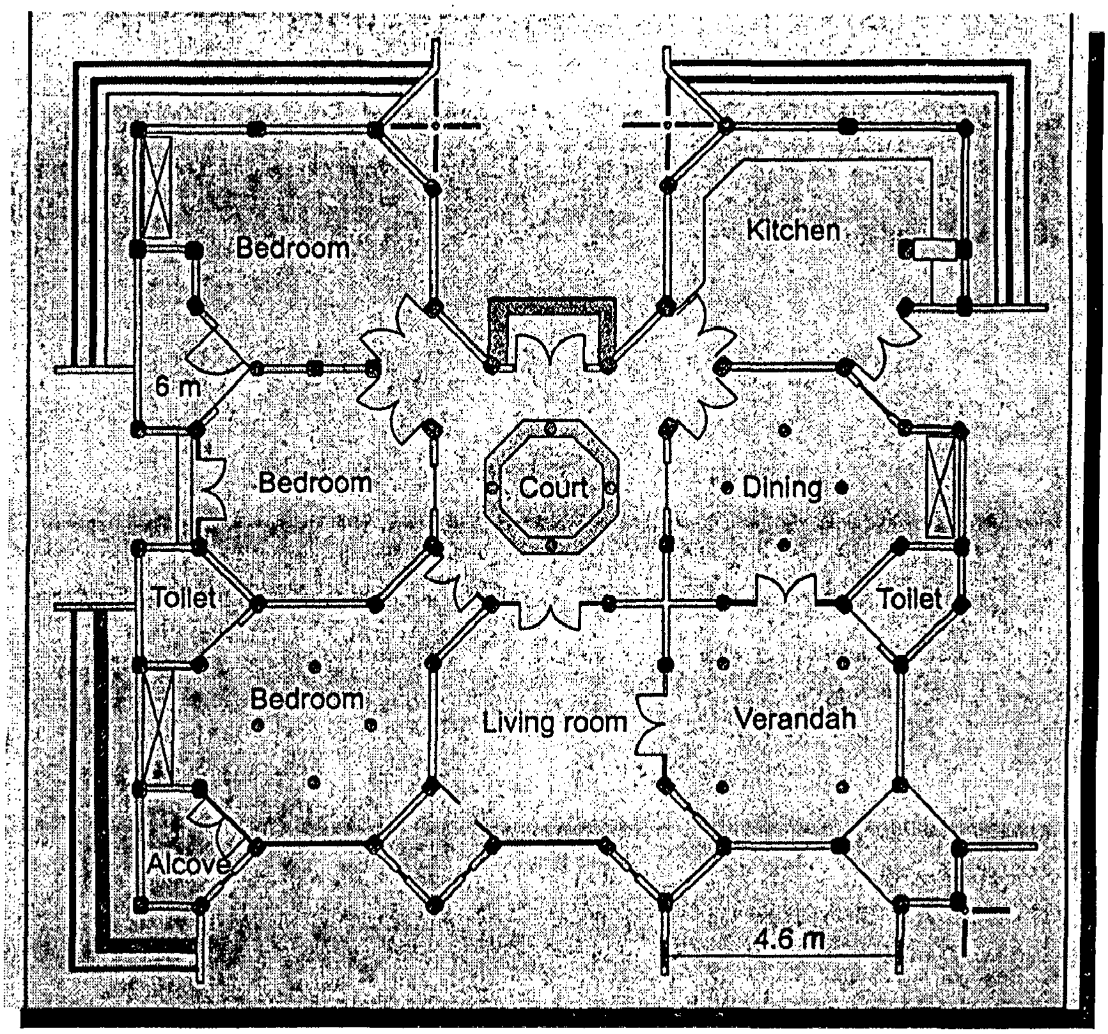


FIGURE 4.5.2: THE BUILDING PLAN IS A TRADITIONAL COURTYARD HOUSE WITH CENTRAL COURTYARD FLANKED BY ROOMS.

PLANNING OF BUILT VOLUMES AND SOUTH ORIENTATION

The single storeyed is mostly set into the earth berms towards the north of the lake. The south side is exposed to the winter sun and shaded in the summer with overhangs and louvers.

COURTYARD

The rooms are arranged around a central patio with a small pool with plants. This enables cross ventilation for all rooms and cooling by evaporation.

LOW ENERGY STRUCTURE

The plan was generated by a pattern of octagons and squares. The structural frame consists of load bearing stone columns, which support beams and stone slabs to form slightly domical enclosures over all the rooms, reminiscent of some of the temples in Dilwara in Rajasthan (hence the name of the house). The in-fill walls are from adobe blocks (hand made mud bricks).

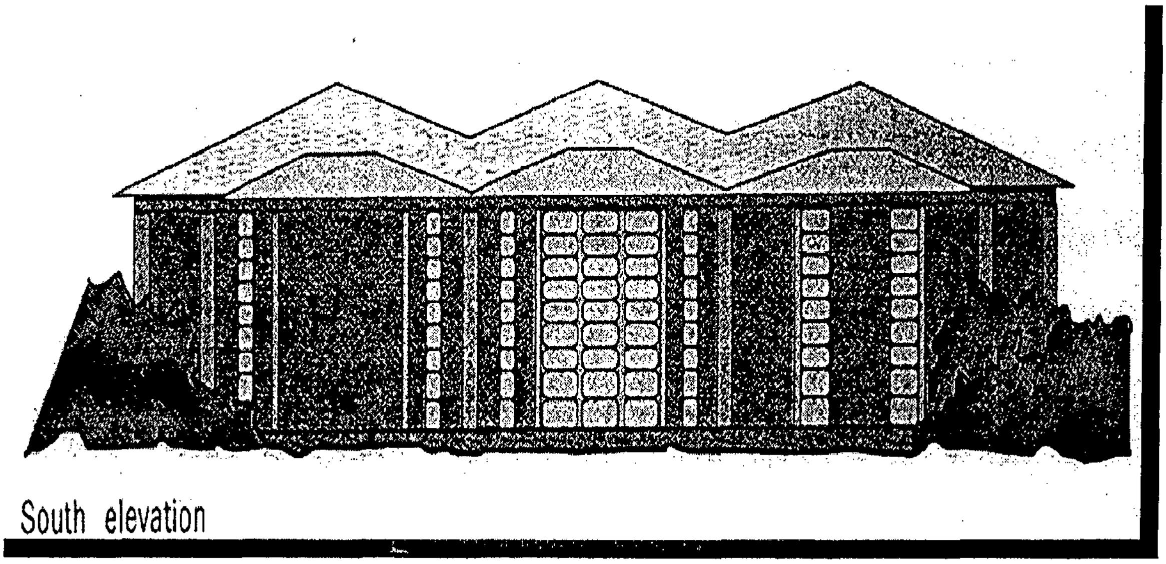


FIGURE 4.5.3: THE BUILDING OPENS UP TO THE SOUTH FOR WINTER GAINS

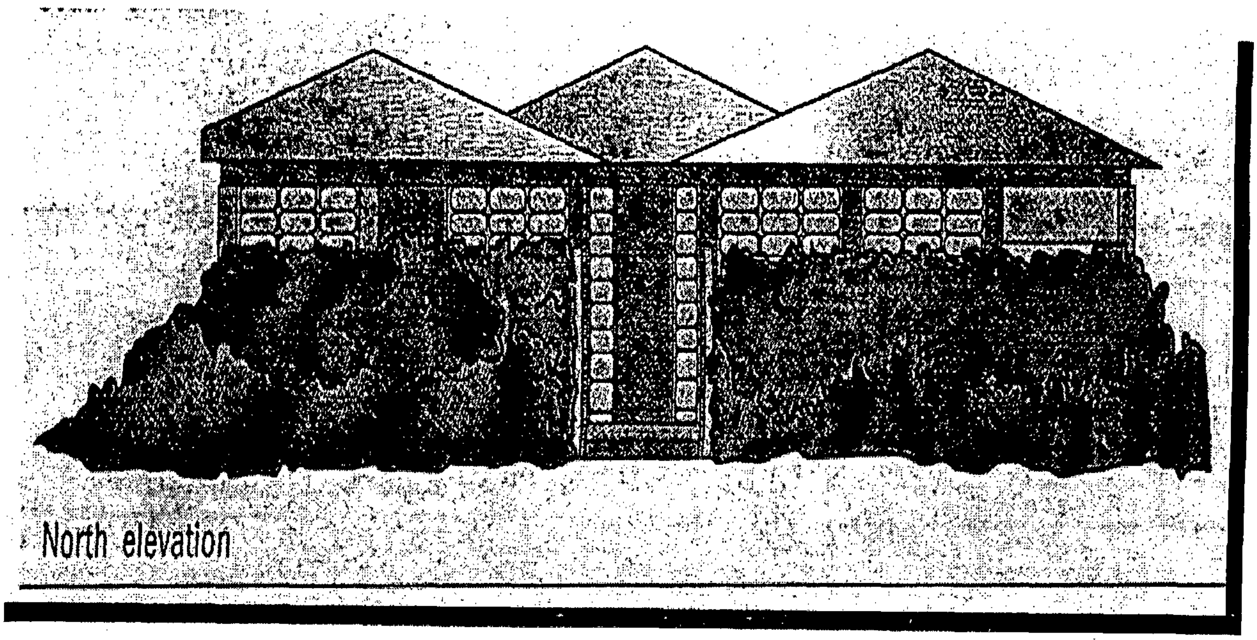


FIGURE 4.5.4: NORTHERN FAÇADE IS PARTIALLY EARTH BERMED FOR OPTIMUM DAYLIGHTING

INSULATION AND SHADING

A conical, light colored stone roof above the domical slab creates an air cavity and also provides reflection of solar radiation, besides shading the roof below. Wherever the berms cover the external face, an inclined stone slab resting against the wall forms an air cavity. All external surfaces of the building have either an air cavity or summer shading by overhangs and louvers.

DAYLIGHT

The stone louvers are designed to take over the function of a usual steel security grill and at the same time provide sun shading and reflect the daylight into the rooms, acting like small light shelves.

PERFORMANCE

The orientation works well in winter and with earth tunnel system, eliminates the requirement of all artificial lighting. The dry summer season performance is good. Monsoon comfort is dependent on strategically opening or closing the windows.

This earth tunnel system is probably the longest in personal use. The coefficient of performance is studied to be as high as 20 at various seasons. The only problem reported is the absence of sufficient air circulation sometimes. This is because the ceiling fans are not installed in order to appreciate the domical ceilings better. Floor mounted fans are not very effective.

ECONOMICS

The initial cost of the project was high, though not necessarily due to the essential features but due to the complicated sourcing of stone and craftsmen. The tunnel system has eliminated the need for central air conditioning by accepting a system of lesser control. The running cost is now in the form of 2kW of electricity for tunnel system and LPG in the kitchen.

