DESIGN GUIDELINES FOR GREEN HABITAT IN HOT AND DRY CLIMATE: SPECIAL REFERENCE TO NAGPUR CITY

A DISSERTATION

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

MASTER OF ARCHITECTURE

By

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CANDIDATE'S DECLARATION

I hereby certify that the work, which is being presented in the dissertation, entitled **Design Guidelines for a Green Habitat in Hot and Dry Climate: Special Reference to Nagpur City**, in partial fulfillment of the requirements for the award of the degree of Master In Architecture submitted to the Department Of Architecture And Planning, Indian Institute Of Technology Roorkee, is an authentic record of my own work carried out during the period from August 2004 to June 2005 under the supervision of Prof. Rita Ahuja, Associate Professor, Department Of Architecture And Planning, I IT Roorkee, Roorkee

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

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Place: Roorkee

This is to certify that the above statement made by the candidate Ms. Aabha L. Dongre is correct to the best of our knowledge.

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CERTIFICATE

Certified that this report titled **Design Guidelines for a Green Habitat in Hot and Dry Climate: Special Reference to Nagpur City** , which has been done by Ms. Aabha L. Dongre, in partial fulfillment of the requirements for the award of the post graduate degree in Master Of Architecture, in the Department Of Architecture And Planning, Indian Institute Of Technology Roorkee, Roorkee is the students own work carried out by her under my supervision and guidance .the matter embodied in this dissertation has not been submitted for the award of any other degree.

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AABHA L. DONGRE

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CHAPTER 1
INTRODUCTION

Introduction:

We are all building the body of civilization. The point of all shelter is to protect the human organism. It is not useful to construct our shelter out of materials that poison us, or to heat it or light it with an energy source that poisons our world. For this time being this is the only planet we have, and our bodies cannot easily survive without it. If we will care for it then it will care for us.

The built environment has a tremendous impact on the natural environment. However our buildings can interact more positively with environment if we pay special attention to preserving the site's integrity and natural characteristics, landscaping properly, and selecting materials that have lower embodied energy and those that are produced locally. Our ecological conditions that are specific to a projects location, designers can develop climate responsive buildings, resulting to buildings utilizing less energy and provides a high quality and comfortable environment to occupants.

Sustainable architecture basically comes down to three purposes - first, to advance the purely selfish motive of survival by a cooperation with nature; second, to build shelter in concert with ecological principles as part of this objective; and third, to address the deeper philosophical conflicts surrounding the issue of whether we really deserve the luxury of this existence, given our appalling track record of environmental abuse.

This dissertation is an attempt to show how the current trends in the practice of architecture are evaluated as actions of humankind, with reference to the impact they have upon our planet earth. And also by introducing **Green Architecture** into our conventional practices (old and new) how we can approach to holistic way of designing buildings, so that our buildings are an output of materials, building components and building systems integrated to minimize the impacts upon the environment and occupants of the building.

1.1 Identification of the problem:

From an ecological perspective, mainstream architecture for the past two decades has sent out all wrong messages. As a result of designers obsessive desire to maintain the stylistic imagery identified with the 20th century's industrial and technological dream, buildings have continuously displayed characteristics reminiscent of everything from factories to turbines, carburetors, oil derricks, ocean liners, rockets and space stations - in fact communicating a whole range of associations other than a connection with the earth itself. These machine age influences represent the profligate consumption of fossil fuel and a techno centric and anthropocentric view of the human habitat.

Particularly from 1970's to the present, the celebration of such high-tech features as exposed structural systems, vast expanses of plate glass, and cantilevered, titled, or skewed steel trusses has somehow become synonymous with a progressive look in architecture. Machine age imagery is also the antithesis of relevant architecture at the threshold of an ecological revolution. It can be safely predicted that, because of the urgency and increasing expansion of the environmental movement, architecture will probably change more radically over the next two decades than it has changed in the past 100 yrs. Far beyond the usual self-conscious motivations of the style and theory, the shape of buildings will finally be forced to respond to the demands of limited resources and earth - centric imperatives. Today as we have known that our stylistic commitments may be under attack - there is no reason why this revolution cannot be optimistically approached as the threshold of a great creative era. It has been a profound misjudgment on the part of the architecture profession that is at the root of the environmental problems we face today. By insisting a set of design standards divorced from ecological responsibility, architecture has forfeited its richest source of ideas, caused incalculable environmental damage, and failed to communicate with the very constituency it is obligated to serve.

The next decades but will surely produce consistently more dramatic evidence of environmental technology, the earth sciences, and natural landscape expressively transformed into an unmistakable architectural iconography for the Age of Ecology. Even the most advanced advocates of ecological design are still struggling with ways to integrate environmental technology, resource conservation and aesthetic content. With all three components in place, there is little chance for truly enduring architecture. A major factor contributing to the longevity of buildings that have survived form the past is their fusion of nature and art.

With our greed driven economies we began to believe in the illusion that nature could be conquered thru' science for the exclusive benefit of commerce.

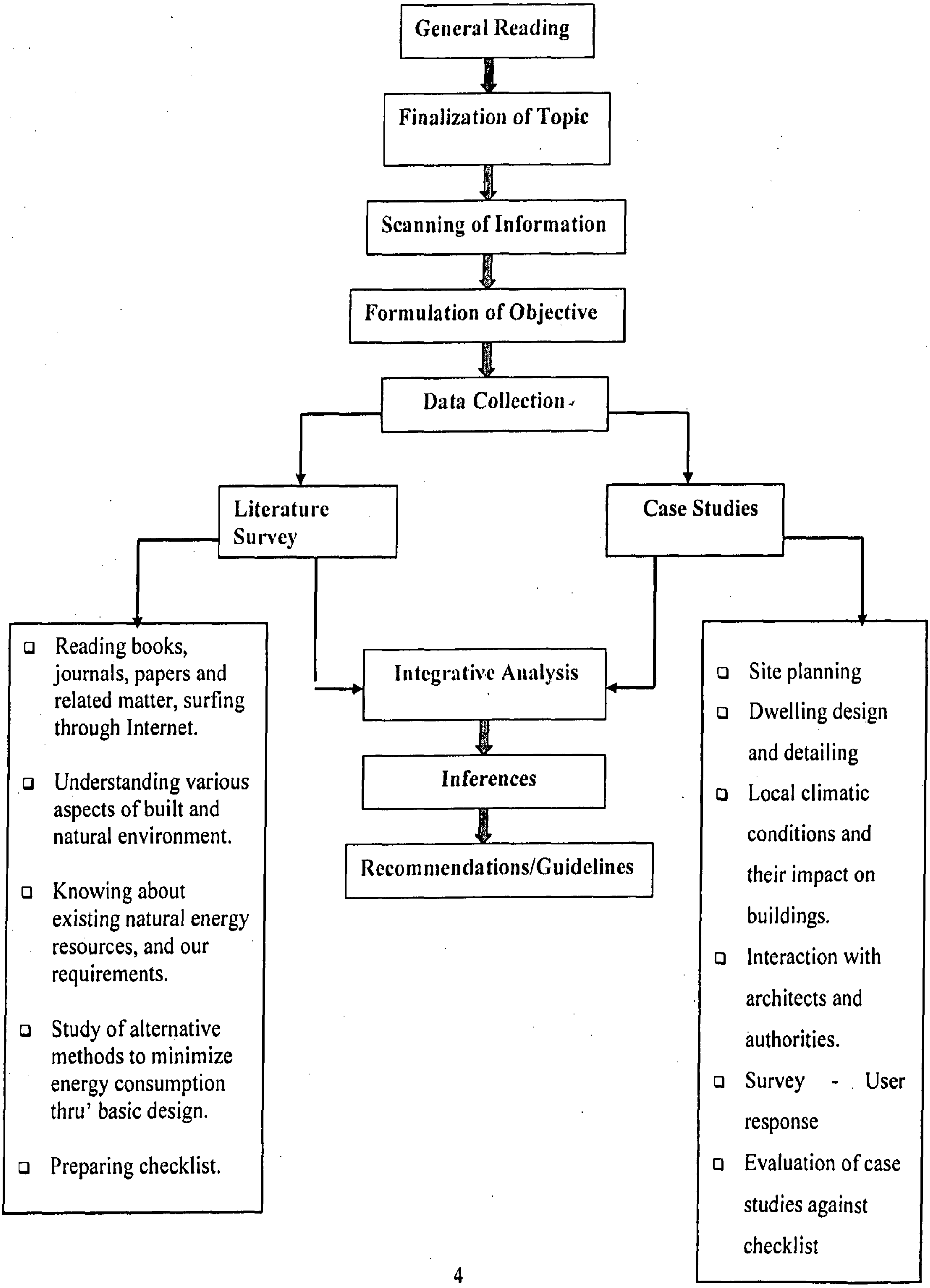
1.2 Objectives

- To critically analyze the extent to which the built environment is guided by the principles of **Green Architecture.**
- To give a holistic design methodology for making green buildings in Indian context, keeping in view the environmental, socio-cultural and economic aspects.
- Framing of design guidelines for Green residences in Hot Dry climates.

1.3 Scope.

Looking in to the vastness of the present research, the scope of dissertation focuses on the study of residential areas. The study shall be limited to single family residences.

1.4 RESEARCH METHODOLOGY



CHAPTER 2

ARCHITECTURE AND ENVIRONMENT

2.1 Transition of Architecture from Vernacular and Traditional, to the Modern Day Mechanized Form

With the exception of some technological advances, the strategies of energy-efficient design have existed for many centuries. Vernacular architecture provides many lessons in designing for specific climates. The igloo for example, utilizes the most available (and only) building material, snow and ice, and configures the architecture into the most heat-efficient shape, the spherical dome. This vernacular form of architecture was developed thousands of years ago by the Inuit as a matter of survival in the harsh climate of the arctic. Solar orientation, to take advantage of passive heating and cooling, as well as natural day lighting, was practiced by the Egyptians, Greeks, Chinese, Aztecs, Incas, and many other ancient cultures around the world.

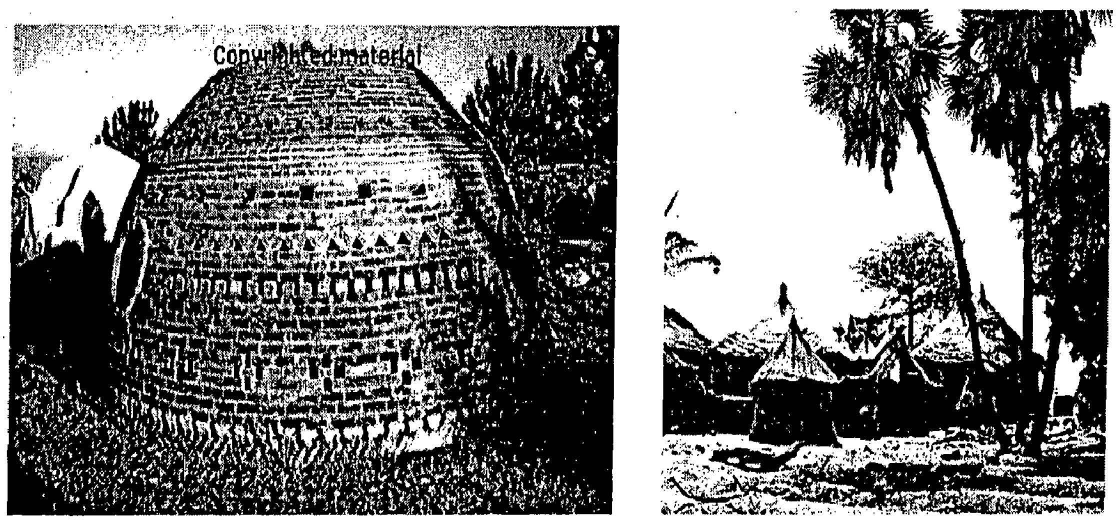


Fig. 01: Eathern shelters (10)

Right from the Stone Age and even before ever since human kind has undergone that transition or the metamorphosis, the development of human brain, from what we were to what we are today, very much different from the Neolithic man, man has been in search of or innovating methods and concepts for the development and survival.

Fig. 02: Eathern shelters (10)

The efforts for better and better survival necessitated the immediate action of new innovations towards managing a higher comfort level. Man has always been a technical animal and for that matter every living creature finds out the necessary technology for survival.

Our ancestors in spite of having no educational background or refined teachings have created marvels into architecture that still stand the test of times, unshaken and unharmed. The basic fact behind this being that they approached towards local factors to justify their needs. A methodology or system that works upon indigenous factors.

The traditional methods and materials that incorporated available stuff is still the best sustainable practice. The traditional or the local architecture does not get into issues like disturbing or destroying nature. It rather maintains harmony with nature in the sense of belongingness, considering every aspect that is land, topography, climate, etc.

It is therefore that our architectural wonders of the past have never incorporated any mechanical device for comfort ability criteria. Design and comfort ability governed each other. Therefore we see no intrusion of foreign attachments for the purpose. Buildings automatically responded to the climate variations and adjusted themselves to bring out the required comfort for the occupants. The system of construction, labor, material, skills, everything was native to the land the building belonged to. Due to the absence of foreign elements there was absence of hazards to environment.

With advent of machines, steam engine, transport conveyances, came up industrialization and flourished soon. This led to accelerate the innovations of various newer machines and also started the massing or the urban concentration. Technological innovations though facilitated many things but also did it allow man to conveniently go against the laws of nature.

With the onset of technology, the invention of air conditioning and furnaces, many of these practices were dropped. The illusion that fuel is cheap and abundant has caused the architectural field to use technology as a crutch in design. As a result, many buildings today depend on overpowering the natural forces of nature with technology rather than working in concert with it.

Sustainable architecture is not anti-technology; it simply calls for wiser design, which uses technology to augment the energy-efficiency of buildings instead of depending on technology alone. Green architecture, sustainable design, whatever the name, the new generation of architects must relearn and revive some of these age old lessons and adapt them to our modern world.

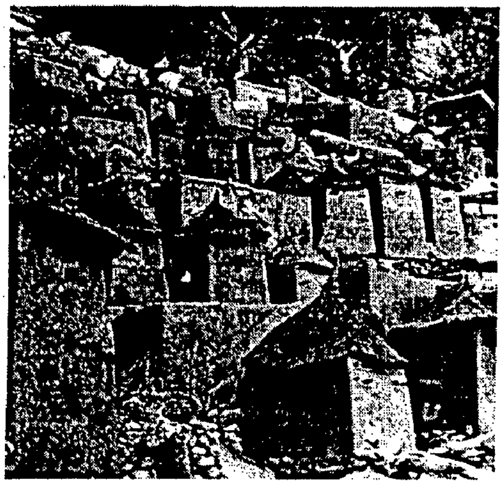
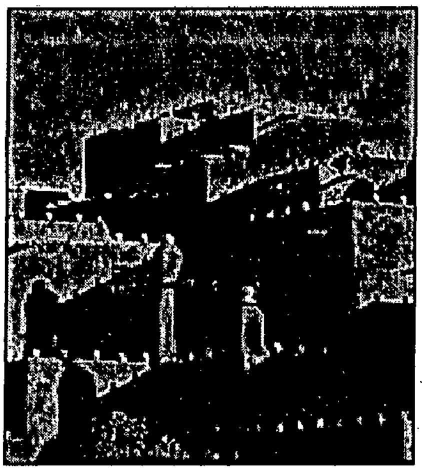
 

Fig 03 Earthen structures (10)

There are many wonderful building styles from all over the world that can inform us with their shapes, materials, arrangements, decorations, concepts for heating and cooling, etc. Vernacular architecture has been loosing ground over the last couple of centuries, as modern methods prevail. This is unfortunate since many of the old ways employ natural materials and simple concepts that are energy efficient. Also the buildings themselves are often beautiful. Perhaps you will find some ideas from among these pages to help with your own designs.

Why does the centuries old Amer fort in Jaipur, Rajasthan, seem so appropriate? Not because of its style but because it evolved out of its own habitat. The master builder, who was a local, had all the local data he needed to influence his design - climate, available materials, labour, culture and economy. Any building whose design is dictated by local conditions and gets to be an integral part of its landscape, can sustain itself for very long.

Traditional architecture not only represents technologies and practices best suited to local conditions, but is also in tune with the values intrinsic to the human condition: a concern for life, for beauty, for community. Here India has an embarrassment of riches, from the decorated mud villages of Kutch and Rajasthan to the desert city of Jaisalmer to the fishing villages of Kerala.

Present day architects face the challenge of being perceived as perfect consultants. They not only have to design aesthetic and functional buildings, but also have to be far sighted, with a view to creating buildings that last for at least 50 to 100 years. In this context, modern architectural standards, Green and Sustainable Design are two terms that are increasingly used interchangeably.