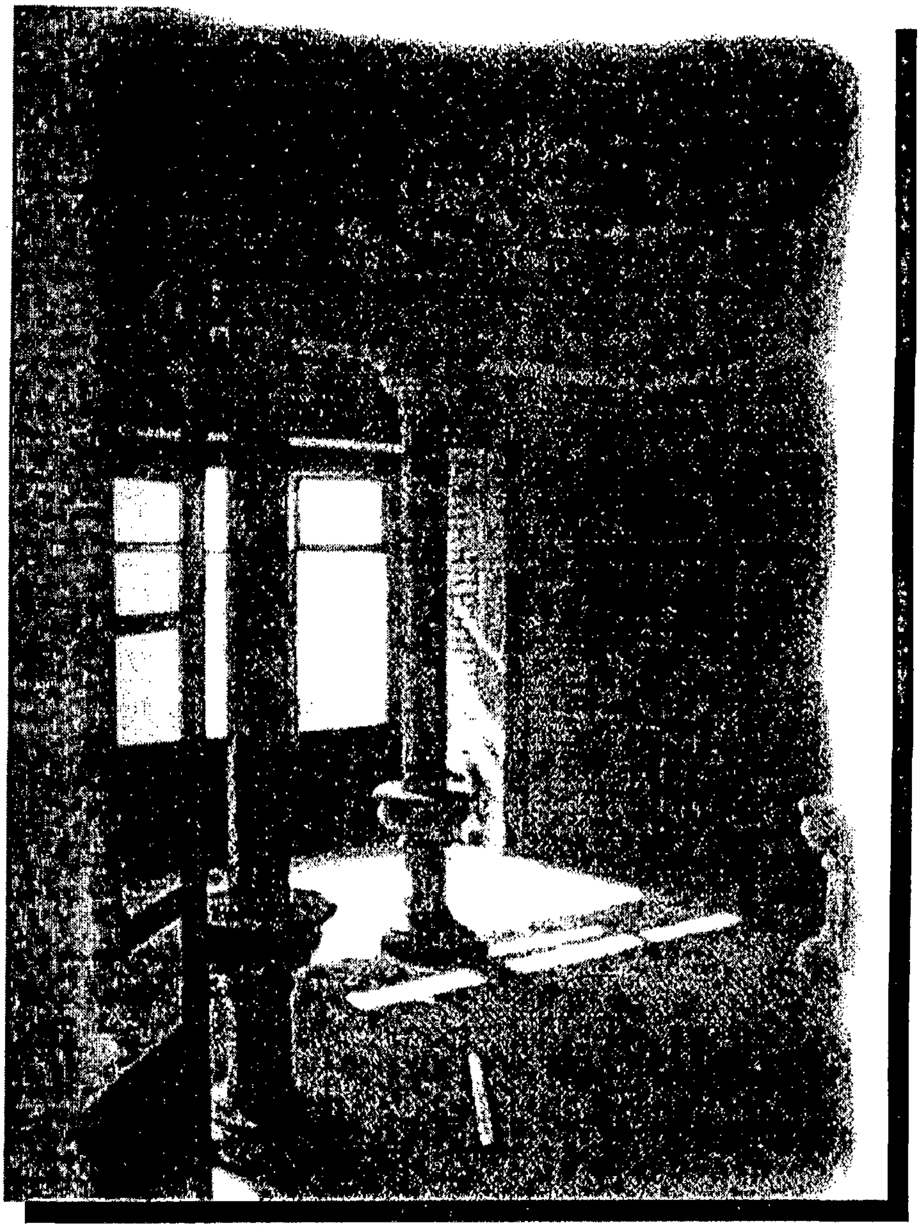


FIGURE 4.5.5: THE ADOBE IN-FILL WALLS WITH NATURAL EARTHEN COLOR GIVES THE FEEL OF A TRADITIONAL VILLAGE HOUSE.

EARTH TUNNEL SYSTEM

Additional cooling in the summer months is provided to each room by an earth tunnel system. The distance from the 2 kW fan to the building is about 60 m. The section consists of two masonry ducts at an average depth of 3m below surface. Max. Air velocity is kept to 6m.

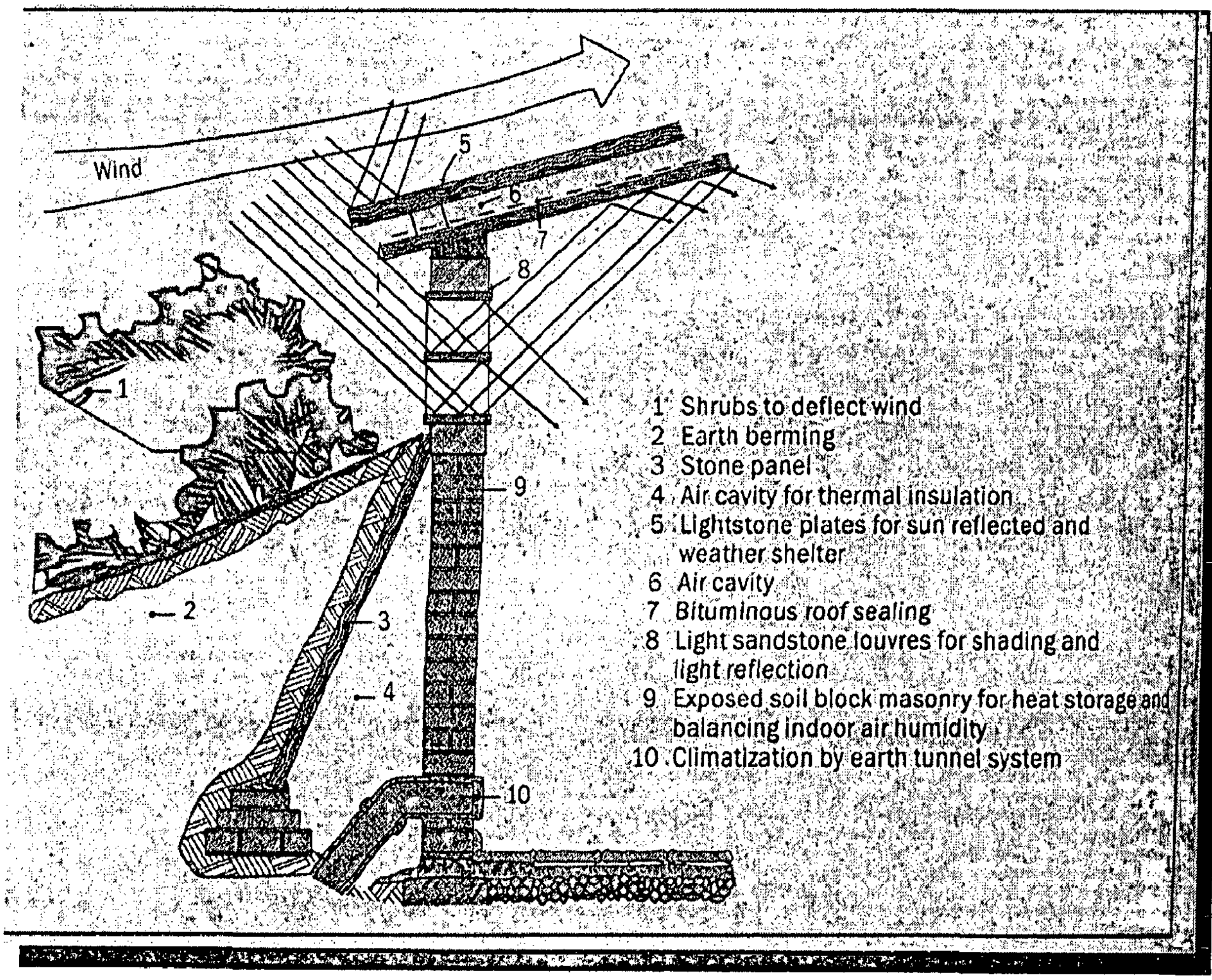


FIGURE 4.5.6: WALL SECTION SHOWING EARTH BERMING AND EARTH AIR TUNNEL

5. ANALYSIS AND INFERENCES

5.1 FORM AND PLANNING

Climate with changing seasons sets a difficult task for designers. The composite climate is such that form suitable for one season may be unsatisfactory for others. This is because the climatic variations are so much that the designing of the dwelling has to be done keeping in mind the extremes of climate. For example the temperature soar too much for almost half of the year whereas, for the other quarter the temperatures drop down drastically and for the remaining part of the year its raining heavily. So this makes the designing of any dwelling in a composite climate a real challenge for any architect. He has to have real cutting edge and understanding of the principles of architecture so that he may apply it as such in his dwellings and achieve his aim of providing comfort to the residents and also achieve energy efficiency at the same time. Since for once architect can take the help of mechanical means to achieve comfort but this does not solve the problem at all. What every architect should keep in mind is that he has to achieve energy efficiency in his building and that too with minimum energy input and that is a bit difficult task, but only for those who do not have a real understanding of the architectural and climatic principles.

"If the architect is well versed with all theories and design principles then he will be able to design the most energy efficient dwelling and that too a most comfortable one without incurring any additional cost".

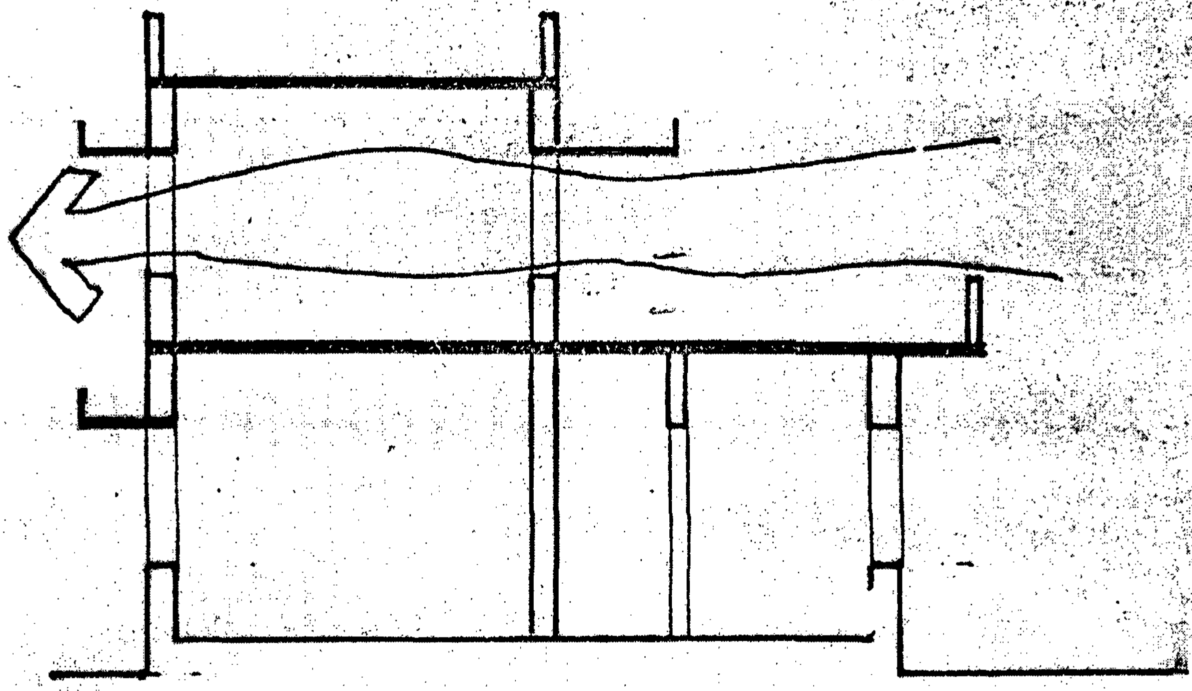
Moderately compact internal planning will be of benefit for a larger part of the year. Courtyard type buildings are very suitable. Dwellings should be grouped in such a way as to take advantage of prevailing breeze during the short period when air movement is necessary.