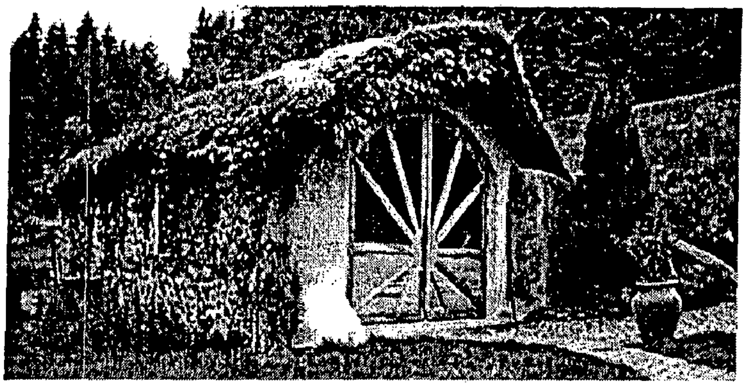


Fig 04 Green roof structure (15)

As far back as the nineteenth century, structures like London's Crystal Palace and Milan's Galleria Vittorio Emanuele II used passive systems, such as roof ventilators and underground air-cooling chambers, to moderate indoor air temperature. In the early twentieth century, skyscrapers like New York's Flatiron Building and the New York Times Building employed deep-set windows to shade the sun.

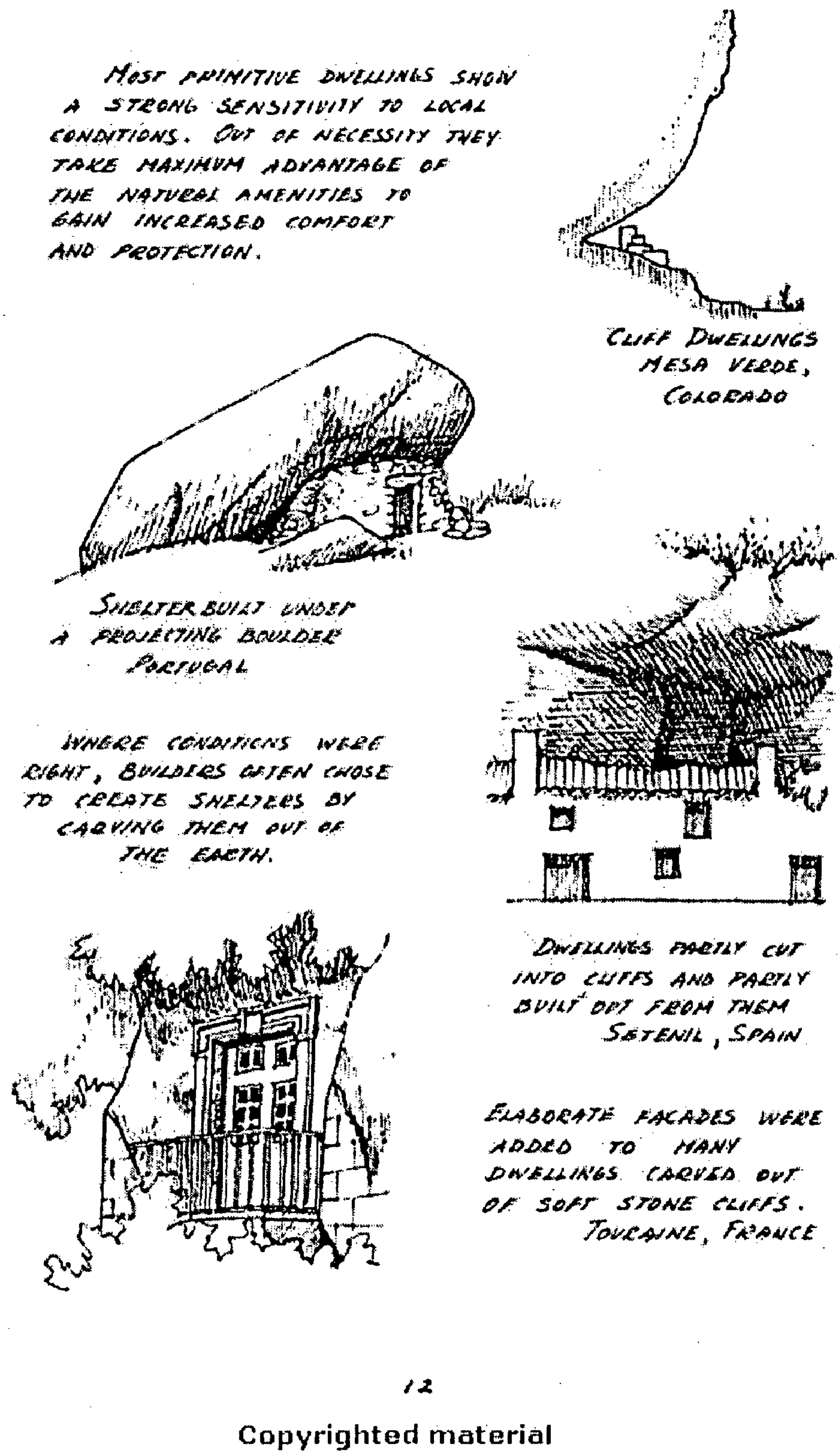


Fig 05 Shelter of the primitive man (10)

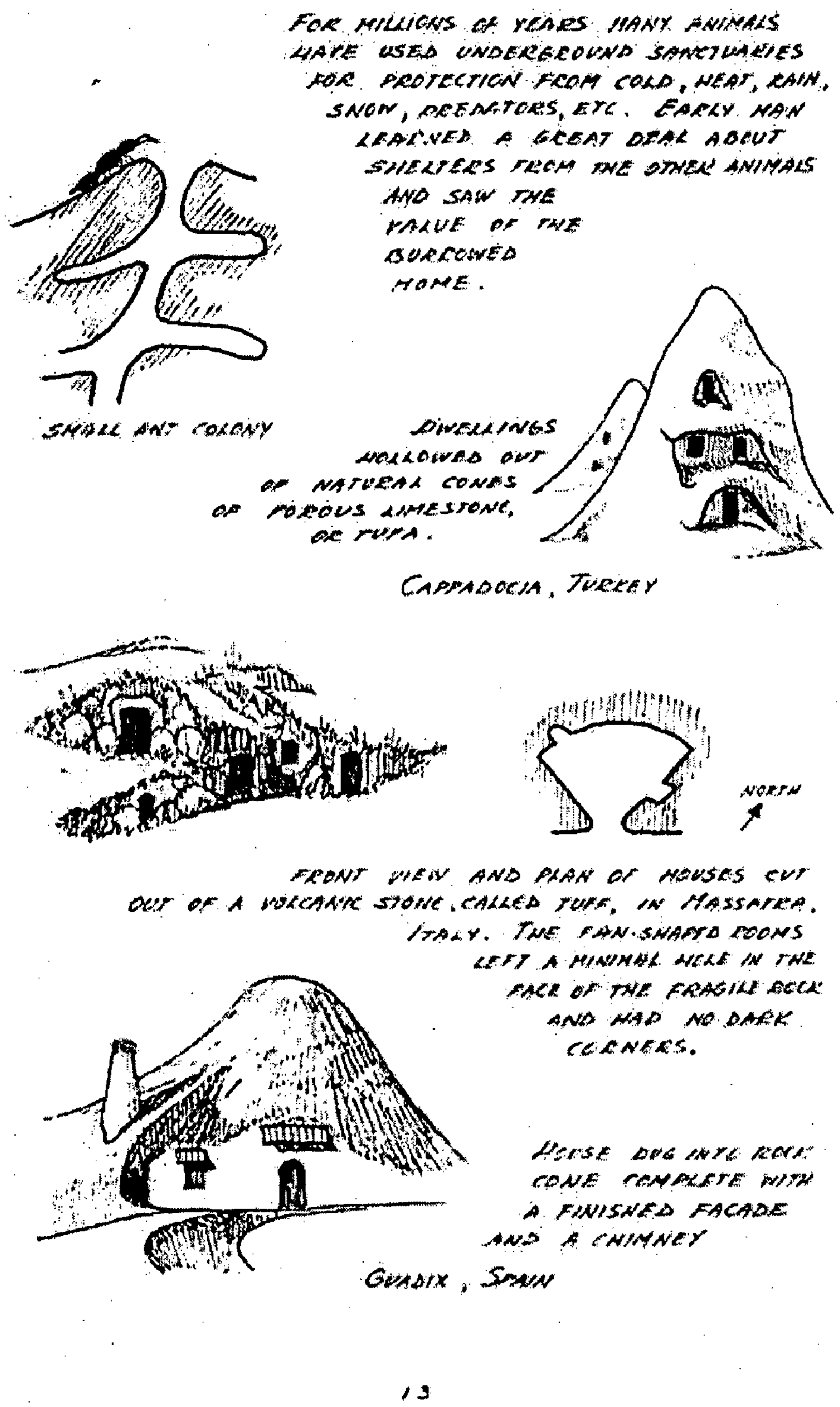


Fig 06 Early dwellings in natural form (10)

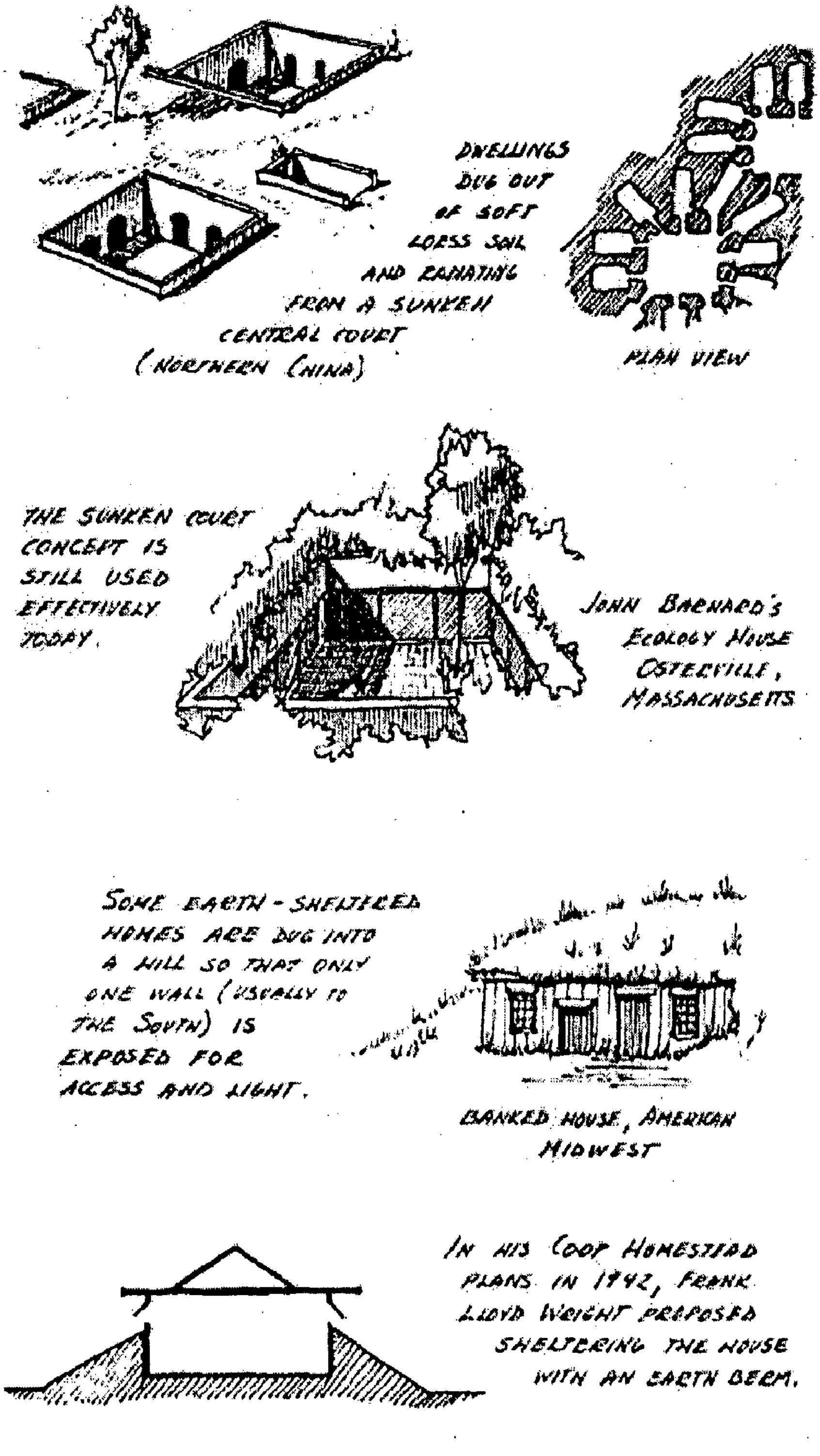


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Fig 07 Vernacular dwellings (10)

2.2 Impacts of architecture on environment

The whole world today harbors feelings of misgiving over the crisis facing the global environment and the general loss of our spiritual culture. Now, more than ever, it is time to return to our point of origin, to deepen our understanding of the environment and to correct our ways of mishandling the earth's forests and woodlands which play such an important role in shaping and developing the human spirit.

The cities of the twentieth century were built on a basis of function and rationality. Technological innovation and changes in social structure have caused an excess of people and things to become concentrated in urban areas. The entire world has generally shared the common belief that an economy-led society is the ultimate and desired direction. Driven by consumption, mankind has generated tremendous amounts of dynamic power, never before seen in our history, by converting the planet's irreplaceable fossil fuels and, in doing so; we have also released massive volumes of by-products into the air and the seas. We have also produced many non-biodegradable chemicals not found in Mother Nature.

The result of our attempt to use resources that have been the products of billions of years of solar energy within what is relatively a mere instant has been, conversely, to spew more substances and energy into the environment than the planet is capable of digesting, and this has thrown the entire global ecosystem out of balance.

All over the world we are finally beginning to recognize the threat that abnormal weather and pollution in the air, water and ground are posing to civilization. Economic development that wastes limited resources and destroys the environment brings only momentary prosperity; it lacks sustainability and threatens the very existence of future generations. Now is the time to change our consciousness in this regard and, focusing on solar energy, to come up with the appropriate means of utilizing our resources such as wind, water, and so on.

Buildings have diverse effects on the environment during their entire life cycles. Although the tangible impacts are visible only after construction begins, decisions made on the drawing board have long-term environmental consequences.

A majority of architecture students choose the field because of their artistic aspiration, and their primary interest is in form making. While students are generally sympathetic to the environmental cause, they may not be active environmental advocates. Thus, it is important to make them aware of the following:

1. Form-making (i.e., architecture) impacts local as well as global environments.
2. Their profession is responsible for some environmental problems.
3. They can contribute to a healthy global environment by practicing sustainable design.

The operating energy use in buildings represents a major contributor to fossil fuel use for space heating and cooling, lighting and the operation of appliances. Fossil fuels release greenhouse gases such as carbon dioxide and nitrous oxide. For this reason, the need to save energy by reducing operating energy consumption in buildings is widely recognized throughout the world. Less attention has been given to the need to reduce the embodied energy of structures because the amount of embodied energy is small in comparison to the amount of operating energy over a building's life cycle. Nevertheless embodied energy results in considerable emissions of water pollutants to our rivers and oceans and emissions of air pollutants contributing to air pollution and greenhouse gas emissions. There are complex issues surrounding the concept of sustainability. Immediate actions to address the environmental impacts of buildings and construction focus on the reduction of construction waste and the reduction of energy consumption in buildings.

In the process of changing our ways, we should focus on the natural cleansing effects and the power of self-regeneration found within thick, foliated woodlands and learn to use these limited resources carefully under the guidance of the earth's ecosystems.

Though it is troublesome to make biodegradable goods and to utilize natural energy in our present ways of life, it is not impossible. We have already developed sufficient technologies to effectively utilize Mother Nature while sustaining her unspoiled beauty, and now is the time for the entire world to awaken to the limits of our materialistic ways and to change our society as a whole.

2.3 Energy Issues in Buildings

Today's worldview of energy efficiency is very different from the energy conservation mentality of the 1970's, which is recalled by those of us who were around then as a time of long lines at the gas pumps and diminished comfort in our homes and places of work. The energy efficiency model of today involves benefits, not sacrifices. In environmentally effective (high performance) buildings, energy efficient design begins with a methodical reduction of the building's heating and cooling loads – those imposed by climate and those generated by people and equipment. With all loads minimized, mechanical systems are then selected based on highest output for lowest fuel consumption. The new efficiency means optimizing the performance of each of the buildings components and systems both individually and in interaction with other energy-consuming systems – air-conditioning, lighting, domestic hot water, etc. This is known as the practice of 'design integration.' In tandem with other energy efficient practices, building systems integration can provide excellent returns on the initial investment. Current practice also embraces the use of renewable energy technologies that reduce our reliance on fossil fuels and help alleviate carbon dioxide and other greenhouse gas emissions.

One-third of operating energy usage in the developed world goes for heating, cooling, lighting and the operation of appliances in non-industrial buildings such as homes, offices, hospitals and schools.

These estimates do not take into account the amount of embodied energy in building products and its impacts on the environment. Operating energy efficiency in residential and commercial buildings is greatly enhanced in highly insulated and airtight building envelope systems, high performance windows, high-energy efficiency heating, cooling and water heating equipment, low energy lighting and energy efficient home appliances.