A moderately dense, low rise development is suitable for these climatic changes, what'll ensure:

- **Protection of outdoor spaces**
- **Mutual shading of the external walls**
- **Shelter from the wind in cold season**
- **Shelter from dust and reduction of surfaces exposed to solar radiation**

A two storied building will modify the internal comfortable conditions in hot months as well as cold season. It will improve the environment by:

- Reducing the area of horizontal surface exposed to receive solar radiation
- Keeping the lower areas cooler during the daytime
- Improving wind flow at upper levels
- Collecting more solar radiation with less obstruction in winter when the altitude of sun is low.
- Having open terraces at upper levels as outdoor spaces.



EFFECT OF TWO STOREYED DWELLING ON INTERNAL CONDITIONS

1 Double banked rooms give a high heat capacity.
2 Upper floors can be used in the humid season at the day time when air movement is needed.
3 Lower floors, with its higher heat capacity, can be used in hot dry season.

FORM OF DWELLING

FIGURE 5.1: EFFECT OF FORM ON INTERNAL CONDITIONS

5.2 INFERENCES FROM CASE STUDIES

1.) For any building in composite climate, the architect should make all the considerations-

- cooling requirements for summer months
- heating requirements for winter months
- Humid conditions prevalent during hot summer months.

2.) The design concept should be to spread out and open so as to capture and direct the seasonal and daily winds.

3.) Provisions should be made for considerable air movement so as to bring the combination of high temperatures and humidity into the comfort zone.

4.) Three basic concepts should be considered while designing any building for thermal comfort:

- Energy efficiency and economy
- The human response to a thermal environment, climatic and micro-climatic condition.
- The hardware of the building structure fabric and thermal services and system.

5.) The building should be designed in such a manner that it responds to the positive and negative effects of temperature, humidity, wind and radiation, so that the occupant comfort zone is altered as the external climatic conditions change.

6.) With the scarcity and rising cost of conventional fuel and the cost of mechanical services, the most effective and economic approach would be to design the building as a whole to respond to external climatic conditions. This can be achieved by combining the solar utilization aspects and various architectural design elements into one.

7.) It is the duty of the architect to try and avoid any usage of mechanical means if the same thing can be done through design variations. For once, he can make some compromises in the aesthetic part of the design if that is hindering the adoption of any energy efficient design principle.

8.) While designing any dwelling unit, the architect should make it a point to work from part to whole and vice versa. He should start working from minutest detail and then achieve results on the whole and also, he should start from his site on the whole and work to the minutest detail. This won't leave any chances of him missing out on anything.

6. DESIGN PARAMETERS FOR ENERGY EFFICIENT DWELLING IN COMPOSITE CLIMATE OF INDIA

6.1 THE COMPOSITE CLIMATE

"....true regional character cannot be found through a sentimental or intimate approach by incorporating either old emblems or the newest local fashions which disappear as fast as they appear. But if u take the basic difference imposed on architectural design by climatic conditions....diversity of expressions can result......if the architect will use the utterly contrasting indoor outdoor relations.....as focus for design conception."

- WALTER GROPIUS

Climate, comfort, building characteristics and solar systems shape the design of the dwelling using solar energy in various forms. Dwelling design responsive to the demands of the sun and climate will give rise to architectural styles particularly suited to various climatic regions.

Three basic concepts are involved in the design of a dwelling for thermal comfort:

- **Economy and efficiency**
- **The human response to a thermal environment**
- **The hardware of the building structure fabric and thermal services and system**

Climate is the primary form giving factor and the solar system and architectural images are also important for different climates. For the purpose of design of buildings on climatic and environmental considerations, India can be divided into six climatic zones. Essential characteristics of each of these zones, requirements for human comfort and design guidelines are outlined in the "Building Digest No. 114 of C.B.R.I., Roorkee.

These six zones are:

- West coastal tropics
- East coastal tropics
- Peninsular plains
- Gangetic plains
- Desert areas
- Eastern hill areas

"Tata Energy Research Institute", TERI, which is doing extensive research is being carried out in the field of energy efficiency has also divided India into six climatic zones. They are:

- **Cold and cloudy**
- **Cold and sunny**
- **Composite**
- **Hot and dry**
- **Moderate**
- **Warm and humid**

Each of these has its own special environmental physical characteristics and these should be considered in the planning of buildings.

6.2 DESIGN CRITERION

The main function of the dwelling is to provide good comfortable living conditions. All the requirements for comfort should be satisfied as far as possible required in the comfort zone of the bioclimatic chart.

The comfort zone is established by analyzing the relationship between air-temperature, humidity, air velocity and radiations. This analysis establishes the range of thermal conditions. The comfort zone is an imprecise approximation of human thermal comfort, realizing the many variations due to human preferences, physiological and psychological characteristics and the nature of activity being performed. However, it provides an estimate of human thermal comfort by which outdoor climatic conditions of a locale may be evaluated to achieve a comfortable indoor climate.

The dwelling should be designed in such a way that it should respond well to the positive and negative affects of temperature, humidity, wind and radiation so that the occupant comfort zone is altered as the external climatic conditions change.

The scarcity and rising cost of fuels and the cost of mechanical climate control equipments, the most effective and inexpensive approach may be to design the dwelling as a whole to respond to the external climatic conditions. This can be achieved by combining the solar utilization aspects and various architectural design

		CONDUCTION	CONVECTION	RADIATION	EVAPORATION
WINTER	Promote gain			Promote solar gain	
	Resist loss	Minimize conductive heat flow	Minimize external heat flow Minimize infiltration		
SUMMER	Resist gain	Minimize conductive heat flow		Minimize solar gain	
	Promote loss	Delay periodic heat flow	Promote ventilation	Promote radiant cooling	Promote evaporative cooling

DESIGN OBJECTIVES

FIGURE 6.2: DESIGN OBJECTIVES

6.3 ROLE OF CLIMATE IN ENERGY EFFICIENT DWELLING

The climate of a particular region is important in deciding the approximate measures for energy conservation. This will help in the better understanding of the architectural principles that can be applied to our design of a comfortable dwelling unit. Thus, it is very necessary to do a critical study of the climatic factors of the area.

6.3.1 CLIMATIC FACTORS

The climatic factors that influence the design of a dwelling unit and effect its energy consumption are as follows:

- **Solar radiation**
- **Daylight**
- **Dry bulb temperature**
- **Wind speed**
- **Humidity**
- **Sunshine**

This diagram shows the direct solar radiation on clear days. It shows that the horizontal surfaces receive maximum solar radiation in summers and minimum in winters, while the south wall receives less in summer and more in winter. Solar heat and daylight contribute special features of tropical climate which can be suitably utilized for energy conservation in heating, cooling, lighting and hot water supply.

The temperature goes as low as to 12^0C in winters and high upto 38^0C in summer. The worst season is monsoon i.e. July to September, when humidity increases to 80-

90% and also the DBT with no air movement. Thus, the bioclimatic study becomes necessary to reveal the comfortable conditions in the dwelling.

6.3.2 BIOCLIMATIC STUDY

In January, the lower outdoor temperature and high humidity move the comfort zone downward, thereby intense solar radiation and dehumidification is needed.

In the night the rapid fall in temperature and humidity create uncomfortable cold conditions indoor, the heat is required in the night to make the internal environment comfortable.

In May, high outdoor temperature with low humidity creates the condition of hot and very dry weather resulting in the upward movement of the comfort zone. Air movement is required to remove the heat by convection and also the humidification of air. Nights are cool and comfortable for outdoor sleeping. Dwelling becomes very hot due to high outdoor day temperature. Wind velocity increases due to low pressure and brings dust, so the whole atmosphere becomes dusty sometimes.

In August, the monsoon period increases the humidity. The high outdoor temperatures after rain create intolerable conditions of sweating with no air movement. A little fall in temperature in the night modify the condition but air movement is very necessary which is almost absent in the whole period.

In November, the conditions are better than in any month. The outdoor temperatures are within the comfortable range, but the humidity remains the same which shows the need for air movement. Nights are cooler but the comfort can be achieved through infiltration.

The wind flow is from northwest and southeast direction. Many times calm air requires the need of mechanical ventilation systems such as fans.

The sun shines very bright throughout the year, except during the monsoon season when the sky is wholly or partly covered with the clouds. The sun shines for approximately 290 days of the year.