Increased insulation in foundations, walls and attics, and insulated doors and windows reduces the operating energy in buildings. However the need for insulating products contributes to higher embodied effects. Wood is a good and natural insulator. Due to its cellular structure, wood traps air resulting in low conductivity and good insulating properties. Steel conducts heat 400 times faster than wood. High conductivity causes thermal bridging leading to increased energy use for heating and cooling.

Because steel and concrete must overcome lower R values due to thermal bridging, there is a need for additional insulation. Understanding the need to reduce operating energy in buildings and the importance of the embodied energy of structures leads to a more rigorous approach to sustainability. While it is easier to focus solely on the conservation of operating energy, the effects of embodied energy in structures, such as global warming potential, solid wastes, air and water pollution, are significant. Of the major building materials, wood requires the least energy to produce. The initial embodied energy in buildings represents the energy consumed in the acquisition of raw materials, their processing, manufacturing, transportation to the site, and construction. The initial embodied energy has two components. The direct energy, that is the energy used to manufacture and transport building products to the site and to construct the building. The indirect energy is the energy use associated with processing, transporting, converting and delivering fuel and energy to its point of use. The recurring embodied energy in buildings represents the non-renewable energy consumed to maintain, repair, restore, refurbish or replace materials, components or systems during the life of the building. As buildings become more energy efficient the ratio of embodied energy to lifetime operating energy consumption becomes more significant.

What the Building Community Can Do to Conserve Energy

From Union of Concerned Scientists at http://www.ucsusa.org/energy/index.html.

Town Planners

- Pay close attention to the layout of building lots to allow for solar orientation energy-efficient landscaping.
- Suggest the redesign of new developments and renovations that do not consider the simple principles of renewable energy.
- Assess how people will get to and from the development, or how effectively job and workplace opportunities are provided within the development.

Building Inspectors

- Educate builders and planners about the ideas presented in this paper. Your efforts will increase local expectations for energy performance.
- Enforce energy-efficiency standards.

Developers

- Develop energy-efficient buildings that take advantage of renewable energy opportunities. Doing so will increase the marketability of your product, help your customers save money, and contribute to a healthier environment.

Real Estate Brokers

- Promote energy-efficient buildings by educating the buyer and builder about the benefits of saving energy.
- Highlight desirable energy features when marketing buildings or developments.
- Emphasize the attractiveness and comfort of buildings that use renewable energy.
- Educate building trades people about the advantages of renewable energy
- Technologies and practices.
- Work with trades people who promote environmentally responsible building.
- Go beyond the energy codes in your community.

Builders

- Exceed local building codes in terms of insulation, windows, mechanical units, and construction quality.
- Educate owners, architects, inspectors, and others involved in the building trades.
- Use durable, healthy building materials that come from local sources.
- Minimize waste on the construction site.

Architects

- Become knowledgeable about design practices that incorporate renewable energy and energy efficiency.
- Educate clients and builders.

Suppliers

- Provide energy-efficient, healthy materials.
- Work to create a market for recycled products and renewable energy.
- Promote interest in energy efficiency with educational displays and special incentives.

CHAPTER 3

LITERATURE REVIEW

We are at the dawn of civilization where every act of humankind is going to be evaluated in terms of its impacts on the environment. After the energy crisis of 1970's we realized that, the rate of depletion of our natural resources is very fast due to our enormous extraction activity plus the regardless style consciousness exhibited by architecture of today.

Now that we realize, that our dreadful acts towards seeking luxury are going to exhaust our resources, there has come up a sudden rise in the research of eco-friendly solutions. These research going on round the globe have brought us into a pool of related terminologies like **Green Architecture, Green Building, Eco-friendly, Sustainable development, Environmental sustainability, Passive solar architecture etc.**

"The term passive solar architecture no longer defines the architectural needs of the day. Hence terms like climate-conscious architecture, bio-climatic architecture, energy-efficient architecture, and now, sustainable architecture, have rapidly found space in the vocabulary of architects and designers." --Ar.Sanjay Prakash, TERI (http://www.TERI.edu.in)

These terms are quite overlapping in their meanings and it depends on how we perceive them, or the context that we refer to.

"Architecture presents a unique challenge in the field of sustainability. Construction projects typically consume large amounts of materials, produce tons of waste, and often involve weighing the preservation of buildings that have historical significance against the desire for the development of newer, more modern designs." -- The Earth Pledge (http://www.earthpledge.org/)

3.1 DEFINITIONS:

3.1.1 Green Buildings:

Green buildings are buildings in which all of the materials and systems are designed with an emphasis on their integration into a whole for the purpose of minimizing their impact on the globe and on the occupants.

3.1.2 Green Architecture:

Green Architecture recognizes that buildings play a role in the environment, and that we have a responsibility as architects to conserve resources. So green architecture tries to optimize the performance of a building, to conserve important resources like water, land, and energy.

3.1.3 Sustainable Development:

"**Sustainable Development** is development which meets the needs of the present without compromising the ability of future generation to meet their own needs." -- World Commission on Environment and Development, 1987.

3.1.4 Sustainable Construction:

Sustainable construction is defined as "the creation and responsible management of a healthy built environment based on resource efficient and ecological principles".

3.1.5 Sustainable building:

"**Sustainable building**" can be defined as those buildings that have minimum adverse impacts on the built and natural environment, in terms of the buildings themselves, their immediate surroundings and the broader regional and global setting.

3.1.6 Ecological building:

A movement in contemporary architecture that aims to create environmentally friendly, energy-efficient buildings and developments by effectively managing natural resources.

3.2 Built and Natural environment:

The design, construction, and maintenance of buildings have a tremendous impact on our environment and our natural resources.

The design, construction, and maintenance of buildings have a tremendous impact on our environment and our natural resources. The challenge is to build them smart, so they use a minimum of nonrenewable energy, produce a minimum of pollution, and cost a minimum of energy dollars, while increasing the comfort, health, and safety of the people who live and work in them.

3.3 Buildings as a major source of pollution and depletion of resources

Further, buildings are a major source of the pollution that causes urban air quality problems, and the pollutants that contribute to climate change. They account for

- 49 % of sulfur dioxide emissions,
- 25 % of nitrous oxide emissions,
- 10 % of particulate emissions.

All of which damage urban air quality. Buildings produce **35 % of the country's carbon dioxide emissions**—the chief pollutant blamed for climate change.

Present day architects face the challenge of being perceived as perfect consultants. They not only have to design aesthetic and functional buildings, but also have to be far sighted, with a view to creating buildings that last for at least 50 to 100 years. In this context, modern architectural standards, Green and Sustainable Design are two terms that are increasingly used interchangeably.

The construction and operation of buildings consume the majority of the worlds Natural resources and energy, and contribute the bulk of landfill waste. Thus, development of sustainable habitats becomes a key solution to resolve growing concerns.

GLOBAL POLLUTION	
POLLUTION	**BUILDING RELATED**
Air quality (Cities)	50%
Global warming gasses	40%
Drinking water pollution	40%
Landfill waste	20%
CFCs / Huffs	50%

Table 01: Building related global pollution (3)

GLOBAL RESOURCES

RESOURCES	BUILDING USE
Energy	50%
Water	42%
Materials (by bulk)	50%
Agricultural Land Loss	48%
Coral Reef Destruction	50% (indirect)

Table 02: The amount of global resources which buildings use (3)

Pollution and Depletion:

- 70% of surface water resources in India suffer from pollution due to various reasons.
- Domestic and urban sewage contribute to 90% of the pollution.
- At present India emits 0.2 metric tons of carbon per capita, against the global average of 1.2 metric tones of carbon per capita.
- The green house effect and the depletion of stratospheric ozone have been recognized as the major potential environmental problems.
- The build-up of green house gasses will raise the earth's temperature by 1.0 to 3.50 degree Celsius by the year 2100 AD.

- An increase in the housing activity has already put an immense pressure on our dwindling energy sources and other vital resources like water, which has lead to increasing environmental degradation.

3.4 Eco –Technology

Today we have a unique opportunity to use a whole new range of environment-friendly technologies in our cities. Efficient energy systems, such as combined heat and power generators, fuel cells and photovoltaic modules are now available. New materials and concepts of architectural design allow us to greatly improve the energy performance, and to reduce the environmental impact of materials used in buildings.

Recycling technologies can facilitate greater efficiency in the urban use of resources. Transport technologies are also undergoing a major overhaul. Fuel-efficient low emission vehicles are at an advanced stage of development. Rapid urban transit systems are starting to reappear, which would reduce the dependence on private transport.

The cities worthy of the new millennium will be energy and resource efficient, as well as culturally rich and socially responsible.

3.5 Energy sources

The sun, wind, earth, and water are the primary energy sources of the world. The energy crisis of the 1970's jolted the world into greater awareness for alternative energy development. We have to realize that solar energy is the only source of our past and future energy.

Passive design of buildings for climate comfort is not only essential for a conducive environment, but also important to save demands of energy, particularly electrical power. With a proper approach and a comprehensive strategy, energy efficiency and economy can be achieved. These can be summed up as: architectural design, integration of architectural design with lighting (both day lighting and artificial lighting) and lighting technology.

India is endowed with an abundance of the sun; however, its potential in producing energy is still to be explored. In a cloudless region, a roof area of 100sqm receives about 500kw per day from eight hours of sunshine.

Photovoltaic power generating systems can be used in remote electric supplies for water pumps, electric fences, communications and navigation equipment; stand alone power systems for consumer products like calculators, radios, etc.

Wind power which is inexhaustible and non-polluting, is a promising way out of the energy crisis. Large windmills are capable of generating 10,000 or more kilowatts of electric power. Already new types of vertical axis wind-turbines have been designed and installed in various parts of the country, which are producing electrical energy and being utilized for grinding and to pump water.

Similarly, flowing water can be used as a source of energy. If the site has a running stream, it can run a mini powerhouse to generate electricity by turning a turbine.

3.6 Rainwater harvesting

India having a total geographical area of 329 million hectares has an extraordinary diversity of eco-systems. Most parts of the country are endowed with the monsoon season of the rainfall. Rainwater has always been considered as an asset, which was treated with respect and preserved with care. This is evident in the numerous lakes, ponds, wells, tanks, channels, and canals found all over the country. However, during recent times, the concept of water shortage has remained neglected, resulting in severe shortage of water and ecological imbalance.

The concepts of zero-run off with a series of retention ponds, balancing reservoirs provides an economical and pragmatic solution to drainage and water harvesting.

Various methods like underground rainwater storage, step wells, on-channel storage, canals, and etc. can be adopted for rainwater harvesting at the project level, depending upon the ground contours, rainfall and requirements, vis-à-vis economic consideration. For a building project, underground rainwater storage together with a step well can be a pragmatic solution.

3.7ResourceConservation:

Conserving resources is a cornerstone of green building techniques. There are many ways to conserve resources during the building process. For example, selecting materials that have at least some recycled content can conserve natural resources and virgin materials. Minimizing construction waste can ease the impact on landfills and resources. Installing water- and energy-efficient products can conserve resources while reducing operating costs. Choosing a green (plant-covered) roof can reduce energy use, cool urban heat islands, and prevent storm water runoff, as well as contributing to wildlife habitat and air quality.

3.8IndoorAirQuality:

Energy-efficient buildings are more airtight and therefore hold greater potential for indoor air quality problems, especially if not properly ventilated. Building products can contribute to poor air quality, but selecting materials lower in chemicals and toxins, and installing mechanical ventilation systems to ensure an adequate fresh air supply can reduce these potential problems.

3.9 Major areas in green architecture:

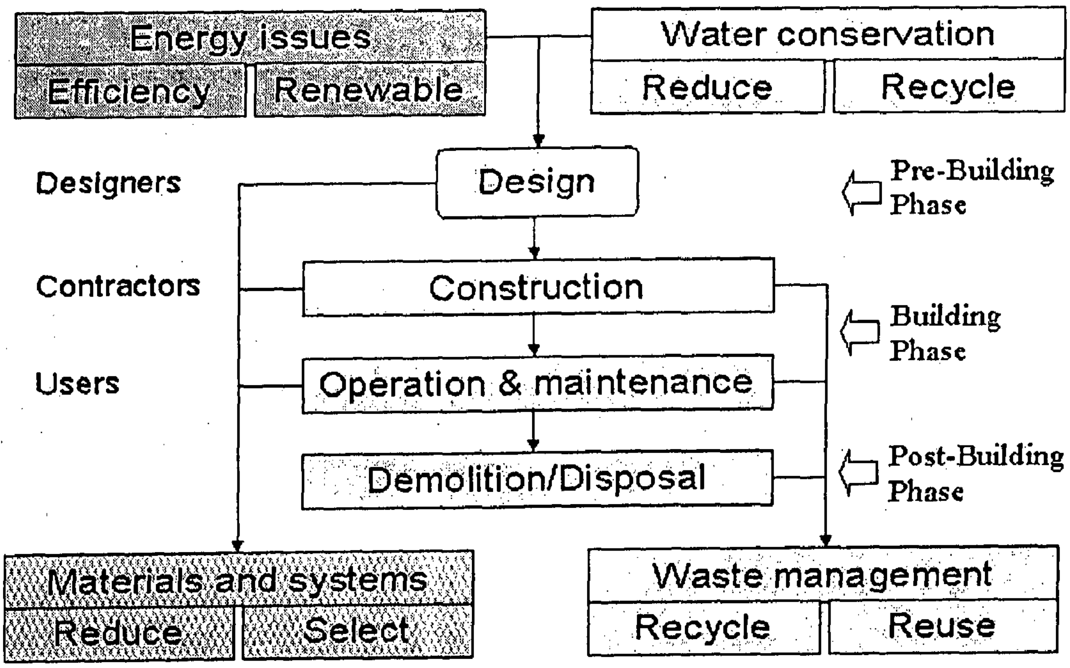
Environment	Building Fabric	Building Technology
Air	**Facade and roof**	**Cooling energy**
Free air	Transparent insulating material	Direct
- Natural ventilation	Photovoltaic	- Electrically driven chiller
- Wind force	Absorber surface	- Absorption chiller
- Energy content	Storage masses	- Gas-motor driven chiller
Stack effect	Planted surfaces	- Cooling towers
- Solar energy, diffuse radiation	Rainwater	Indirect
- Solar energy, direct radiation	Daylight elements	- Cold storage in building
	Collectors	- Cold storage in terrain
Soil	**Construction**	**Heat energy**
Aquifer	Storage masses	Direct
- Heat storage	Passive solar absorber	- District heating
- Cool storage	Heat exchanger elements	- Boiler (gas, oil, coal, biogas, condensing)
Groundwater	Night cooling by outside	
- Cold energy		

- Heat energy Earth/rock - Geothermal cooling - Heat energy **Water surfaces** Lake - Pump water or grey water - Heat energy - Cold energy River - Pump water or greywater - Heat energy - Cold energy Sea - Pump water or greywater - Heat energy - Cold energy	air **Atria** Green zones Evaporative cooling Passive solar energy Heat buffer	- Electric boiler (with storage) Indirect - Solar thermal system - Combined heat and power (CHP) - Heat pumps - Flue gas heat exchanger **Electrical energy** Mains supply - Commercial power supply utilities Self supply - Combined heat and power (CHP) - Emergency generator - Photovoltaic - Tandem system - Wind energy generator **Water** Pure water - Public supply (drinking, cooking) Greywater - Waste water (condenser water, flushing, cleaning) Rainwater - Flushing, cleaning, cooling

Table 03: Major areas in green architecture (6)

Green Features		
Manufacturing Process (MP)	**Building Operations (BO)**	**Waste Mgmt. (WM)**
Waste Reduction (WR)	Energy Efficiency (EE)	Biodegradable (B)
Pollution Prevention (P2)	Water Treatment & Conservation (WTC)	Recyclable (R)
Recycled (RC)	Nontoxic (NT)	Reusable (RU)
Embodied Energy Reduction (EER)	Renewable Energy Source (RES)	Others (O)
Natural Materials (NM)	Longer Life (LL)	

Table 04: Green features in buildings (6)



Process of sustainable development (6)

3.10 Energy intensiveness of materials:

The energy intensiveness of materials can act as a rough guide to the "greenness" of buildings. The more it is refined, the more energy it contains. However to judge the energy content of materials of a building their weight together with their energy content must be carefully calculated. The following is an attempt to put values to energy intensiveness, so that materials can be ranked.

Materials	Energy content: kWh/kg
Low energy materials	
Sand, gravel	0.01
Wood	0.1
Concrete	0.2
Sand-lime brickwork	0.4
Lightweight concrete	0.5
Medium energy materials	
Plasterboard	1.0
Brickwork	1.2
Lime	1.5
Cement	2.2
Glass	6.0

Porcelain (sanitary ware)	6.1
High-energy materials	**Energy content: kWh/kg**
Plastics	10
Steel	10
Lead	14
Zinc	15
Copper	16
Aluminum	56

Table 05: Showing energy intensiveness of various materials

3.11 Stages when green design can be incorporated

At any stage, though it would be best to incorporate green elements right from the planning stages itself. This is a more economical way of going about it.

Trying to incorporate green design elements into a conventionally designed building may be somewhat more expensive, since it invariably involves correcting some features. So you either plan from the first to do it right or pay extra later for correcting it.

3.12 'Green design' concepts can be divided into five areas:

- Site & Land use [including transportation issues],
- Energy Efficiency,
- New bio-sustainable materials,

- Indoor ecology,
- Waste recycling.

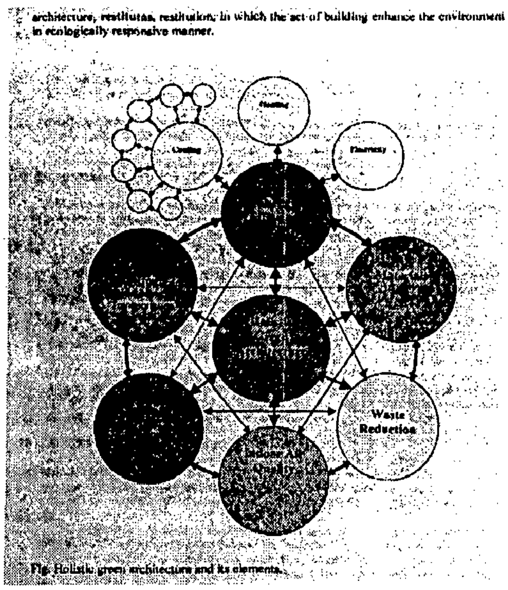


Fig 08 Green architecture and its elements (4)

3.13 Environmental dimensions of sustainability

- Reduced waste, effluent generation, emissions to environment
- Reduced impact on human health
- Use of renewable raw materials
- Elimination of toxic substances

Environmental sensitivity means paying attention to the materials and systems that go into your building, orienting it to take full advantage of the site, and planning for the future.

Sustainable design at a macro level has to be region based - example, water conservation in the Kurnool region of A P may be the top priority, where as, in the costal Andhra region would definitely be site preservation form soil erosion may. This does not mean giving anything up; but improving the built environment. Sustainable sites here would include measures to prevent soil erosion and promote rainwater harvesting.

3.14 Affordability

Sustainable design should be equally applicable to low-cost housing and high-end, custom designed houses. Low cost local material and proper planning and design can achieve the same effect.

A carefully designed building also reduces long-term maintenance and operational cost on materials used. Hence, the cost incurred for adopting these methods is generally recovered in the first year itself through lower bills.

Energy conservation with the use of world-class energy efficient gadgets and on-site renewable energy can be practiced. In an industry that claims about 40 per cent of the energy, 40 per cent of the virgin minerals used and 25 per cent of the virgin wood consumed worldwide per year, what else could we ask for?

The effects of some sustainable materials are apparent while in that of others is less obvious I e one can't really 'see', that a product is saving energy or that it didn't create toxic waste during manufacturing.

Demolition of buildings produces great quantities of waste, disposal of which is expensive. Most of these materials should be reused Water management such as gray water recycling, rain water recycling up to 100 per cent and reduction in the use of potable water, landscaping through drip irrigation, construction of check-dam if possible, ground water recharging pit, etc are the features to be incorporated in the design.

There is a thin line between building that are environmentally astute and those that are so green that they're intimidating. The challenge is to incorporate as many "GREEN Building" strategies and technologies as possible without increasing the cost and complexity of any project so much that it becomes impractical.

3.15 Environmental Architecture (6)

Five principles of an environmental architecture (Thomas A. Fisher, AIA, November, 1992):

- **Healthful Interior Environment:**

All possible measures are to be taken to ensure that materials and building systems do not emit toxic substances and gasses into the interior atmosphere. Additional measures are to be taken to clean and revitalize interior air with filtration and plantings.

- **Energy Efficiency.**

All possible measures are to be taken to ensure that the building's use of energy is minimal. Cooling, heating and lighting systems are to use methods and products that conserve or eliminate energy use.

- **Ecologically Benign Materials**

All possible measures are to be taken to use building materials and products that minimize destruction of the global environment. Wood is to be selected based on non-destructive forestry practices. Other materials and products are to be considered based on the toxic waste out put of production.

- **Environmental Form.**

All possible measures are to be taken to relate the form and plan of the design to the site, the region and the climate. Measures are to be taken to "heal" and augment the ecology of the site. Accommodations are to be made for recycling and energy efficiency. Measures are to be taken to relate the form of building to a harmonious relationship between the inhabitants and nature.

- **Good Design.**

All possible measures are to be taken to achieve an efficient, long lasting and elegant relationship of use areas, circulation, building form, mechanical systems and construction technology. Symbolic relationships with appropriate history, the Earth and spiritual principles are to be searched for and expressed. Finished buildings shall be well built, easy to use and beautiful.

3.16 Building energy audit

Building energy auditing is the measuring and recording actual energy consumption, at site, of a completed and occupied building (expressed in units of energy, not monetary value); fundamentally for the purposes of reducing and minimizing energy usage." Energy audits identify areas where energy is being used efficiently or is being wasted, and spotlight areas with largest potential for energy saving. They are useful for establishing consumption patterns, understanding how the building consumes energy, how the system elements interrelate and how the external environment affects the building.

There are different approaches to conducting a full building energy audit, but the following stages are often adopted.

i. An audit of historical data
ii. Survey
iii. Detailed investigation and analysis

A proper energy audit is useful for more than energy conservation goals. Energy audits can be employed to assist in areas such as:

- Establishment of data bank and consumption records
- Estimating of energy costs
- Determining of consumption patterns and utility rates
- Establishment of an operational overview

Checklist for Energy Efficiency in Buildings

(Note: P = planning; D = design; C = construction; M = maintenance and management.)

1. Architecture

Item	Key points	P	D	C	M
Siting and surroundings	• Thermal environment of surroundings - sunshade, sunlight, wind, reflecting surfaces	X	X		
Thermal design of outdoor environment	• Effect of plants - shading by trees and plants - wind shielding by trees and plants	X	X		
	• Cooling effects by ponds and fountains	X			X
	• Reflection from road or floor surfaces and plants	X	X		
Shape of the building	• Ratio of envelope surface area to total floor area - usually the smaller the better	X	X		
	• Aspect ratio of floor plan - usually the smaller the better	X	X		
	• Number of floors and building height - floor-to-floor height, light well's height	X	X		
Orientation of facades	• Desirable orientation from thermal viewpoint	X			
	• Optimal strategy of orientation - for the same floor plan, east-west axis is better than north-south one	X	X		
	- main wall openings to face south	X			
Design of building plan and section to enhance thermal performance	• Zoning and location of air-conditioned and non-air-conditioned spaces - non-air-conditioned spaces and spaces without occupants may have more exterior walls - plant rooms to be placed on the topmost floor	X	X		
	• Appropriate provision for different building functions - hours of using the space - moving of heavy objects by occupants - provision of smoking lounge - provision of store room - spaces with high internal loads (lights, people and equipment) may compensate heat loss at the building envelope	X	X		
	• Use of transit areas for thermal buffer zones	X	X		
	• Design of wind-shielded area under openings	X	X		
Thermal insulation and thermal storage of the roof	• Thermal insulation - material selection - thickness - thermal properties (and moisture barrier)	X	X		
	• Construction of the roof - double slab - thermal bridge prevention	X	X	X	
	• Treatment on the roof - soil and planting - drainage of rainwater	X	X		X
	• Sunshade provision	X	X		X
	• Glare control	X	X		
	• Thermal storage - heavy structure (thermal mass) - interaction with thermal insulation	X	X		

1. Architecture (continued)

Item	Key points	P	D	C	M
Thermal insulation and thermal storage of the exterior walls	• Thermal insulation - material selection - thickness - thermal properties (and moisture barrier)	X	X		
	• Construction of the walls - use of air cavity - ventilation of air cavity - location of thermal insulation - thermal bridge prevention	X	X	X	X
	• Sunshade provision - louvres and shading devices	X	X		X
	• Reduce radiant heat - *use of trees for shading and shielding* - select materials for glare control - *provision of ventilated cavity*	X	X		X
	• Thermal storage - heavy structure (thermal mass) - interaction with thermal insulation	X	X		
Thermal insulation, air tightness, ventilation properties and daylight properties of windows and doors	• Thermal insulation - Type and construction of window glass: plain glass, insulating glass, reflective glass, tinted glass, double glazing, low-e glass, etc. - window-to-wall ratio - shading coefficient - use of trees, sidewalls, louvres and balcony for shading - use of internal shading devices like blinds and curtains - orientation (south facing is preferable, and if in other directions, the facing angle of window glass may be adjusted)	X	X		
	• Air tightness - air leakage properties - shape and design of door openings: double door, automatic door and rotating door	X	X	X	X
	• *Ventilation (natural)* - possibility of windows being opened - openings and path have less resistance to air flow	X	X		X
	• Daylight penetration - reflective louvre - skylight - design of light wells - light transmission properties of window glass - array of window openings	X	X		
Glare control of exterior and interior walls	• Solar absorptivity, control of glare from sunlight and artificial lighting	X	X		

Table 06 Checklist for energy efficiency in buildings

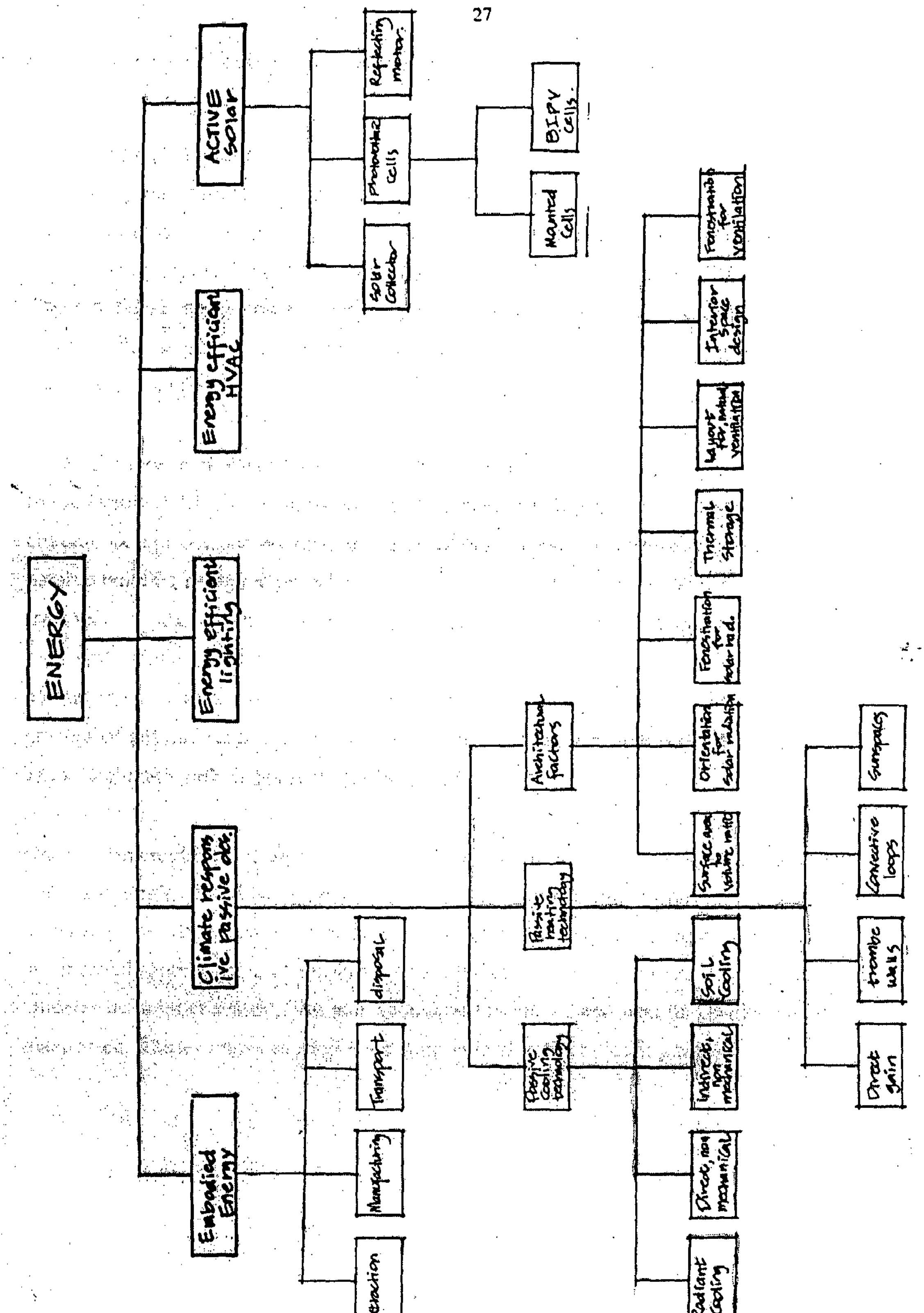


Fig 09 Diagram showing all considerations for energy efficiency in design (3)

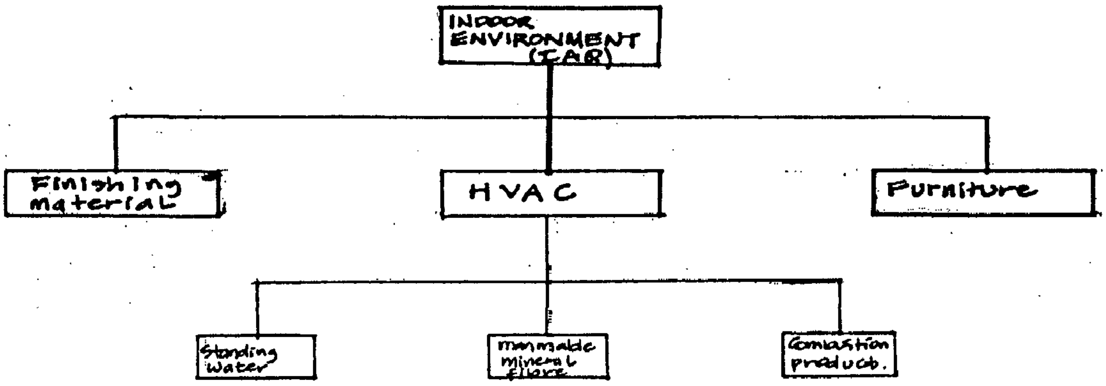


Fig 10 Diagram showing all considerations for indoor air quality(3)

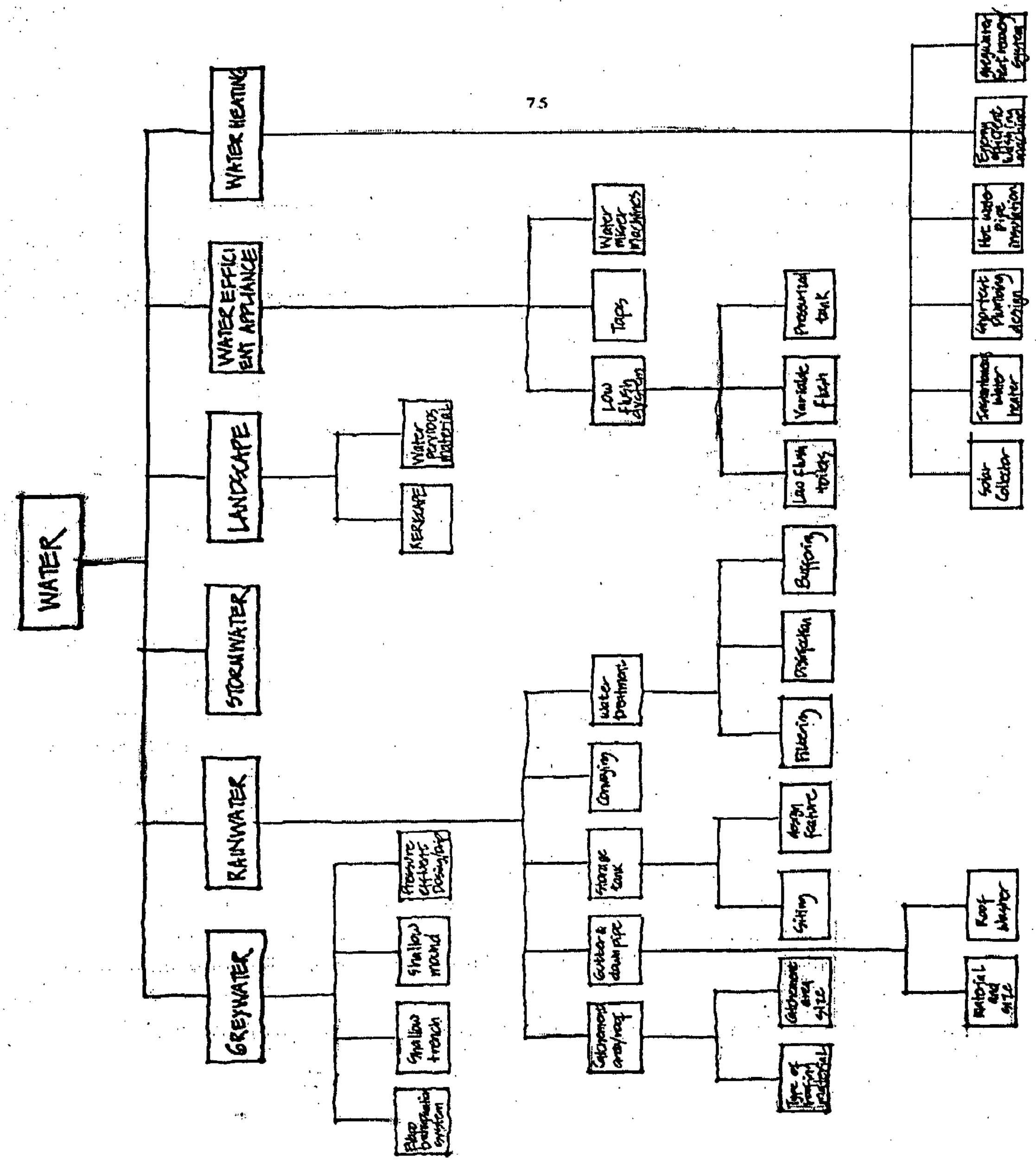


Fig 11 Diagram showing all considerations in water management (3)