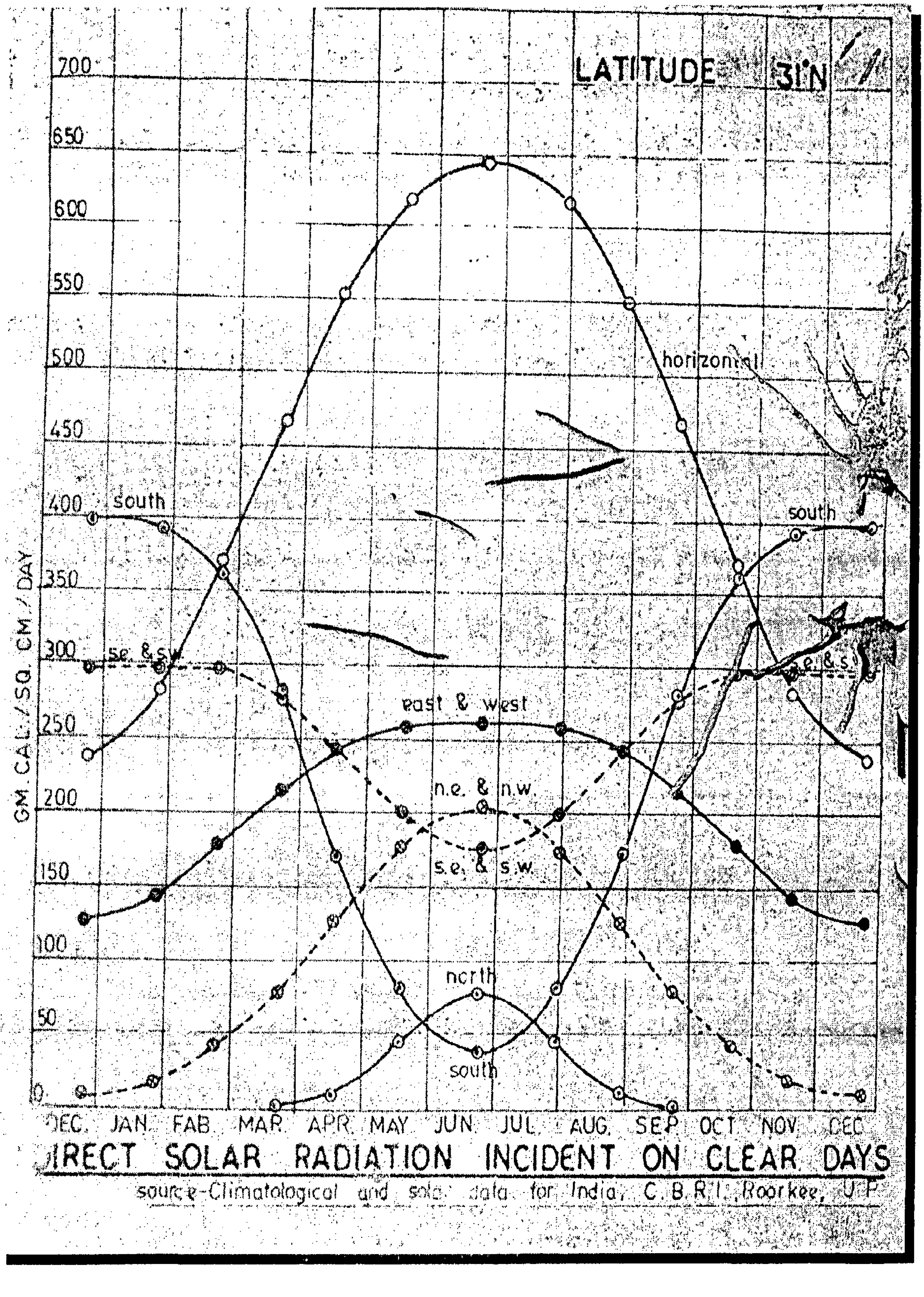
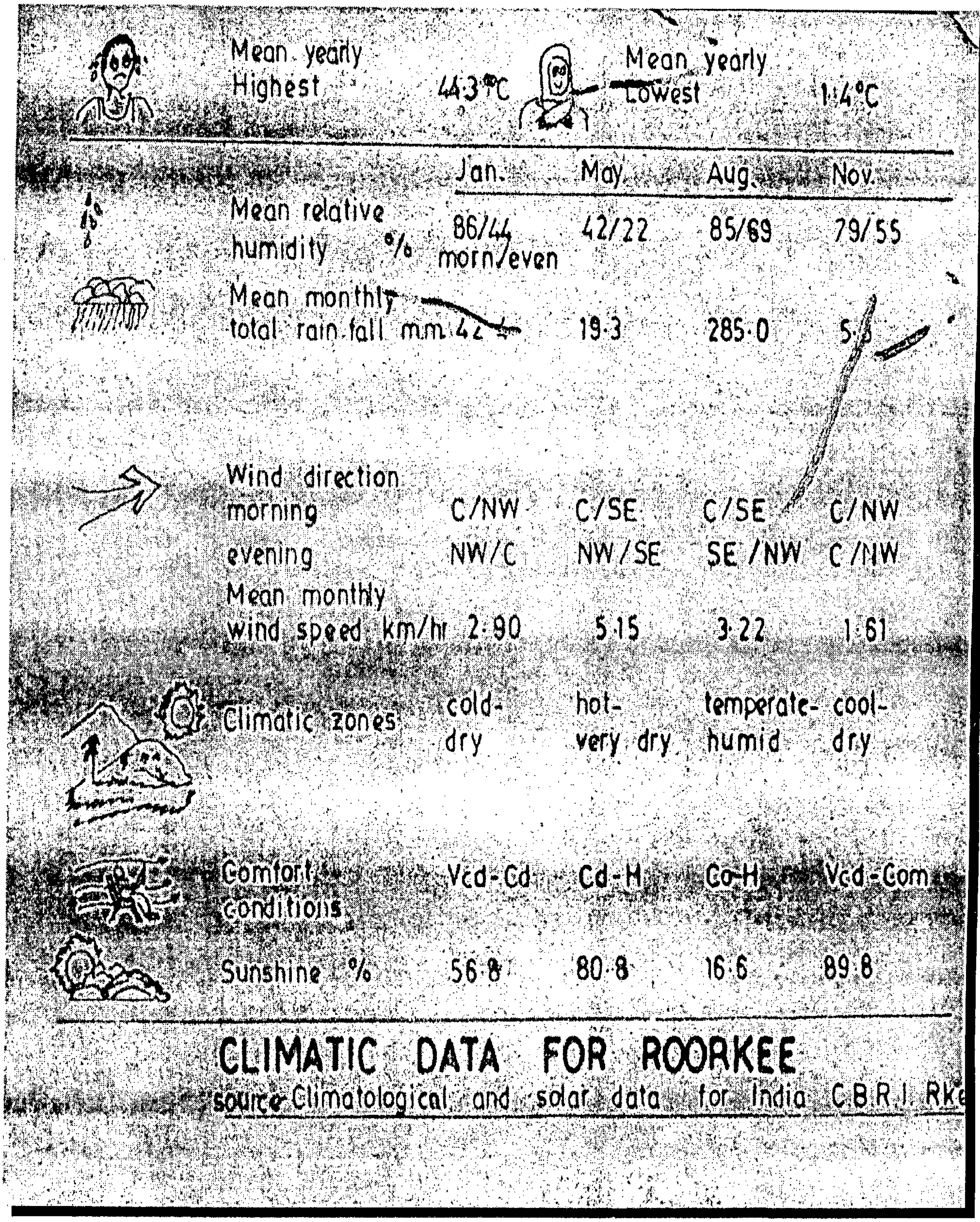


FIGURE 6.3: DIRECT SOLAR RADIATION ON CLEAR DAYS



Mean yearly Highest 44.3°C | Mean yearly Lowest 1.4°C

	Jan.	May	Aug.	Nov.
Mean relative humidity % morn/even	86/44	42/22	85/69	79/55
Mean monthly total rain fall mm	42	19.3	285.0	5
Wind direction morning	C/NW	C/SE	C/SE	C/NW
evening	NW/C	NW/SE	SE/NW	C/NW
Mean monthly wind speed km/hr	2.90	5.15	3.22	1.61
Climatic zones	cold-dry	hot-very dry	temperate-humid	cool-dry
Comfort conditions	Vcd-Cd	Cd-H	Co-H	Vcd-Com
Sunshine %	56.8	80.8	16.6	89.8

CLIMATIC DATA FOR ROORKEE

source Climatological and solar data for India C.B.R.I. Rke

FIGURE 6.4: CLIMATIC DATA FOR A CITY IN COMPOSITE CLIMATE

6.4 SITE CONSIDERATIONS

Before designing a dwelling unit, the study of the site is the most important aspect. The topography of the site, the texture of the land and the existing elements; trees, water bodies, hillocks etc. affect the microclimate of the site and the wind pattern, which directly affects the orientation and form of the dwelling.

6.4.1 TOPOGRAPHY OF THE SITE.

The topography of the site selected for the dwelling units plays a very important role in designing the most energy effective dwelling unit. The following two factors should be studied in detail before proceeding with the designing:

- **MACROCLIMATE OF THE SITE:** the land topography has the peculiar characteristics of the climate of the place. The macroclimate of the site should be studied so as to apply the design principles and achieve desired results. The contours, if any, should be studied and drawn since these will affect our planning and location of various areas within our site.
- **MICROCLIMATE OF THE SITE:** a small variation can be judged in the microclimate of the site. The study of the microclimate of the site is one other very important aspect which should be studied and considered while designing the dwelling unit. This study includes the study of the temperature variations in particular to that site because of the presence of any special features in its vicinity like a water body or marshy areas nearby or hillocks, if any.

6.4.2 OPTIMUM ORIENTATION

Orientation's role is very important in the designing of a dwelling unit which is both, energy efficient as well as comfortable. The diagram shows the sun path diagram observed at latitude 31 degree north.

The sun path diagram indicates the following points for a composite climate:

- The sun never comes in north.
- Duration of sunshine in peak summer season i.e. in June is 14 hours.
- Duration of sunshine in winter season i.e. in December is 10 hours.
- The altitude of the sun in summer is 82^0 and in winter 35^0.

Preliminary decisions that can be made by these points are as follows:

- The solar radiation when the sun is at zenith in summer should be minimized.
- The walls in northeast should have similar dimensions to avoid summer sun penetration in evening and morning.
- The walls facing south, southeast and southwest should have larger dimensions and fenestrations.

The wind pattern is from northwest and southeast. Southeast winds are desirable in all seasons, while the northwest winds are very hot in summer and cool in winter. Therefore, the orientation should maximize the proper utilization of the air movement.