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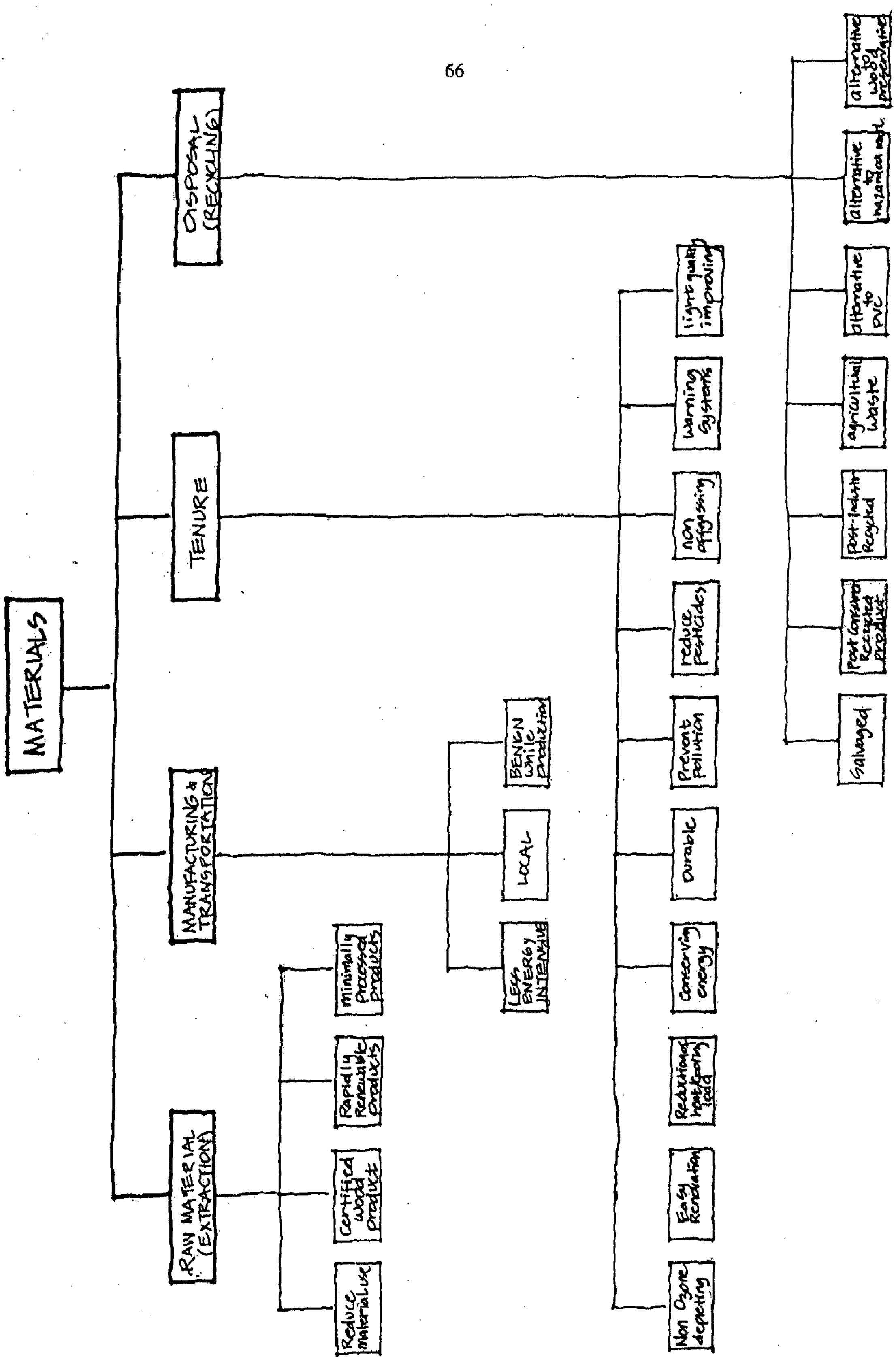

Fig 12 Diagram showing all considerations in material management (3)

3.17 Environmental Assessment

Need for Environmental Assessment of Buildings

Nationally and globally, buildings contribute significantly to energy consumption, as well as to other environmental impacts, such as air emissions and solid waste generation. Buildings are an exceedingly complex industrial product with a lifetime of decades. Emerging health issues syndrome, have intensified awareness of the role buildings play on our environmental well-being.

While certain efforts have been on-going to control and manage individual aspects of the environmental qualities of buildings (i.e. energy codes, automation and control schemes, thermal comfort), comprehensive approaches have been lacking, particularly in the design stages of a building's life span. Unfortunately it is in the design stage when the greatest opportunities are available to affect changes whose benefits can last for decades. In the last decade new methods have emerged that regard buildings as a network of interrelated environmental impacts and seek to juggle these impacts to create a more integrated and environmentally benign building.

Environmental Assessment: Two Approaches (3)

Significant research efforts have already focused on specific aspects of buildings such as material properties, equipment performance and simulation of building physics. Much research has also explored building-related environmental performance in areas such as energy consumption, day lighting, recycled materials and air quality. However as owners, designers, regulators and occupants increasingly desire that the entire building provide improved environmental performance, integration of these individual research strands is required.

Generally, integrated approaches to understanding environmental impacts falls under the description of environmental assessment. Assessment has the dual goals of documenting environmental impacts and communicating those impacts to an intended audience. Any given party may conduct an environmental assessment for internal purposes, such as examining processes, or it may be part of a larger effort to communicate environmental information to consumers, regulators or investors. Currently, there are several methods that attempt to assess environmental impacts related to buildings. Each system has its own set of assumptions and limitations, each is designed to address certain aspects of environmental impacts and further, each system is designed for utilization by different participants in the building process, a condition that can "profoundly influence the outcome."

There are two primary methods of communicating environmental attributes that relate to buildings, which will be discussed here, Eco-labeling and Life Cycle Assessment (LCA). While many eco-labels are derived from LCA procedures, they are differentiated here on the basis of their reporting formats.

Evaluation of LEED™ Using Life Cycle Assessment Methods

Eco-labeling: Marketing and Policy Tool (3)

Eco-labeling is the practice of branding environmental qualities of a product or system so that consumers can more easily make environmentally based decisions.

In simple terms, environmental labeling is defined as making relevant environmental information available to the appropriate consumers. Environmental labeling is the practice of labeling products based on a wide range of environmental considerations (e.g., hazard warnings, certified marketing claims, and information disclosure labels). Labeling contributes to the decision-making process inherent in product selection, purchasing, use and disposal, or retirement. Yet unlike most regulations that affect the behavior or actions of a limited number of entities (e.g., facilities or companies), labeling is designed to influence all consumers. In this context, the definition of "consumers" encompasses all individuals and organizations making purchase decisions regarding products and services, ranging from procurement officers of governments and corporations to individual retail consumers. Environmental labeling often also affects manufacturers and marketers as they design and formulate products that must compete based on quality, price, availability and, to varying degrees, environmental attributes.

Eco-labels are appealing to manufacturers as a marketing tool because they can convey environmental qualities without revealing proprietary information. They are often appealing to environmental advocates as a policy tool, based on the assumption that informed consumer's will ***Eco-labeling: Marketing and Policy Tool***

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Eco-labels are appealing to manufacturers as a marketing tool because they can convey environmental qualities without revealing proprietary information. They are often appealing to environmental advocates as a policy tool, based on the assumption that informed consumers will stimulate market demand for environmental products, driving manufacturers to compete for environmental performance [9]. When eco-labels first began to appear on products claims were often inaccurate or misleading ("recyclable", "eco-friendly") and as a result consumer confidence suffered. Many governments or third party organizations responded by assuming responsibility for eco-label certification processes in order to ensure validity of labels [10]. Each label has a different set of criteria, which underlie its results. In some cases it may be a single attribute such as "75% recycled", in others it may be the result of a more comprehensive process analysis such as "certified sustainable timber" or utilize a life cycle assessment approach.

Life Cycle Assessment (LCA) (3)

LCA is a comprehensive methodology whereby all the material and energy flows of a system are quantified and evaluated. Typically, upstream (extraction, production, transportation and construction), use, and downstream (deconstruction and disposal) flows of a product or service system are inventoried. Subsequently, global and regional impacts are calculated based on energy consumption, waste generation and a select series of other impact categories (i.e., global warming, ozone depletion, & acidification). This is often referred to as a "cradle-to-grave" approach. LCA allows the impacts from discrete systems and materials to be weighed against each other.

The structure of an LCA is a key element to its value. By documenting the specific procedures, data sources, boundaries and assumptions utilized, an LCA promotes clarity of information and allows for greater comparability of products.

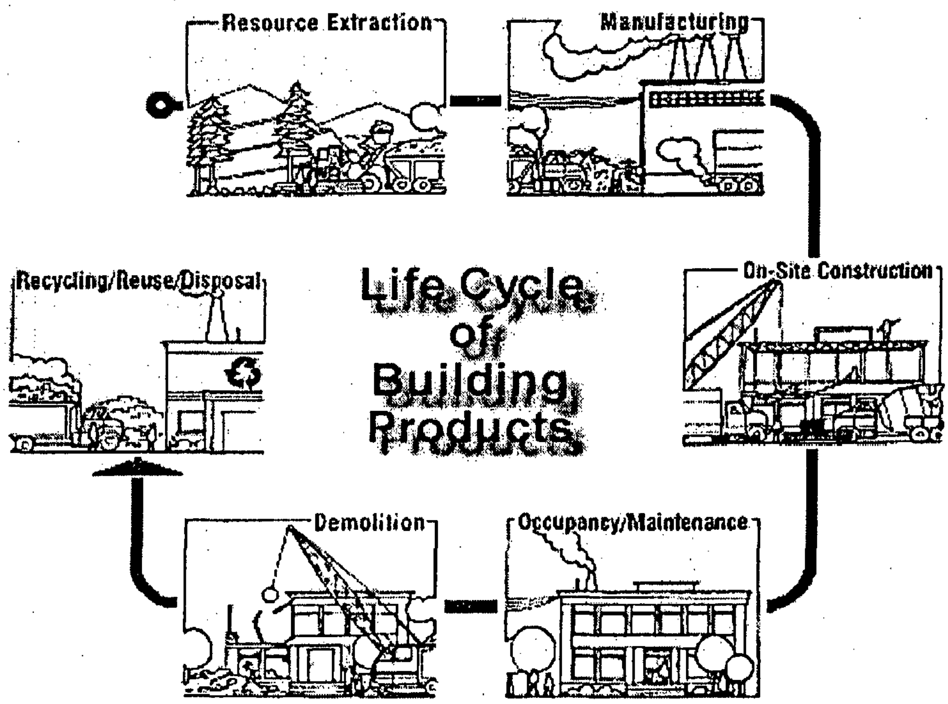


Fig 13 Life cycle of building products (cradle to grave) (1)

LEED (Leadership In Energy And Environmental Design)

A new program has emerged in the U.S., which attempts to wed elements of the previous two assessment approaches into a national "Green Building"ı rating system. The Leadership in Energy and Environmental Design (LEED) rating system is not the first green building program in the U.S. but it is the only program with national scope and the only program that has been adopted by many private organizations (Herman Miller, Ford Motor Co., Natural Resources Defense Council) as well as local (Portland OR, Seattle WA, San Jose CA) and federal (GSA, Department of State) government bodies.

LEED is a voluntary rating program whose goal is to "evaluate environmental performance from a whole building perspective over a building's life cycle, providing a definitive standard for what constitutes a 'green building'". According to the USGBC [31], LEED was created for the following reasons–

☐ Facilitate positive results for the environment, occupant health and financial return

☐ Define "green" by providing a standard for measurement

☐ Prevent "green washing" (false or exaggerated claims)

☐ Promote whole-building, integrated design processes

Evaluation of LEED™ Using Life Cycle Assessment Methods

LEED is a credit-based system. 64 credit points are divided among 5 environmental impact areas –

☐ Sustainable Sites (SS)

☐ Water Efficiency (WE)

☐ Energy and Atmosphere (EA)

☐ Materials and Resources (MR)

☐ Indoor Environmental Quality (IEQ)

In addition there are 5 credit points for *Innovation and Design Process (ID)* activities. There are prerequisites in 4 of these areas that every building must meet and several credit options in each area. Many credits have several tiers for increasing performance achievements. In order to earn a LEED certification a minimum of 26 points must be achieved (in addition to all the prerequisites). A Silver rating is achieved by earning between 33 and 38 points, Gold between 39-51 and Platinum between 52-69.

Every credit consists of a description of intent, requirements and documentation submittals. In many cases there is a referenced standard and credit calculation procedures. Credit requirements are accompanied by descriptive information about economic, environmental and community issues related to the credit. In many cases, examples and additional resources are also listed.

The LEED process consists of registering a building project and then fulfilling the credit requirements and submitting the required documentation.

Various other organizations working for environmental assessment of buildings are as follows:

- Assessment Methods: Design [University of Salford]
- ATHENA Sustainable Materials Institute
- BEES (Building for Environmental and Economic Sustainability)
- BRE Environmental Profiles
- BREEAM UK
- BREEAM Canada
    - Copy from CSA
- Building Environmental Quality Evaluation for Sustainability Through Time (BEQUEST)
- Construction and City Related Sustainability Indicators CRISP
- EcoHome (UK)
    - Info from Battle McCarthy
- Eco-Pro (Finland)

- Eco-Quantum (Netherlands)
- ENVEST (environmental impact estimating design software) [UK BRE]
    - Assessment Process & Benifits [Battle McCarthy]
- Environmental Support Solutions
- EQUER (France)
- GBTool
    - Green Building Assessment Tool - GBTool 1.3
    - A Second-Generation Environmental Performance Assessment System for Buildings
- Green Building Rating System (Korea)
- Green Globes
- Interactive Tools Survey [University of Weimar, Germany]
- International Association for Impact Assessments (IAIA)
- LCAid (Australia)
- LEED Green Building Rating System
- LISA (LCA in Sustainable Architecture)
- New Measures for Building Performance
- SimPro life-cycle assessment software (PRe, Product Ecology Consultants)

3.18 What Makes a Green habitat?

A "green" building places a high priority on health, environmental and resource conservation performance over its life cycle. These new priorities expand and complement the classical building design concerns: Economy, Utility, Durability, and Delight. Green design emphasizes a number of new environmental, resource and occupant health concerns:

- Reduce human exposure to noxious materials.
- Conserve non-renewable energy and scarce materials.
- Minimize life-cycle ecological impact of energy and materials used.
- Use renewable energy and materials that are sustain ably harvested.
- Protect and restore local air, water, soils, flora and fauna.
- Support pedestrians, bicycles, mass transit and other alternatives to fossil-fueled vehicles.

Green buildings are high-quality buildings; they last longer, cost less to operate and maintain, and provide greater occupant satisfaction than standard developments. Good green buildings often cost little or no more to build than conventional designs.

Environmental Impact Assessment is another dimension, which has accelerated up and gained a position amongst the top priorities of the issue.

Round the globe there are many organizations, institutes, research centers, working upon the subject trying to find solutions, to the problems that we ourselves have created for our selfish motives of luxury.

3.19 Utilization of Waste from Construction Industry

Indian Construction Industry is highly employment intensive and accounts for approximately 50% of the capital outlay in successive 5-Year Plans of our country. The Projected investment in this industrial sector continues to show a growing trend.

Construction activity leads to generation of solid wastes, which include sand, gravel, concrete, stone, bricks, wood, metal, glass, plastic, paper etc. The management of construction and demolition waste is a major concern for town planners due to the increasing quantum of demolition's rubble, continuing shortage of dumping sites, increase in transportation and disposal cost and above all growing concern about pollution and environmental deterioration.

Central Pollution Control Board has estimated current quantum of solid waste generation in India to the tune of 48 million tons per annum of which waste from

Construction Industry accounts for 25%. Management of such high quantum of waste puts enormous pressure on solid waste management system.

Construction waste is bulky and heavy and is mostly unsuitable for disposal by incineration or composting. The growing population in the country and requirement of land for other uses has reduced the availability of land for waste disposal. Re-utilization or recycling is an important strategy for management of such waste.

Apart from mounting problems of waste management, other reasons, which support adoption of reuse/ recycling strategy are-, reduced extraction of raw materials, reduced transportation cost, improved profits and reduced environmental impact. Above all, the fast depleting reserves of conventional natural aggregate has necessitated the use of recycling/ re-use technology, in order to be able to conserve the conventional natural aggregate for other important works.

Recycling of demolition waste was first carried out after the Second World War in Germany to tackle the problem of disposing large amounts of demolition waste caused by the war and simultaneously generate raw material for reconstruction.

Considerable research has been carried out in U.S.A, Japan, U.K, France, Germany, Denmark etc. for recycling concrete, masonry & bricks, bituminous and other constituents of waste from Construction Industry. These studies have demonstrated possibility of using construction waste to substitute new materials of recycling.

In view of significant role of recycled construction material and technology in the development of urban infrastructure, Technology, Information, Forecasting and Assessment Council (TIFAC) has commissioned a techno-market survey on 'Utilization of waste from Construction Industry'. The focus of the present study is housing /building sector and road construction segment.

Waste is generated at different stages of construction process. Waste during construction activity relates to excessive cement mix or concrete left after work is over, rejection/ demolition caused due to change in design or wrong workmanship etc.

Estimated waste generation during construction is 40 to 60 Kg. per sq. m. Similarly, waste generation during renovation/ repair work is estimated to be 40-to 50-kg/sq. m. The highest contribution to waste generation is due to demolition of buildings. Demolition of Pucca and Semi-Pucca buildings, on an average generates 500 & 300-kg/ sq m. of waste respectively.

Concrete appears in two forms in the waste. Structural elements of building have reinforced concrete, while foundations have mass non-reinforced concrete. Excavations produce topsoil, clay, sand, and gravel. This may be either re-used as filler at the same site after completion of excavation work or moved to another site.

Large quantum of bricks and masonry arise as waste during demolition. These are generally mixed with cement, mortar or lime. Stone arises during excavations or by demolition of old buildings.

Metal waste is generated during demolition in the form of pipes, conduits, and light sheet material used in ventilation system, wires, and sanitary fittings and as reinforcement in the concrete. Metals are recovered and recycled by re-melting.

Timber recovered in good condition from beams, window frames, doors, partitions and other fittings is reused. However, wood used in construction is often treated with chemicals to prevent Termite infestation and warrants special care during disposal. Other problems associated to wood waste are inclusion of jointing, nails, screws and fixings

Bituminous material arises from Road planning, water proofing compounds, Breaking and digging of Roads for services and utilities. Other miscellaneous materials that arise as waste include glass, plastic material, paper, etc.

The total quantum of waste from construction industry is estimated to be 12 to 14.7 million tons per annum.

Quantity of different constituents of waste that arise from Construction Industry in India are estimated as follows:

Constituent	Quantity Generated in million Tons p.a. (Range)
Soil, Sand & gravel	4.20 to 5.14
Bricks & Masonry	3.60 to 4.40
Concrete	2.40 to 3.67
Metals	0.60 to 0.73
Bitumen	0.25 to 0.30
Wood	0.25 to 0.30
Others	0.10 to 0.15

Table 07 Quantities of various waste materials from construction

Management of solid waste is the responsibility of Municipal Bodies or health officers. They notify landfill sites for disposal of solid waste.

Hard core material from demolition operation is required for land fill activities to provide daily cover over domestic waste, bulk fill capping, hard standings etc. Some Municipal Corporations require demolition waste for their landfill activities, while others want to minimize it to prolong useful life of landfill sites. However, all respondents are unanimous that in the long run, recycling of waste from construction industry is necessary in view of limited landfill space and increasing quantum of demolition waste.

Different constituents of waste are not segregated prior to disposal. Municipal Authorities incur cost of Rs 60 to 80 per ton of waste, but presently they levy no charge on the owner or builders.

Builders/ Owners bear the cost of transportation, which at present range between Rs.250 to Rs.500 per truckload depending on the distance of demolition site from landfill area.

Though directives exist for disposal of waste to landfill areas, presently penal action against violators is practically not taken.

Presently management of waste from construction industry in India, comprise of the following elements:

- Re-use of materials salvaged in good condition during demolition.
- All metal items are sent for re-melting through scrap dealers.
- Disposal of other items to low lying sites.

According to findings of survey, the most dominant reason for not adopting recycling of waste from Construction Industry is "Not aware of the recycling techniques". While 70% of the respondents have cited this as one of the reasons, 30% of the respondents have indicated that they are not even aware of recycling possibilities.

The response of industries, which can use the recycled product, indicates that presently, the specifications do not provide for use of recycled product in the construction activity. Sixty Seven percent of the respondents from user industry have indicated non-availability of recycled product as one of the reasons for not using it.

Concrete and masonry constitute more than 50% of waste generated by the Construction Industry. Recycling of this waste by converting it to aggregate offer dual benefit of saving landfill space and reduction in extraction of natural raw material for new construction activity.

Basic method of recycling of concrete and masonry waste is to crush the debris to produce a granular product of given particle size. Plants for processing of demolition waste are differentiated based on mobility, type of crusher and process of separation.

There are three types of recycling plants Viz. Mobile, Semi-Mobile and Stationary plant. In the Mobile plant, the material is crushed and screened and ferrous impurities are separated through magnetic separation. The plant is transported to the demolition site itself and is suited to process only non-contaminated concrete or masonry waste.

In the semi-mobile plant, removal of contaminants is carried out by hand and the end product is also screened. Magnetic separation for removal of ferrous material is carried out. End product quality is better than that of a Mobile unit.

Above plants are not capable to process a source of mixed demolition waste containing foreign matter like metal, wood, plastic, hardbound etc. Stationary plants are equipped for carrying out crushing, screening as well as purification to separate the contaminants. Issues necessary to be considered for erection of a Stationary plant are: plant location, road infrastructure, availability of land space, provision of weigh-bridge, provision for storage area etc.

Different types of sorting devices and screens are used for separating contaminants from end-product and grading the recycled product in various grain sizes. Vibrating screens, star screens or disc-separators are used for removal of impurities. Three main processes used for purification are:

- Dry Process
- Wet Process
- Thermal Process

Properties of recycled aggregate have to be compared to those of natural aggregate to evaluate its suitability for applications in Construction Industry. Density of recycled aggregate is lower and water absorption is higher than that of original aggregate. This is primarily due to mortar adhering to the concrete and higher porosity of bricks that are recycled.

Recycled aggregate can be used as general bulk fill, sub-base material in road construction, fills in drainage projects and for making new concrete.

While using recycled aggregate for filler application, care must be taken that it is free of contaminants to avoid risk of ground water pollution. Mixed debris with high gypsum, plaster, should not be used as fill.

Use of recycled aggregate as sub-base for road construction is widely accepted in most countries. It is possible to use crushed concrete as coarse fraction of gravel in sub-base for road, but crushed brick is not suitable owing to its high bitumen requirement and high void content.

For using recycled aggregate to make new concrete, water absorption of the recycled aggregate must be determined in the laboratory to decide the mix design. Use of fine recycled aggregate for concrete making is not recommended as it increases the water demand and lowers the strength and durability of concrete. Pre-soaking of recycled aggregate is suggested to take care of high water absorption so that concrete of uniform quality is produced.

Concrete made from recycled aggregate has lower compression strength caused by the bond characteristic of recycled aggregate and the fresh mortar. Fraction of less than 2mm of recycled aggregate brings about the largest reduction in strength of recycled aggregate concrete (RAC). Fine aggregates also reduce frost resistance of recycled aggregate concrete. Drying shrinkage of recycled concrete is higher than that of concrete with conventional aggregate. Workability of concrete decreases with increased portions of demolition waste. Up to 30% of natural coarse aggregate can be substituted, by coarse recycled aggregate, without any impact on the quality of concrete.

Problem associated with use of recycled aggregate, for manufacture of new concrete, is the possibility of contaminants in original debris passing into new concrete. Such impurities reduce the strength of the concrete. Waste glass is a problem because it is alkali reactive with cement paste under wet conditions. Organic substances like wood, textile fabrics, paper and other polymeric materials are unstable in concrete. Paints may entrain air in concrete.

Test results of aggregate properties and concrete properties prove repeatedly recycled concrete to be both durable and of good quality in all respects. Therefore, existing concrete structures, in addition to providing an aggregate source for the immediate future, may continue to generate an adequate supply of aggregate for concrete construction in the more distant future after once being recycled.

Recycled aggregate of best quality for concrete production is obtained when it is graded. Although there are no standards drawn up in India for recycled aggregate and recycled aggregate concrete, specification drawn in other countries are useful as a guideline. Annexure III includes some of the specification drafted in Japan.

The eighth five-year plan envisages a shortage of aggregates in housing construction sector. Further, for achieving the target for Road development upto 2001, an estimated 750 million cu. m. of coarse aggregate as sub-base material shall be required. Recycled aggregate can fill part of the demand-supply gap. Feasibility analysis has been carried out for a 25000 tons/annum recycling plant to produce recycled aggregate from waste concrete and Masonry & bricks. The location of the recycling plant should be so chosen that there is (a) Availability of feedstock (b) Market for recycled product and (c) It is difficult to dispose off the waste by other means. Equipment like Crushers, conveyors, screens etc. can be sourced from Indian manufacturers, who supply similar machines to Natural aggregate producers. Necessary modifications for adapting the equipment for crushing concrete/ Masonry/ Bricks can be carried out. Due to marked preference of the customers to use natural aggregate, Recycled aggregates have to be marketed at a discount to achieve sale of 25000-tons/ year in 2/3 years time. The unit is viable but its operation is highly sensitive to fluctuations in sale price of recycled aggregate and capacity utilization of the plant.

Non-awareness of recycling possibilities is one of the main barriers due to which waste is disposed to landfill. Absence of technology for recycling is another major hurdle for recycling of construction waste.

Once technology is known, availability of feedstock in sufficient quantities and of requisite quality is another bottleneck for its widespread use.

The acceptability of the recycled material is hampered due to poor image associated with recycling activity in India. Customer specifications do not permit use of materials recycled from Waste.

Cost of disposal of waste from construction industry to landfill has a direct bearing on recycling operations. High dumping costs induce diversion of waste for recycling.

The problem of dumping huge quantity of waste caused by a disaster and the difficulty in finding sufficient quantity of building material for reconstruction can be solved by recycling this waste. Usually, quick removal of debris is necessary to start the rehabilitation work but this leads to mixed demolition waste, which contains all kind of materials.

The waste can be reused for strengthening riverbanks or for producing aggregates for construction of road or building blocks. Experience of recycling operations at two disaster sites, have proven the feasibility of recycling demolition waste. In one of project, most of the debris had been transported and temporarily disposed off. Yet, recycling was carried out successfully. These experiences are relevant to India, in view of damage suffered in recent earthquake in Kumaun and Garhwal regions.

Technology for producing recycled aggregate from concrete, bricks and masonry is quite simple. A mobile unit is best suited to process demolition waste of uniform quality. It can be procured at low investment. It can be useful for low quantum of waste and can be moved to the demolition site avoiding cost of Waste transportation.

A fixed recycling plant requires higher volumes of demolition waste to justify high investment in complex, screening and separation systems, which are necessary to process mixed demolition waste. It has to be located in a place, where large volume of waste is available and the market for recycled product is close by. Unless the market for recycled aggregate is developed, economic viability of such a unit would be questionable.

Indian manufactures are producing crushers, which can be used with suitable modification in a recycling unit to break concrete, bricks and masonry. A comparative study shows that a jaw crusher or impact crusher may be used.

Recycling of bituminous material by hot in-situ recycling technique is advantageous due to savings in consumption of asphalt and energy, avoidance of material transportation and possibility of using the technique for road maintenance and repairs.

Creating awareness & dissemination of information is essential to build public opinion and instill confidence in favor of recycling option. There is a need to create market for the recycled products by involving the Construction Industry to use recycled materials in their construction projects.

Development of standards for recycled materials would provide producers with targets and users an assurance of quality of material. Standards formulated in other countries can be a guideline for development of specification in our country.

Commissioning of a pilot plant as a demonstration unit can help in breaking barriers against recycling of construction & demolition waste. Imposition of charge on Sanitary landfill can induce builders and owners to divert the waste for recycling.

Government support and commitment is vital for development of recycling industry. Development of policy supported by proper regulatory framework can provide necessary impetus. It will also help in data compilation, documentation and control over disposal of waste material.

Providing suitable fiscal incentives by the Government for gestation period can offset low returns from investment in recycling units. These are warranted in the long-term interest of reducing pollution and conserving valuable resources Environmental impact of recycling has both advantages and disadvantages. Advantages are reduced disposal of waste to landfill sites and reduced mineral extraction. Disadvantages are problems of Noise and Dust emission and risk of ground water pollution. Using silencers and providing acoustic enclosures while water spray is useful to control dust emission can manage the problem of noise.

Based on evaluation of the technology, review of Waste Management practices in India and other countries, and assessment of constraints to recycling option in the country, following recommendations along with implementation & action plan are proposed:

There is a pressing need to create awareness about the problems of waste management and the necessity to adopt reuse and recycling options for waste from Construction Industry. It is recommended that Seminars, Conferences and Workshops be held in different parts of the Country. Simultaneously, other media should also be exploited to create an environment in favor of Recycling.

3.20 Benefits of Green Buildings

The cost of passive design elements can run the same or slightly more than conventional building costs. This assumes that design services are used in both approaches - passive solar design and conventional design. Interior thermal mass materials such as stone and brick generally add to the cost of a home but can also be considered aesthetic enhancements.

The direct gain system will utilize 60 - 75% of the sun's energy striking the windows.

3.20.1 Facility specific benefits

- **Reduced Operational Energy Expenditures**
- **Operations and Maintenance Savings**
- **Reduced Water Consumption**
- **Construction Cost Trade-Offs**

Environmentally effective (high performance) buildings with improved envelopes and efficient lighting, equipment, and HVAC systems use less energy than conventional buildings.

Potential savings may be measured by determining an annual energy cost budget for a building designed in accordance with these green design principles and comparing it with a building designed to meet minimum applicable local codes or traditional building practices. The annual operating budget savings will equal the difference between the respective energy cost budgets.

Usage of environmentally effective design principles is likely to result in some discrete first cost savings on certain items. For example, specifying double glazed windows with high performance selective coatings, in conjunction with an energy efficient lighting design, may reduce heat loss and gain to such an extent that it will be possible to downsize the entire HVAC system (chillers, boilers, fans, pumps, ducts, pipes, etc.). Although savings on specific items may be significant, the reduction to the capital budget is likely to be offset by other expenditures, such as the increased cost of high performance windows or measures to assure good indoor air quality. In many cases, the use of these design principles will result in a marginal increase to the capital budget as a whole. Following integrated design and development strategies recommended in following articles in this series is the best way to maximize the opportunities for cost trade-offs and minimize or eliminate any capital cost premiums.

Reduced Disposal Costs for Construction and Demolition Waste

Measures to reduce construction and demolition (C & D) waste include reusing existing structures and materials, avoiding the purchase of excess materials and reducing materials packaging. Reducing waste reduces the cost to contractors who must pay for C & D waste collection and disposal. While savings opportunities exist, there are currently not enough consensuses on C & D waste data to provide a range of savings.

Economic Development

An investment in environmentally effective (high performance) healthcare facilities is an investment in the future of the community and in a larger sense, society. It is likely to produce indirect economic benefits through development of the nascent clean and efficient technologies industry.

To the extent that a society can obtain the same energy services using less energy (through increased efficiency) or through reduced reliance on imported fuel (based on integration of clean technologies such as wind and solar energy), that society will derive social and economic benefits. The first benefit is obvious - improving efficiency reduces energy bills and provides a direct savings to the members of that society. Also, the entire society will benefit from the improved air qualities that result from reduced burning of fossil fuels.

Energy and resource efficient buildings also reduce the amount of money that utilities need to invest in fuel, operations and maintenance, and related costs at power plants. Over time, the need to build and upgrade facilities and to expand the transmission and distribution system is reduced, and the resulting savings can be passed on to consumers. Although efficiency services cost money, these investments pay for themselves in energy savings. Achieving efficiency is a relatively labor intensive process, which provides direct benefits to the society by resulting in more jobs, while any equipment imported from elsewhere to produce energy is a loss to that society. Money that is retained in the local economy contributes to the tax base.