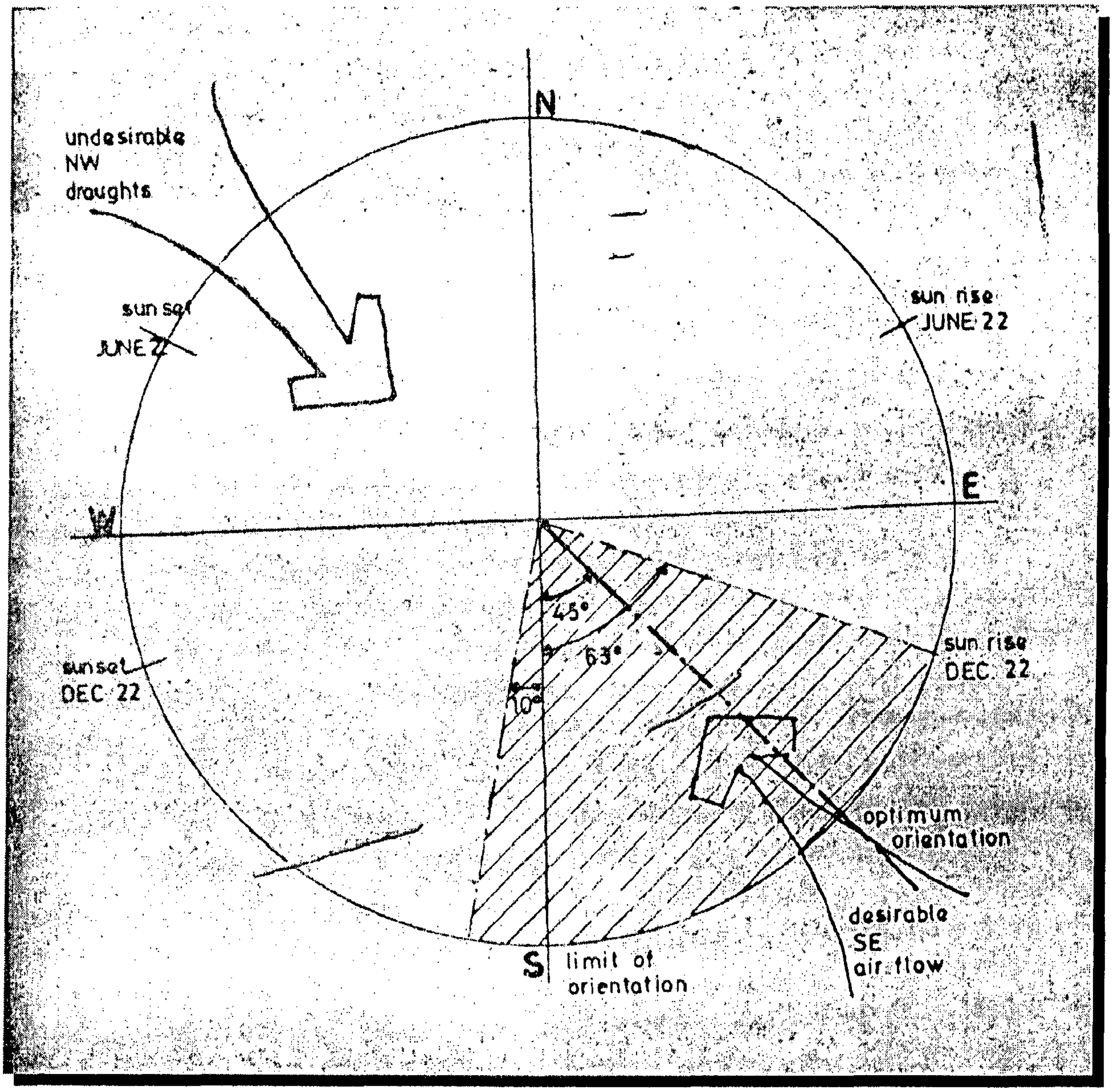


FIGURE 6.5: OPTIMUM ORIENTATION

6.4.3 SOL-AIR APPROACH

The heat radiation of the sun frame out the position of the dwelling. The winter sun at low altitude should be welcomed from south direction while the summer sun should be avoided in the evening from west. It gives an orientation limit of the dwelling from S63E to S10W and the optimum at S45E approx.

The orientation of S45E will reduce the penetration of cool air in winter season from northwest and also the hot air in summer. Further, the landscaping in northwest direction will help in improving the airflow and conditioning of air.

6.5 THERMAL CONSIDERATION

Thermal condition in any dwelling unit depends upon the following:

I. **Climatic conditions**
II. **Thermal performance of the walls**
III. **Thermal performance of the roof**
IV. **Thermal performance of the openings**
V. **Orientation of the rooms**
VI. **Shading devices**
VII. **Mechanical heating and cooling devices**

The retention of nighttime low wall temperature is desirable in the hot dry season only but the same thermal properties will be useful in the cold season to retain the heat of the day for the comfortable cold nights. Therefore, the thermal comfort should be achieved by constructing roofs and walls of solid masonry or concrete to have a 9 to 12 hours time lag in heat transmission. The thermal capacity will be of advantage in both the cold and hot dry seasons. The best arrangement is if the thermal capacity is provided in massive floors and partitions and ceilings, thereby permitting the outer walls to be used more freely for large openings.

6.5.1 THERMAL INSULATION

Heat insulating material can be applied externally or internally on the roof or ceiling respectively. 30 to 40% reduction in cooling load can be obtained in low rise buildings by light colored roof.

Use of thermal insulation is recommended on exposed walls only. Shading of walls is very effective and economical method of reducing heat gain. Cavity walls, hollow bricks, light weight materials like cellular concrete can also be used, provided structural requirement is satisfied. Light colored distemper can also be applied on the exposed walls.

6.6 FENESTRATION DESIGN

The three main aspects for which fenestrations are provided in the dwellings are as follows:

I. **The view point**
II. **Sufficient brightness of the interior**
III. **Proper ventilation**

The location of the fenestration is very important pertaining the available outside view. Appropriate fenestration for day lighting and ventilation with appropriate shading devices can conserve energy in a better way. Plenty of day light is available during most of the daylight hours which can be suitably utilized for providing natural illumination and hence for economizing energy consumption in daytime. Position and orientation of the fenestration improves the internal conditions with the airflow.

6.6.1 DAYLIGHTING

For providing good daylight for different works, C.B.R.I. Building Digest 82 by Dr. B.K.Saxena gives a simplified approach. Recommended daylight factors for the interiors of the dwellings be given in the table as for the Indian code of practice IS: 2440-1968. The table shows that maximum illumination is needed in the kitchen, less in study than bedrooms and living room. Therefore, the fenestration percentage will vary from 8% in living room to 10 to 12% in kitchen according to floor area and location of the window.

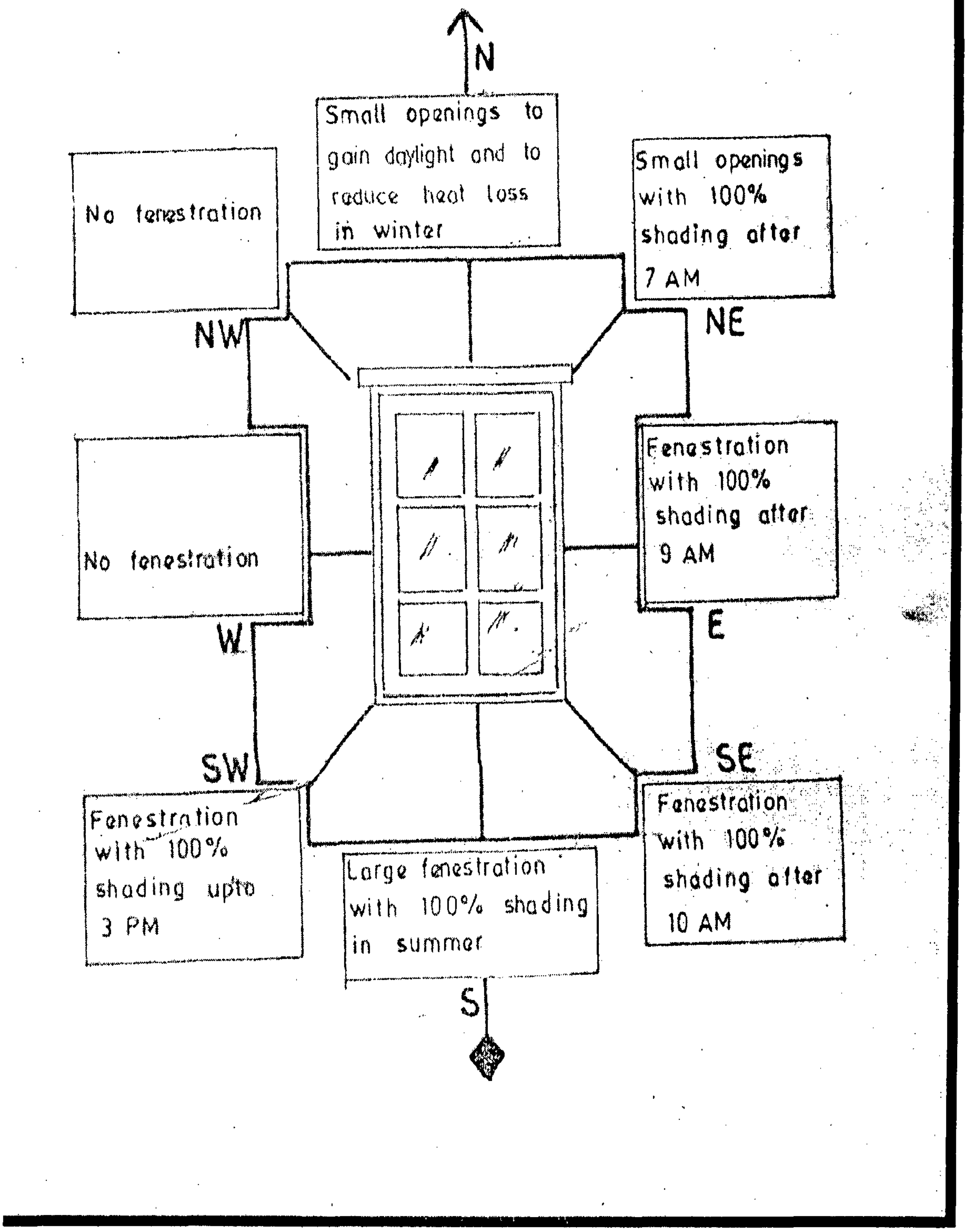
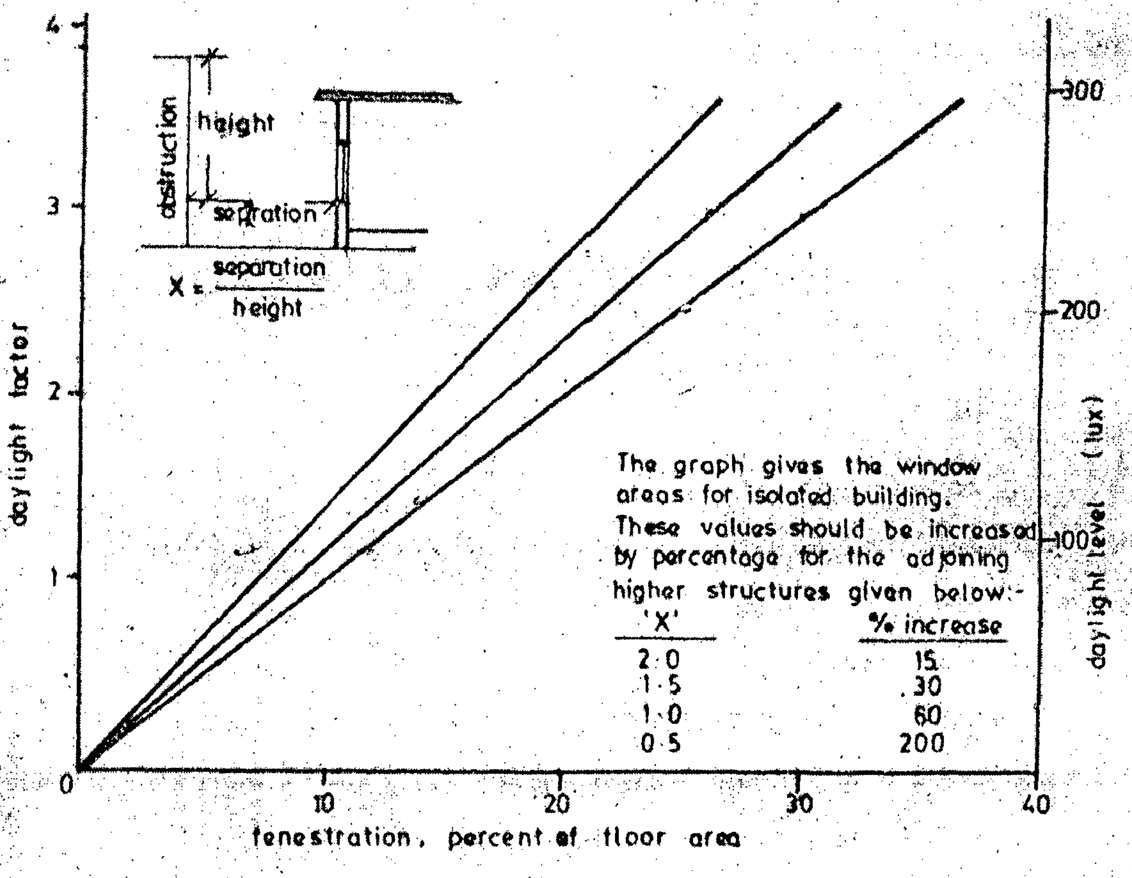