External Environmental Benefits

Reducing energy use lowers the emission of oxides of nitrogen, sulfur dioxide, and carbon dioxide produced by power generation at power plants. These air pollutants contribute to ground level ozone (the primary component of smog), acid rain, and climate change, as well as their related health effects. For example, ground level ozone can cause respiratory problems, especially among the very young, the elderly, and those with respiratory illnesses. Oxides of nitrogen contribute to the formation of particulate matter that is linked to heart and lung disease. Acid rain causes damage to lakes and rivers, as well as to crops and buildings. The appropriate siting of buildings, together with environmentally preferable building materials and products, reduces the impact of real estate development and building use on land and water. By investing in environmentally effective buildings today, the society will be contributing to solving these problems - a much more cost-effective and well-reasoned approach than paying for remediation efforts later on. It owes this foresight to the coming generations, and healthcare facilities as a building type committed to the maintenance of that society's health, owe it to themselves to take the lead.

3.21 Characteristics of Hot Dry climate

From building design point of view, the country is divided into five climatic zones, namely (1) Hot Dry (2) Warm Humid (3) Composite (4) Temperate and (5) Cold

Hot Dry climate refers to the climate, where the summer temperatures are extremely high and the humidity in the air is extremely low. The air remains completely dry, creating uncomfortable conditions for the occupants. High altitude sun adds to the extensive heat.

The main problem to be dealt with in the hot and dry climates is the summer sun and to meet the water demands when water is already a fastly depleting resource. The cooling loads in the building need to be reduced tremendously.

Following are the design features for hot - dry climate.

- Compact plan
- Reflective outer colouring
- Radiant heatproof roof
- Insulated exposed facades
- Small openings properly shaded
- Insulated shutters
- Roof terraces
- North – South orientation of main facades
- Thick walls
- Windows on eastern and western walls should be near the southern end
- Shading of ground by vegetation or turf.

3.22 General information about Nagpur city

- **Geographical Information**

  - North Latitude – 210.07; East longitude – 790.07
  - Height above mean sea level – 312.42 meters
  - Geographical area - 9897 Sq. Km.

Location - It is practically at geographical center of India, in fact the zero milestone of India is in this city. All major highways NH-7 (Varanasi - Kanyakumari) &

NH-6 (Mumbai - Sambalpur - Calcutta) and major railways trunk route (Mumbai, Chennai, Howrah * Delhi) pass through the city. Important Central & State Government offices and institutions are located in Nagpur. Industrial Development exists along the fringe areas like Kamptee, Hingna, Wadi, Khapri, Butibori and Kalmeshwar

Nagpur's Municipal Limits encompass 217.56 Square Kms of land areas.

Nagpur is 837 kms. From Mumbai, 1094 Kms south of Delhi, 1092 kms north of Chennai and 1140 kms west of Calcutta.

- **Climate**
  - Maximum, Average & Minimum Rain fall are 1993 mm, 1205 mm and 606 mm respectively.
  - Nagpur generally has a dry tropical weather
  - Humidity 70% to 20%
  - Elevation 274.5mtrs to 652.70mtrs
  - Forest Cover is 28% i.e. 2818 sq. kms (for Nagpur District)

The climate of Nagpur follows a typical seasonal monsoon weather pattern. The peak temperatures are usually reached in **May/June** and can be as high as **48°C.** The onset of **monsoon** is usually from **July** and the season extends up to **September**, with monsoon peaking during July and August. After monsoons, the **average temperature varies between 27°C and approx 6 to 7°C right through December and January.**

Month	Temp (Celsius)		Rainfall
	Max	Min	
Jan	28	12	16
Feb	33	15	2
Mar	36	20	25
Apr	42	25	20
May	45	29	10
June	38	28	174
July	30	24	352
Aug	30	24	278
Sep	31	23	186
Oct	32	26	61
Nov	30	14	9
Dec	29	12	2

Table 08 Average Temperature and Rainfall in Nagpur

The crux of the matter is that the idea of GREEN ARCHITECTURE is to first reduce light and energy demands through architecture and space designing, and then meet those demands by using energy efficient devices, which are environmentally friendly.

CHAPTER 4

CASE STUDIES

4.1 CASE STUDY 1 (9)

Residence for Sudha and Atam Kumar, Delhi

Architect Sanjay Prakash

This is the inaugural project in a series of EASE (environmentally appealing and saving energy) 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 of the building.

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

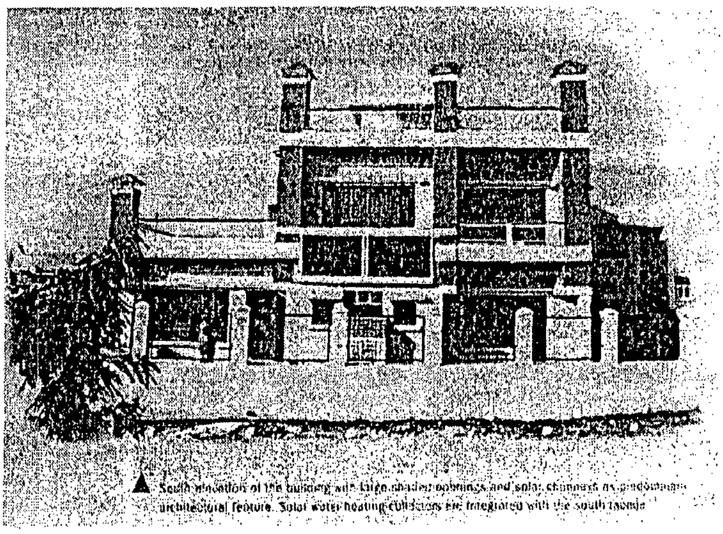


Fig 14 Residence at Delhi built by green Building technology (9)

4.1.1 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 the wider one, reducing possibilities of shadows from the south in the future.

4.1.2 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 the extent feasible, to allow for a large south open area.

4.1.3 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 high thermal mass and high insulation.

4.1.4 Reflective finish

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.

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.

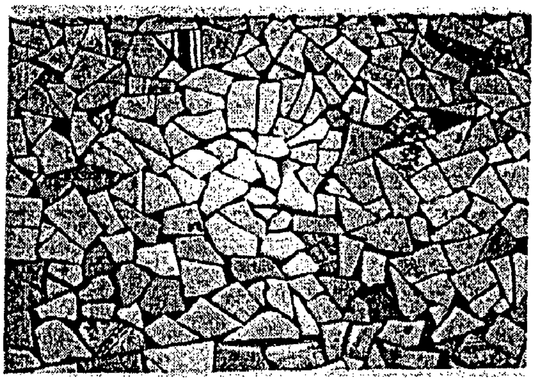


Fig. 15: Reflective finish in terrazzo for terrace (9)

The house was oriented south in the sense that every habitable room has 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 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.

4.1.5 Recessed jamb

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.

4.1.6 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.

4.1.7 Solar chimneys

South-facing thin-walled and dark-coloured 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).

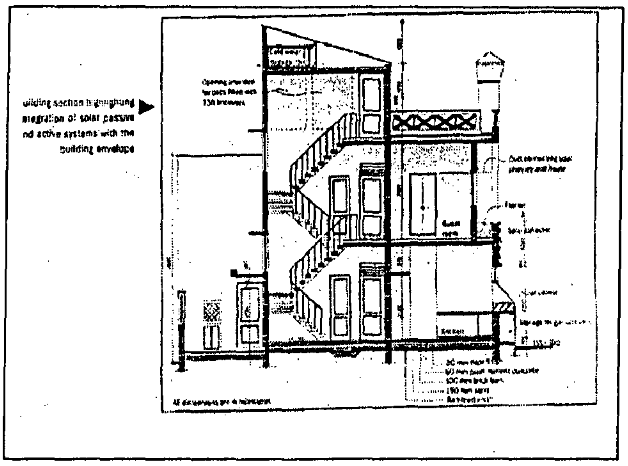


Fig 16 Building section showing solar passive and active systems with the building envelope(9)

4.1.8 Renewable energy systems

4.1.8.1 Architecturally integrated solar water heater.

A 200 litre-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 nonstandard mounting angle reduces the problems of dust accumulation, endemic to Delhi. It reduces chances of breakage due to hail or cats, etc. It also frees up terrace space and is a technique that could be used in multi-storied buildings to provide individual hot water systems without using the roof. A rooftop 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.

4.1.8.3 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 conventional fuel.

4.1.9 Waste recycling and water conservation

4.1.9.1 Compost pits

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.

4.1.9.2 Low water flushes

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

4.1.10 Energy efficient lighting

4.1.10.1 Daylight

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

4.1.10.2 Low energy lights

All lamps and luminaries are based on warm colour CFLs (compact fluorescent lamps) so as to reduce electrical loads to the maximum.

4.1.10.3 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 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 appliance (electric iron, washing machine, etc., not running simultaneously) is added, the house can be run at under 2000 W peak all the time. There is no need to use electricity for space heating and cooling, nor for water heating. Using a careful selection of devices, 15 A circuits can be eliminated from the house altogether.

4.1.10.4 Inverter and future provision of photovoltaic 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.

CASE STUDY 2 (9)

4.2 Residence for Mahendra Patel, Ahmedabad

Architect Pravin Patel

Here is one house that depends on solar energy to *a great extent. Minimally relying the grid for power, the architect has also integrated the house with an automation system for the purpose of saving energy.*

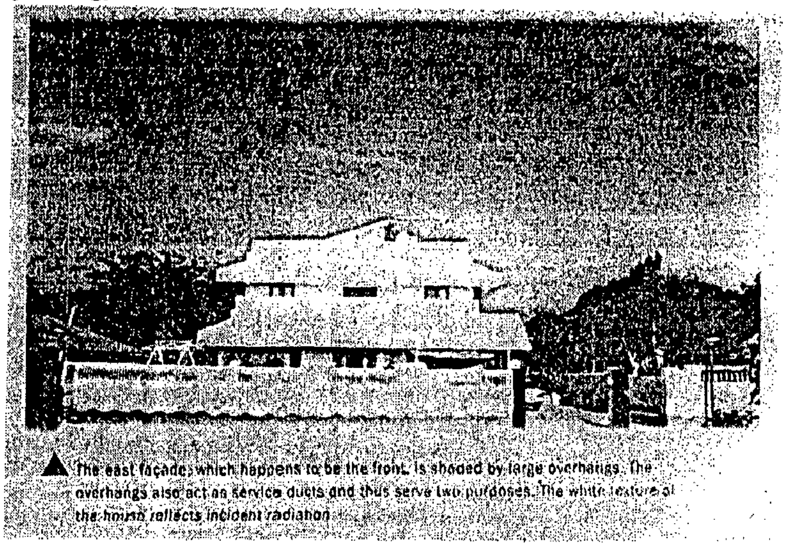


Fig 17 Climatically responsive residence built at Ahmedabad (9)

4.2.1 Building design

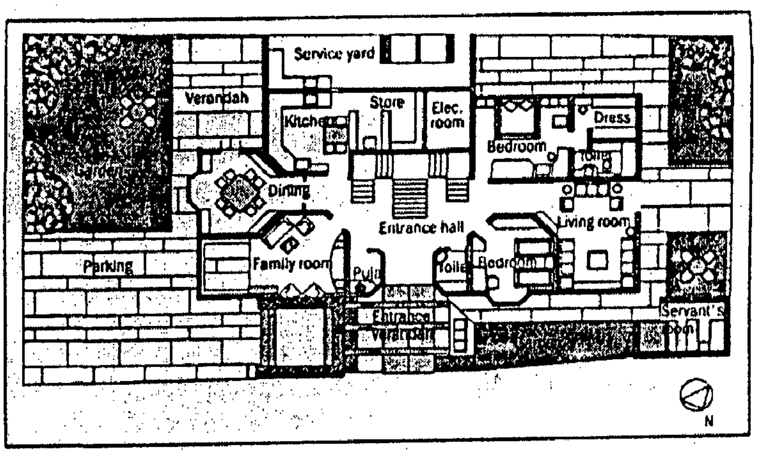
The residence of Mahendra Patel (client), located in the hot and dry climate of Ahmedabad, was required to be fully air-conditioned as per the requirement of the client. However, the client was extremely concerned about the energy usage in the building and wanted to achieve an energy efficient design along with optimized use' of solar energy for meeting a part of its electrical requirements and water heating needs. The architect has tried to minimize the air-conditioning load by applying passive solar design interventions. Judicious use of solar energy systems has been made to meet a part of the energy demand in the building load.

Ahmedabad is located in the 'hot dry' zone where the summer temperature goes up to 45°C. Natural comfort conditions can be achieved by protecting spaces from the heat and glare of the sun. The site of about 755 m2 is oriented east west with the shorter side facing the road.

The house is designed in such a way that all the private spaces on the ground and first floor are connected to the entrance hall through individual doors. This helps in reducing passage area and loss of air-conditioning. The double height of the entrance hall gives a grand look. Though the width of the plot is less, the rooms do not look small because of bay windows and angled walls. The verandahs play an important role in the Ahmedabad climate. Hence, the house has been provided with two big verandahs.

4.2.2 Building envelope

The building has adequately designed windows with overhangs on south wall. Thermally massive stone floors and thick masonry walls moderate diurnal variations. East and west walls are protected by a series of extended terraces developed as building elements to shade walls. Double glass shutters reduce heat gain.



The ground-floor plan

Fig 18 Plan of residence for Mr. Mahendra Patel (9)

Insulation

In this building, an attempt has been made to reduce the annual space-cooling requirement by nearly 30% with high level of insulation. The air-conditioning load was reduced from 36 to 26 tonnes of air-conditioning. Fly ash bricks were used for masonry work. At every stage of the construction, plasticizer is used to decrease voids in the mortar. All the terraces and sloping roofs are finished with white China mosaic and insulated with 50-mm thick expanded polystyrene and sand cement plaster. All the external walls are insulated with 40-mm thick high-density thermocole. These thermocole sheets are adhered over the first coat of plaster by an adhesive (bitumen). Over these sheets, galvanized expanded wire mesh was anchored before application of the second coat of sand-faced plaster. All the walls are externally finished with white paint, which reflects most of the sunlight.

Indoor air quality

A major issue with a super-insulated, airtight house is the quality of the internal air. In a poorly designed system, the low air change rate can lead to persistent odours, high humidity level, and even fungal growth. Problem of light and air quality is eliminated in this house by provision of north light and fresh air unit at the top of entrance hall. This acts as a light shaft, and also aids in the ventilation of the house.

4.2.3 Shading-cum-service ducts

1.2-m wide projections all around the building also work as service ducts to carry all the utility services like electricity, water supply, fan coil units of air-conditioning, etc., in addition to shading the walls. These projections are finished at the top by white China mosaic and covered at the bottom by aluminum false ceiling, which can be opened.

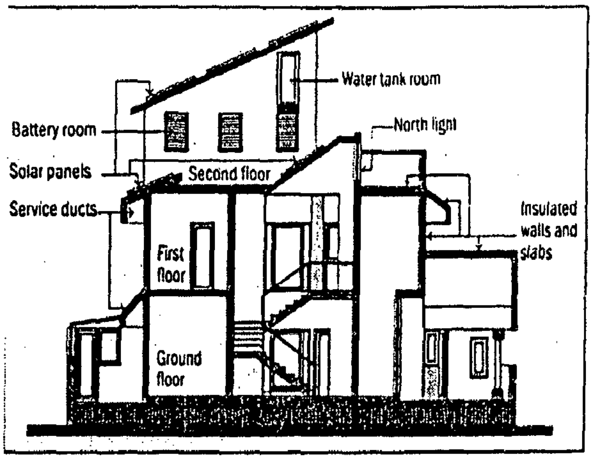


Fig 19 A section of building showing integration of solar photovoltaic panels, location of battery room, service ducts, north light, and insulated walls. (9)

4.2.4 Solar photovoltaic and solar water heating system

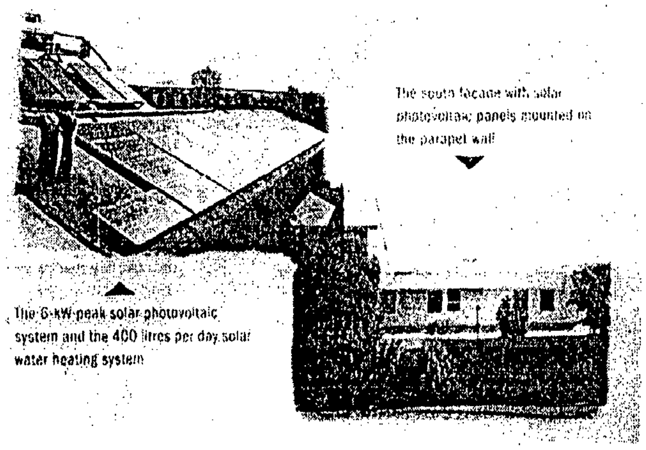


Fig20 Solar photovoltaic and solar water heating system (9)

The solar PV (photovoltaic) system is both technically and economically suitable for household electrification in the long run. Once the decision was made to design a house with PV system, two years of electricity bills from the client's existing residence were studied to work out estimated consumption of energy per day. It was concluded that a connected load of about 18 kW is required to fulfill the client's need.