FIGURE 6.6: FENESTRATION DESIGN

RECOMMENDED (IS: 2440-1968) ILLUMINATION IN DWELLING UNIT

No.	space	daylight factor	lux
1.	Kitchen	2·5	200
2.	Living room	0·625	50
3.	Bed room	0·313	25
4.	Study room	1.9	150
5.	Circulation	0·313	25



WINDOWS FOR OPTIMUM DAYLIGHT

source: C. B. R. I. Building digest 129

FIGURE 6.7: WINDOWS FOR OPTIMUM DAY LIGHT

6.6.2 VENTILATION

Ventilation requirements should be satisfied during the hot dry season by special provision i.e. evaporative cooling, ventilating stacks etc. For promoting cross ventilation outlet openings of about the same order as inlet openings are recommended to be provided in the opposite walls.

Natural ventilation can be improved by the following:

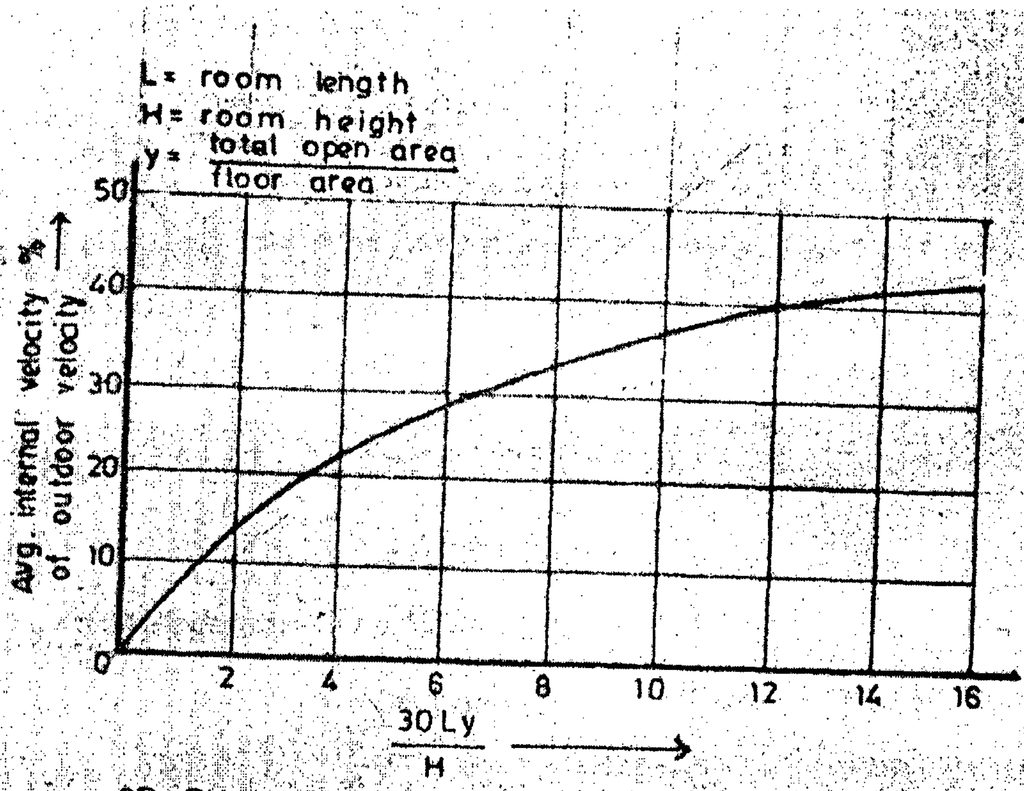
I. At least one window should be provided on the windward wall and the other on leeward wall.

II. Maximum air movement at a particular plane is achieved by keeping the sill height at 85% of the height of the plane. This also agrees with the recommended sill height for day lighting.

III. A room with only one exposed wall should have minimum two windows instead of a single window.

IV. Windows located diagonally perform well than any other arrangement.

V. The larger open area affects a little in the indoor average velocity of air. The fenestration recommended for the daylight fulfills the requirement of ventilation also i.e. 15 to 25% of floor area.



GRAPH FOR DECIDING THE OPEN AREA %

TABLE

dry bulb temp. °C	relative humidity %	desired wind speed km/hr
26·65	50	0·40
26·65	70	1·82
29·45	30	0·40
29·45	40	2·5
29·45	50	5·4
29·45	60	7·3
29·45	70	10·9
32·2	30	9·1
32·2	40	14·5

DESIRED WIND SPEED FOR COMFORT

source – Building Digest 49 C.B.R.I. Rke.

VENTILATION IN TROPICS

FIGURE 6.8: VENTILATION IN TROPICS

6.6.3 SHADING DEVICES

The shading devices help in reducing the gain of solar radiation in hot periods. The appropriate designed shading devices allow the winter solar radiation. Therefore, shading devices have a very important role to play. The shading devices also streamline the architectural shape and style of the building. In the composite climate, shading devices should be carefully designed and provided in the south direction to avoid the solar radiation in summer while permitting it in winter.

The shading time and type of shading device can be decided with the help of sun path diagram and the shading protractor. The graph in the plate gives the relationship of the horizontal/ vertical louvers with respect to the height/ width of the window. With the help of these graphs, a shading device can be decided for the required percentage of shading.

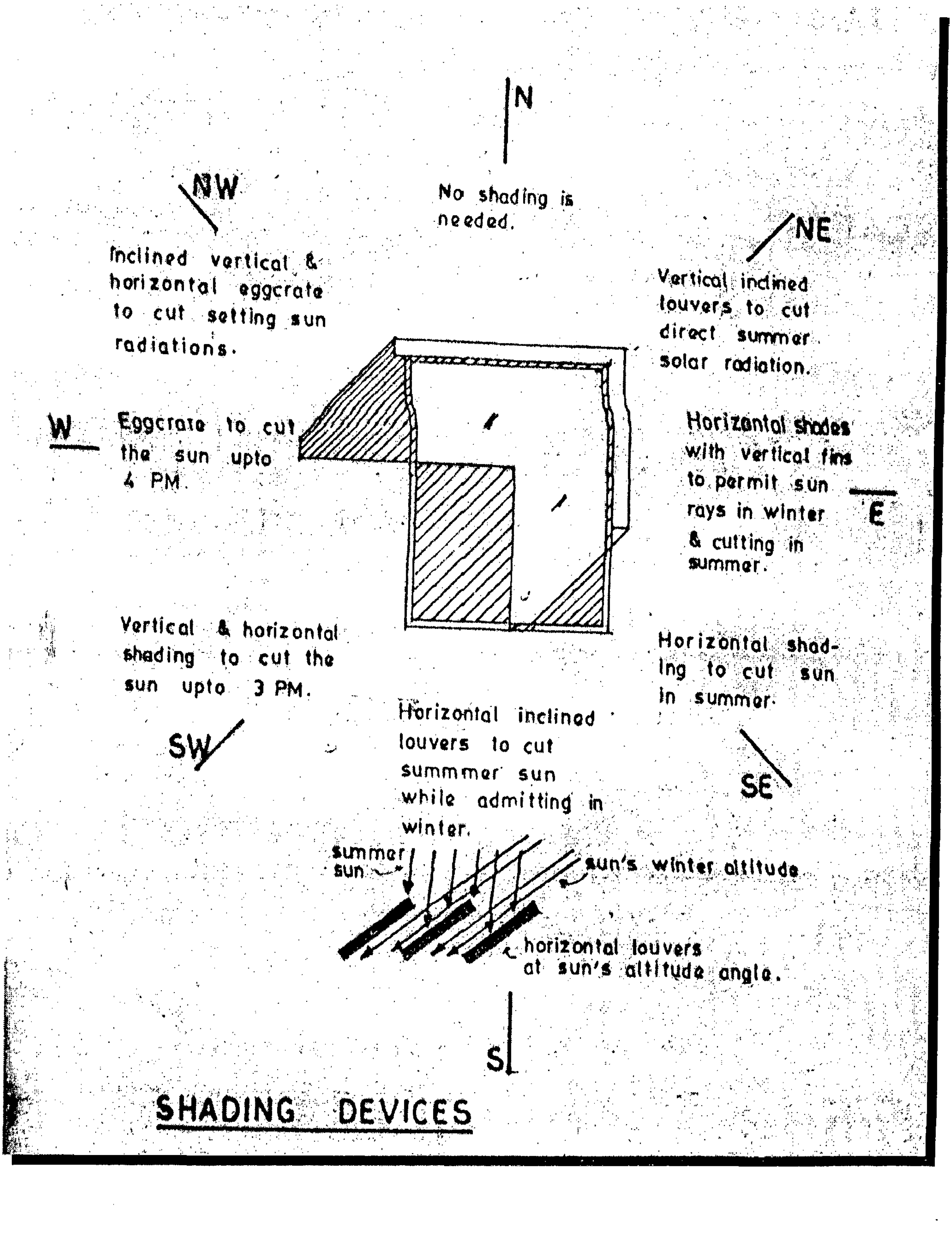


FIGURE 6.9: SHADING DEVICES

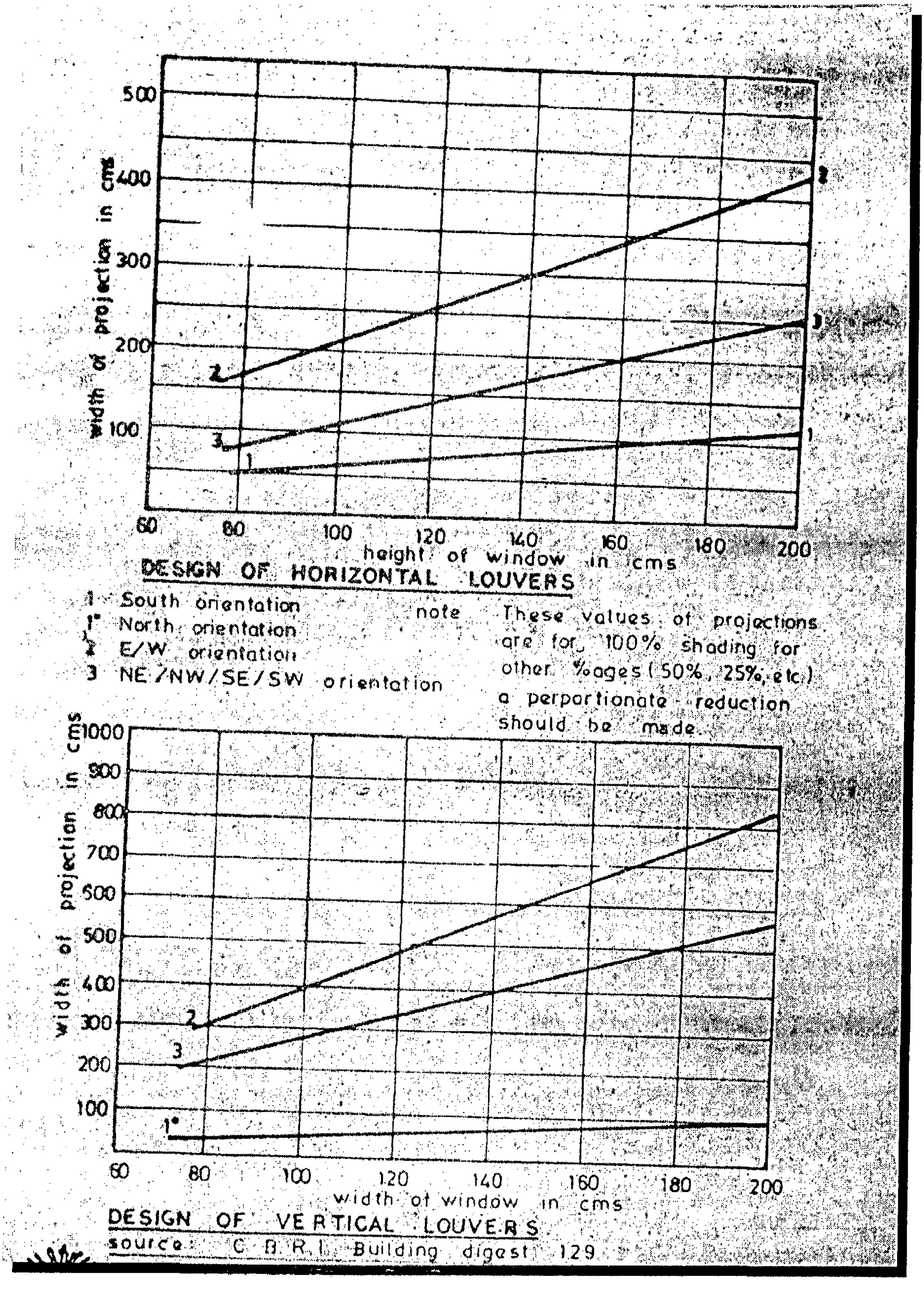


FIGURE 6.10: DESIGNING OF LOUVERS

6.7 SOLAR ENERGY UTILIZATION

Solar energy is a feasible alternative at the time when fuel costs are rising and energy shortage are predicted. The idea of using solar energy to heat and cool is not new.

Solar heating/cooling and domestic hot water systems, which are properly designed and integrated into the dwelling to use radiations effectively, can provide a large percentage of dwelling's space heating and cooling and hot water requirement. It is possible to achieve close 100% heating and cooling, however a more realistic and economically feasible goal, with given present technology would be 705 solar space heating and 90% solar water heating.

6.7.1 SOLAR COLLECTORS

There are numerous concepts for the collectors of solar radiations. These can be divided into two types mainly:

- **ACTIVE: when the solar energy is directly converted for use in the dwelling.**

The diagram shows the basic construction and principle of the non-focusing active solar collector. Three basic types of plate collectors have been discussed here:

I. Open water collectors, which are corrugated metal roofing panels, painted black and covered with a transparent cover sheet.

II. Air-cool collectors, this employs air or gas as transport medium.

III. Liquid cooled collectors; the liquid is heated as it passes through the absorber plate of the collector.

- **PASSIVE: where the solar energy is stored for using it when it is not available.**

Three basic passive solar concepts and often a combination thereof have been employed for the heating and cooling of buildings:

I. Direct gain, in this sunlight is admitted through a window to heat up the interior living space and is also stored in the internal thermal storage mass like floor, furniture, walls etc.

II. Indirect gain (thermos phoning), to minimize the indoor temperature fluctuation, the solar energy is stored in a large storing mass directly from the sun and gradually released to the interior space as and when needed, even during off sunshine hours.

III. Solar ponds, is a passive collector. It can provide for both cooling and heating.

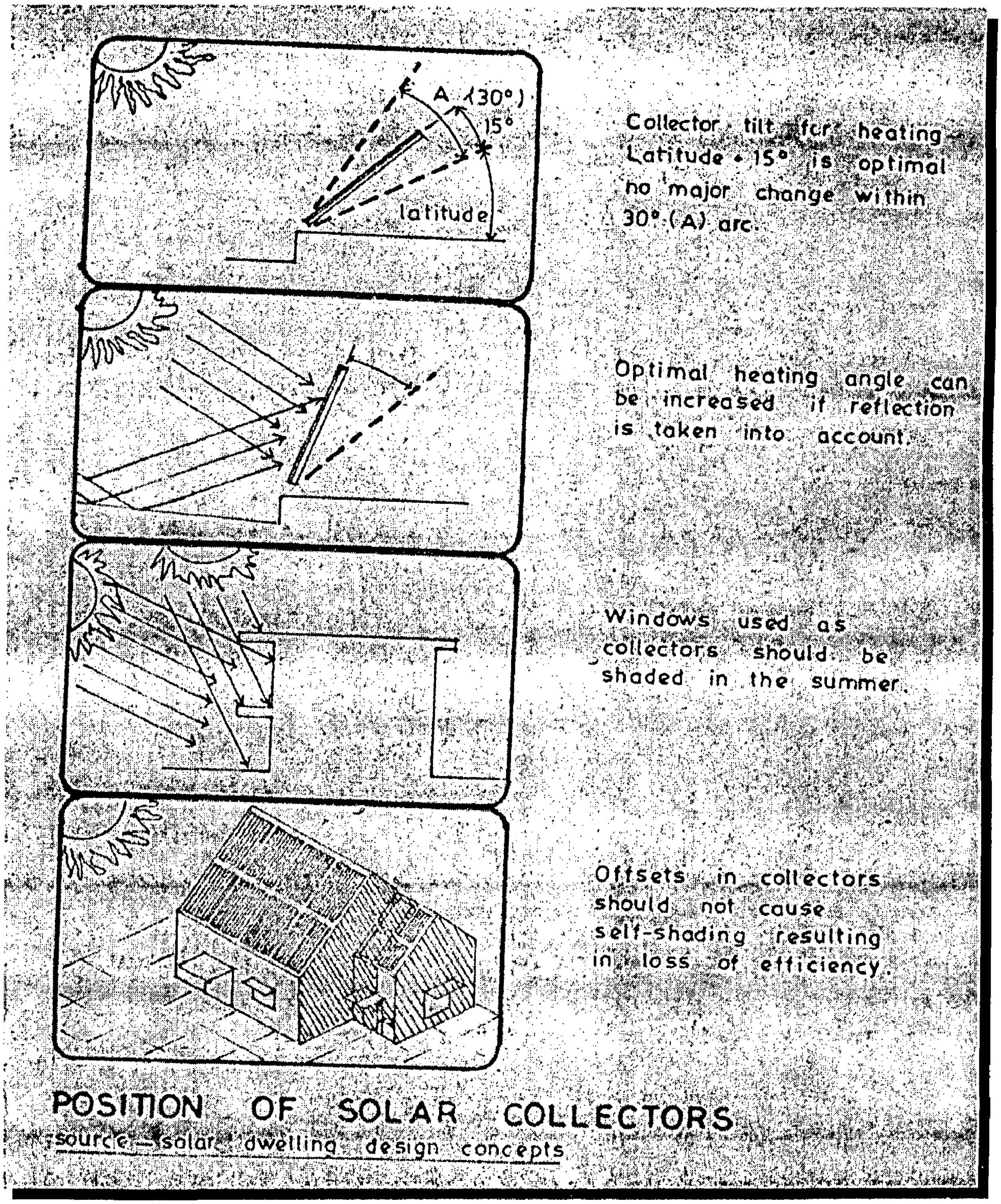


FIGURE 6.11: POSITION OF SOLAR COLLECTORS

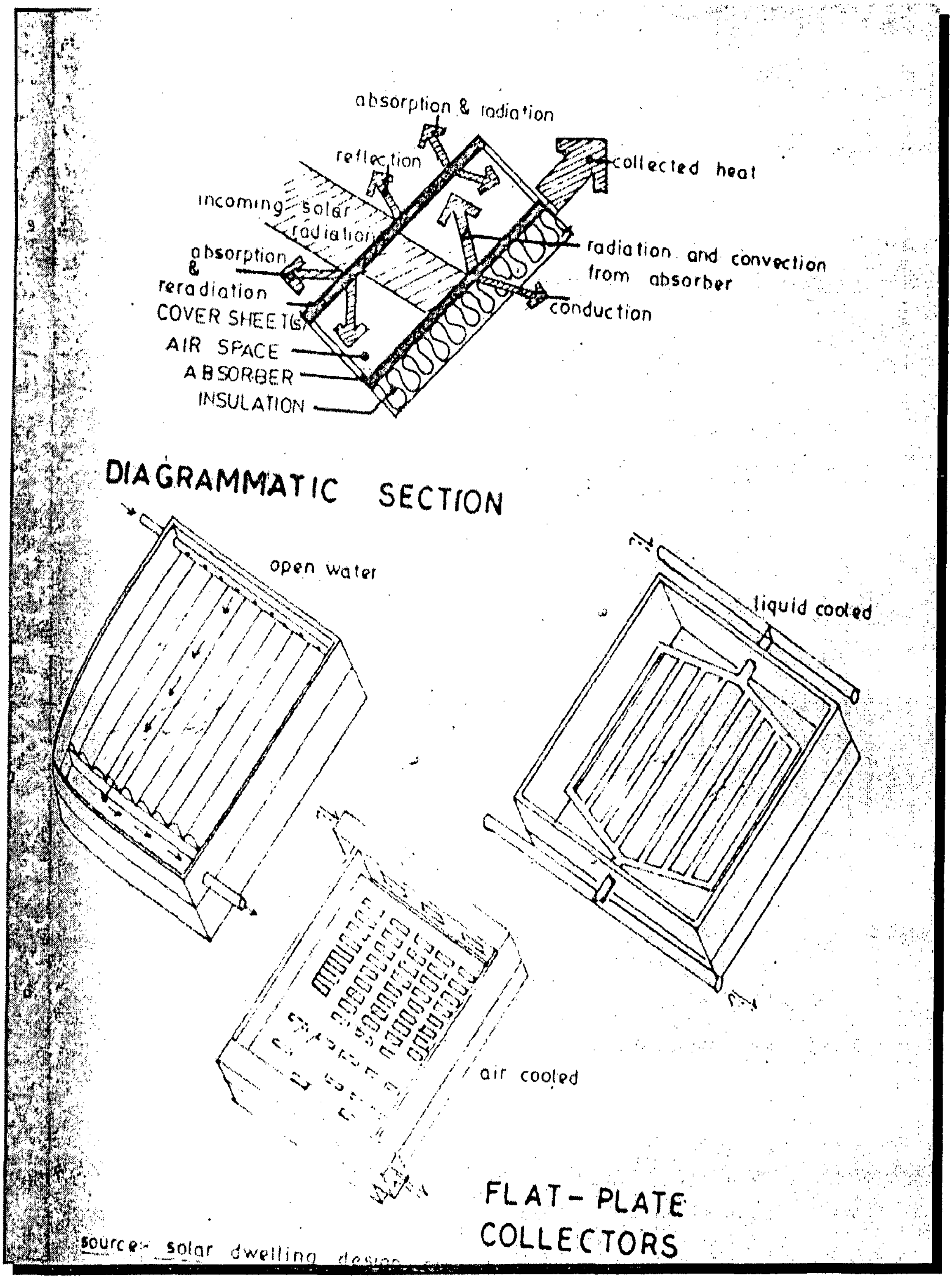


FIGURE 6.12: FLAT PLATE COLLECTORS

6.7.2 SOLAR COOKER

A large amount of energy in dwelling is utilized for the cooking purpose. A solar cooker is a good alternative for the energy conservation in cooking. The principle of the solar cooker is the same as for the active solar collectors. Now- a-days, with the support of the government policies, solar cookers are becoming very popular.

But there are some constraints in the use of solar cookers in the house:

I. The cookers are placed outside in the courtyard or on the terrace, therefore, it becomes difficult to prepare food in the summer days.
II. Always there is a chance for the disturbance and breakage due to easy reach of children or animals.
III. Needs special care if going out of station even for a small period.
IV. Not a regular feature of dwelling though being used regularly.

With these constraints in mind, it becomes necessary to accept the importance of solar cooker as an architectural aspect and important feature of a dwelling. A proper orientation of the kitchen or the location of the built-in solar cooker becomes necessary.

6.7.3 SOLAR WATER HEATER

Approximately 70 to 90% requirement of hot water can be satisfied with the solar water heater. The principle of heating water is same as for the solar collectors. The hot water system can be installed separately on the roof of the dwelling. It can also be constructed as a regular feature of the dwelling if properly integrated and oriented with the dwelling

6.8 SITE PLANNING FOR SOLAR ENERGY UTILIZATION

The building site is an extremely important solar design consideration, the conditions and characteristics of the building site will influence both- the dwelling and the solar systems design. Existing vegetation, geology, topography and climate are the primary site characteristics considered during the site planning and design.

Every building site will have a unique combination of site conditions. As a result the same dwelling placed at various sites will generally require completely different site planning and design decisions. Therefore, the site for a solar heated or cooled dwelling should be selected with care and modified as necessary to maximize the collection of solar energy to minimize the dwellings need for energy.

Site planning for the utilization of solar energy is concerned with two major issues:

1) **Access to the sun.**
2) **Location of the building on the site to reduce it's energy requirements.**

6.8.1 THE SITE

If an option for selecting a site or for determining the precise location on a larger site for the placement of dwellings is given to the builder, developer or designer, the following factors should be analyzed and evaluated carefully for effective solar energy utilization:

1) **Geography of the area surrounding the site.[**
2) **Topography of the site.**

3) **Orientation of the slopes on site.**

4) **Geology underlying the site.**

5) **Existing soil potential and constraints.**

6) **Existing vegetation.**

7) **Climatically protected area on the site.**

8) **Climatically exposed location on the site.**

9) **Natural access routes to and through the site.**

10) **Microclimate of the site:**

- **Solar radiation patterns on the site.**
- **Wind patterns on the site.**
- **Precipitation pattern on the site.**
- **Temperature pattern on the site.**

11) **Water or drainage pattern on or across the site.**

12) **Existing structure near to the site.**

Site analysis can be done through air photos, topographic maps, climatic charts or direct observations on the site.

A building is designed for the specific site on which it is to be placed. Site planning solutions are not easy to replicate because each site has a unique geography, geology and ecology. The most appropriate way to integrate any building and its site is first to analyze the site very carefully, and then place the building on the site with a minimum of disruption and the greatest recognition and the acceptance of the site's distinctive features.

6.8.2 LANDSCAPING

Proper shaping of the land and providing landscaping in phase with sun, wind and earth energies is a prudent design consideration. Landscaping in particularly, should be efficiently designed to supplement total solar energy planning.

Deciduous trees are especially valuable in landscape planning because they respond to seasonal changes by losing their leaves in winter for sun to penetrate and growing new ones in summer for solar shading. Deciduous trees planted on the south side of a building will provide seasonal solar control. Coniferous trees are a year round barrier to sun and wind. Conifers are especially beneficial on the north side of the building.

Topographic shaping of the land in conjunction with shading and surface coloring also has its own effects. The proximity of deciduous trees and other vegetation will shade landforms at certain times of the year. Earth shapes surfaced with highly reflective materials such as white marble chips, light colored gravels or light colored paving or paints, when carefully sized, contoured and located will increase solar gains in winter, onto the solar collectors or through south facing windows.

The type of vegetation used for ground cover and its location related to the building and air intake for ventilation has direct effect on energy consumption. The air temperature beneath broad-leafed ground covered lands is lower than ambient air temperature in hot weather. This results from shading and evaporating cooling effects. Air drawn into buildings from around this type of ground cover can be beneficial for cooling.

7. DISCUSSION AND CONCLUSION

The special features that can be adopted in any dwelling unit for energy efficiency can be summarized as follows:

PASSIVE SYSTEM

A common passive system is used for both heating and cooling in winter and summer respectively. A honeycombed brick duct can be attached with the drawing room and guest room at ground floor and two bedrooms at first floor. The function that this duct will serve is as follows:

WINTER: South-East facing solar collector heats the air and a fan at the top of duct forces the air into the duct to heat up the bricks. The duct is properly insulated to reduce the heat losses. The air is recirculated in the collector from the bottom of the duct. The stored heat in the thermal mass i.e. bricks can be used for heating at nights when solar radiation is not available.

SUMMER: same duct is also used for the summer by disconnecting the solar collectors duct from the thermal mass duct. The same fan can be used for the mechanical air-force in the duct. An automatic flush cistern frequently flows water over the bricks. The air, which passes over the saturated bricks become cooler due to evaporation outlets at the bottom of the duct, is used with dampers to regulate air inlet in the room.

ACTIVE SYSTEM

Direct active solar systems are used for heating of water and also for cooking food. Both are integrated within the building to form a regular feature of the dwelling.

In solar water heating system, the tank is paced at the top of the mumty so that the thermo siphoning action of the water due to hot and cold layers heat up the water automatically.

The solar cooker is placed at the landing level of the staircase so as to reduce the possibilities of shading. It provides safety to cooker as well as its users. To food to be cooked is kept from the inside part of the landing. An open able fenestration at top enables the cleaning of top surface of cooker and also to cover it for reducing the heat loss in night by convection.

EVAPORATIVE COOLING SYSTEM

For conditioning the hot air draughts from northwest, an evaporative cooling system is adopted. The hot air of summer passes through the two leveled shaded water ponds and gets saturated and cooled before entering the upper bedrooms.

OUTDOOR LIVING SPACES

The open terraces at upper level provide safe and cool sleeping space in summers when nights are quiet uncomfortable otherwise. Also, on these terraces the sunny days of winter can be enjoyed since we can soak ourselves in the sun lying there and carry out any activity, if need be.

CONCLUSION

Conservation in building is an important aspect which deserves special attention. The architect can play a vital role in the conservation of energy in building systems. By studying the various aspects of the dwelling unit, following conclusions can be drawn:

1) The microclimate of the area is an important parameter of dwelling design for energy effectiveness.
2) Architectural aspects such as orientation, form, site topography should be handled carefully while preparing a layout for either dwelling or colony.
3) Solar energy can be exploited fully with the proper design of active and passive systems.
4) It needs further study in the development of solar cooking and water heating processes.
5) Orientation directly affects the internal conditions like temperature, humidity, and ventilation etc., of the dwelling.
6) South orientation is optimum for the dwelling to allow for solar radiation to be maximum in winter and minimum in summer.

7) Orientation of the fenestration should be planned in such a manner so as to fulfill the comfortable conditions, for effective daylight use and proper ventilation as well as for psychological satisfaction.

8) Landscaping and topography of the site help in energy conservation by modifying the microclimate.

9) By using the active/passive solar systems, approximately 55 to 65% of the energy demand can be curtailed.

10) The initial expenditure on the construction may be higher due to the solar system incorporated in the dwelling, but it will directly reduce the life-time cost.

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New Delhi.