The installed PV system has a battery bank capacity of 600 Ah/120V nominal. The charging is accomplished during daylight hours by the 6-kW solar modules. The charging of battery bank is controlled by power conditioning unit to prevent excessive discharge or overcharge.

A 400-litre-per-day solar water heating system meets the hot water requirement of the building.

4.2.5 Building automation system

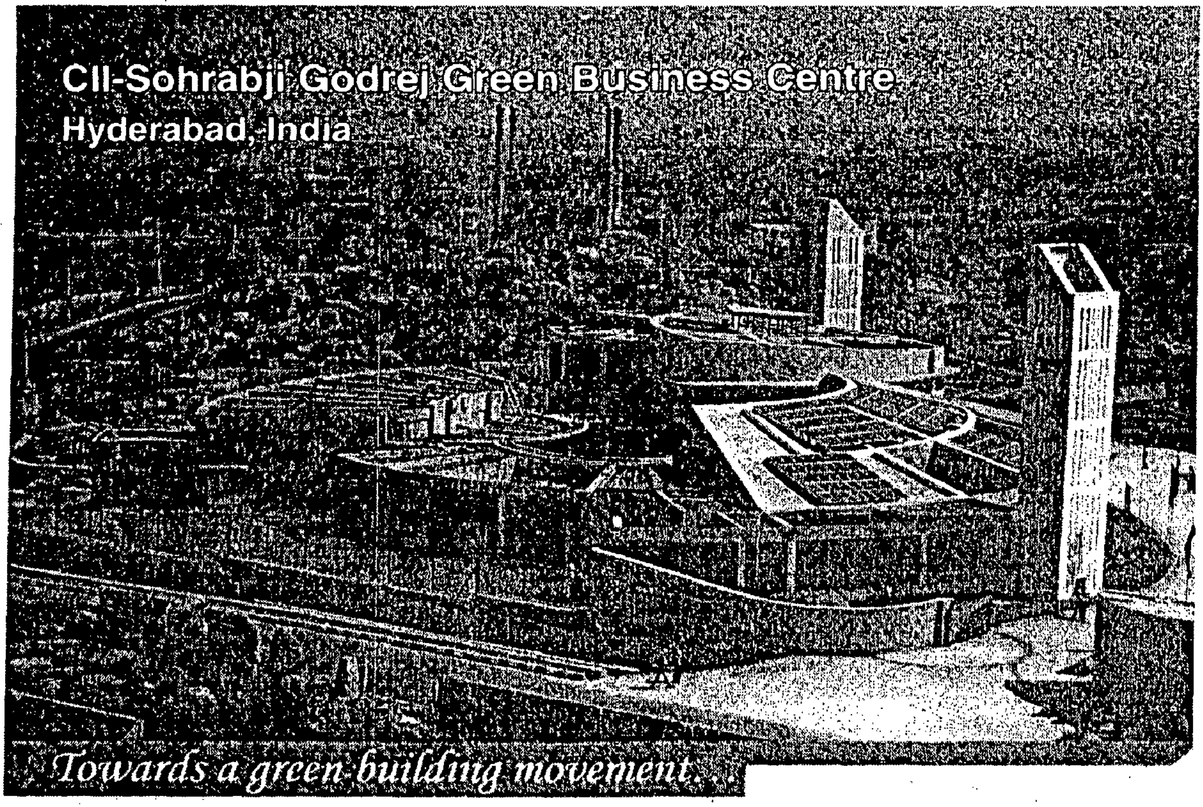
- A building automation system is integrated with the electrical system to reduce energy wastage. The system hardware consists of various input sensors such as Occupancy sensors and temperature sensors for overall utility management.
- Lux sensor for measuring ambient light levels water sensors for monitoring and controlling underground and overhead tanks' water levels
- Breakglass, smoke detectors, and magnetic contacts for security applications.

The inputs from various sensors are processed by the PLC (programmable logic controller) and it controls their allied output systems according to the programme fed into it. The outputs that are controlled by the PLC are light fixtures, fans, 5-amp plugs, pressure pump, softening pump, air-conditioning, and security and fire alarm system.

The hardware is fully interactive in nature-inputs from a particular sensor will not only activate its directly related output device, but also other relevant output systems. A project of this nature not only extends the architect's responsibility to perform as a technocrat, but also supports newly developed systems. Mahendra Patel's house is a good example of a functional solar house with automation system.

CASE STUDY 3

4.3



Hyderabad, the city of pearls and a IT hub of India can now boast of the Greenest Building in the world.

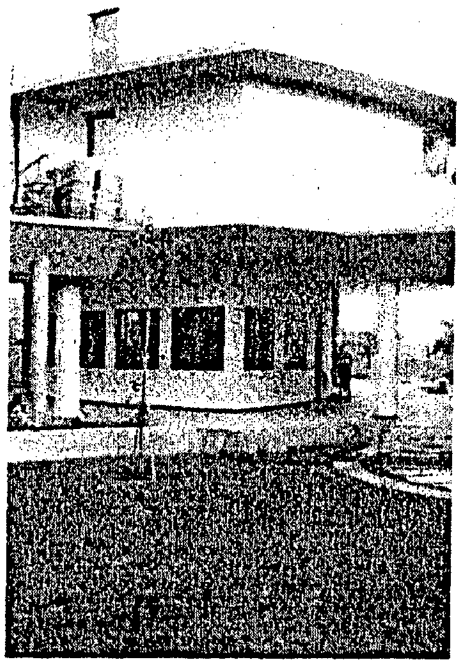
CII-Sohrabji Godrej Green Business Centre (CII-Godrej GBC) is the Greenest Building in the world, as on date.

The building has transformed a sleepy hamlet studded with undulating terrain and a rocky landscape to a focal point on all aspects related to Green.

Amidst environs surrounded by the Hi Tech City and an up-market residential area, the 20,000 sq ft building stands out as a symbol of harmony between nature and architecture.

CII Godrej GBC building has been awarded the prestigious 'Platinum rating' under LEED (Leadership in Energy and Environmental Design) program of USGBC (US Green Building Council).

The CII-Godrej GBC is the Centre of Excellence for Green Buildings, Energy Efficiency, Renewable energy, Environment & Recycling, Water Management and Climate Change activities in India.



The inner courtyard of the building

Green Features

The CII-Godrej GBC building heralds the beginning of the Green Building movement in India.

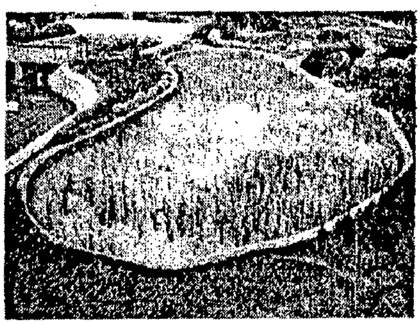
The building has been rated based on the following features:

- Water Efficiency
- Sustainable Site
- Energy Efficiency
- Materials & Resources
- Indoor Environmental Quality

Water Efficiency

Zero water discharge building

Entire waste water in the building is treated biologically through a process called the 'Root Zone Treatment System'. Outlet water has low BOD and COD values and this water is good for irrigation purposes.


Root Zone Treatment System

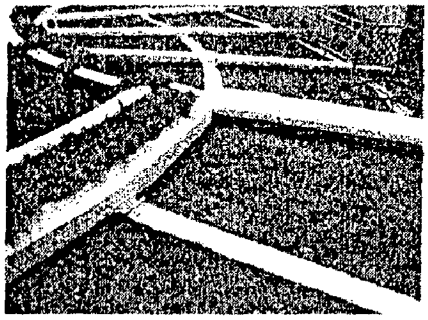
35% reduction in potable water use vis-à-vis a normal building

- Low flow water fixtures
- Waterless urinals
- Use of storm water & recycled water for irrigation

Sustainable Site

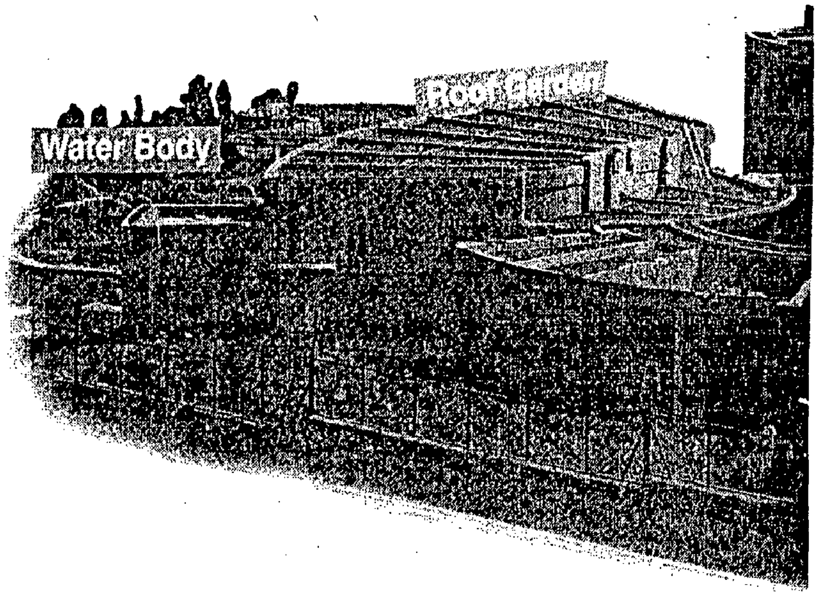
Minimum disturbance to the site

- Extensive erosion and sedimentation control measures to prevent erosion
- Impervious areas like terraces, parking etc., result in

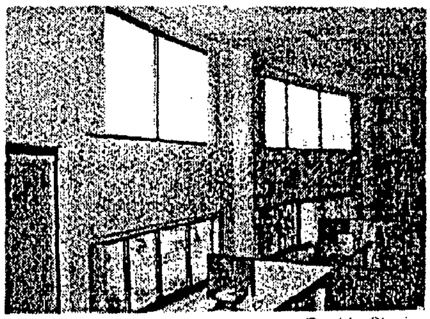

Roof Garden

absorbing heat and radiating it into the building. This is minimized through the roof gardens covering 55% of the roof area

- Rain water harvesting
- Pervious paver blocks which help in storm water seepage into the ground have been installed in pedestrian areas and parking

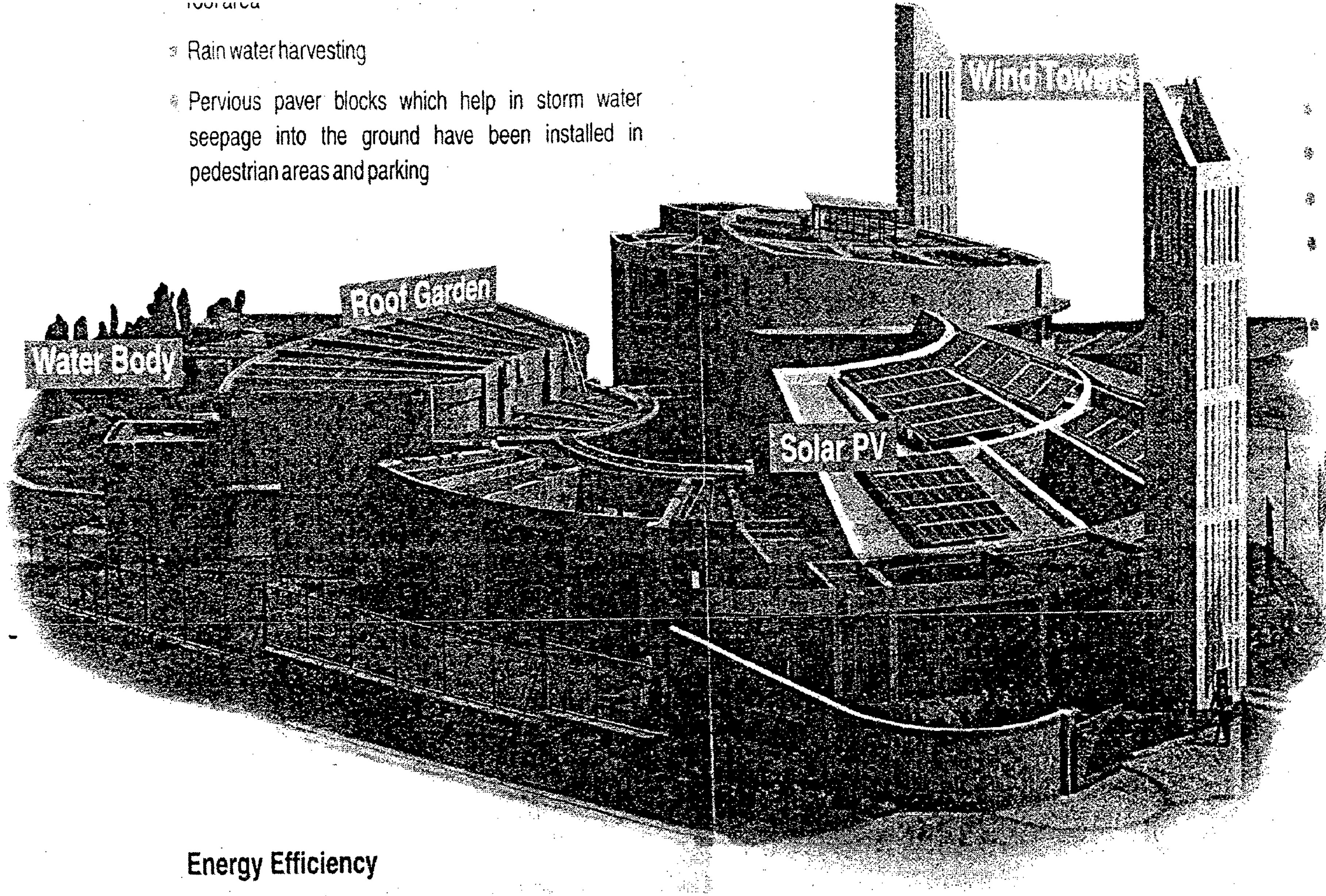


Energy Efficiency


Double Glazing

roof area

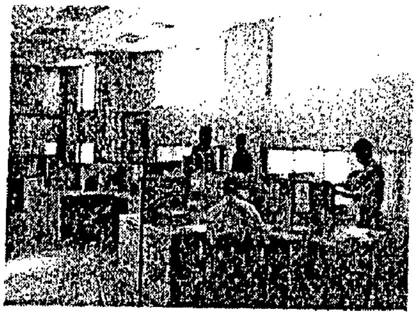
- Rain water harvesting
- Pervious paver blocks which help in storm water seepage into the ground have been installed in pedestrian areas and parking



Energy Efficiency

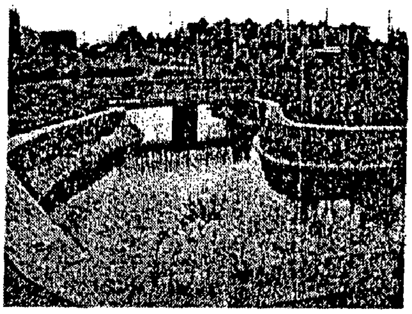
Indoor Environmental Quality

- Indoor Air Quality continuously monitored
- Materials selected so as to have no adverse health impact on the occupants
- Adequate amount of fresh air into the building and control of air quality through Carbon-di-oxide monitoring
- Fresh air drawn into the building through wind towers, as and when requireds
- Use of low Volatile Organic Compound carpets, paints, adhesives and sealants
- 90% of the building daylit
- 75% occupants have access to outside view



Daylight & Views Glazings

Swales



Water Body

Green Buildings Make Business Sense

Tangible benefits

- 50% savings on energy consumption
- 30% savings on potable water
- Operational savings right from day one

Intangible benefits

- Higher productivity (10-15%) as compared to a normal building
- Green corporate image

Investment

- The incremental cost of constructing a Platinum rated building varies from 25-30%, as of today. As the green building movement advances, the incremental cost would substantially decrease
- A Gold, Silver or Certified building would cost 5-10% higher than a normal building
- **The Incremental cost gets paid back in 2-3 years time**

Do You Want to Construct a Green Building?

CII - Godrej GBC offers feasibility study and facilitation services on Green Buildings.

Services include:

- Evaluation of building design to meet Green Building aspects
- Advisory services on Green Building design
- Training on Green Buildings

For more details, contact CII - Godrej GBC

CII

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CASE STUDY- 4 (10)

4.4 RAIN WATER HARVESTING, UDYOG BHAWAN NAGPUR

Water is the most essential element of day-to-day life. As it is readily available in ample quantity in the form of rainfall, this essential commodity till now was least cared and was wasted at every body's will. This has caused a serious threat to the water regime and hence efforts of the administrators are concentrated towards conservation of this important **natural but limited resource** at national and also at the international levels. This can be very well achieved by diverting every drop of water that falls on earth as a rainfall to ground for recharge. This is possible either by using the available *conduits* to the aquifer i.e. the existing dug wells or bore wells or by constructing suitable structures. Such an effort is required on a massive scale so as to use most of the rainwater for recharge and to minimize the water scarcity. Government of India is promoting this technique through all their networks and an appeal has been made to all the citizens to join their hands for this noble task.

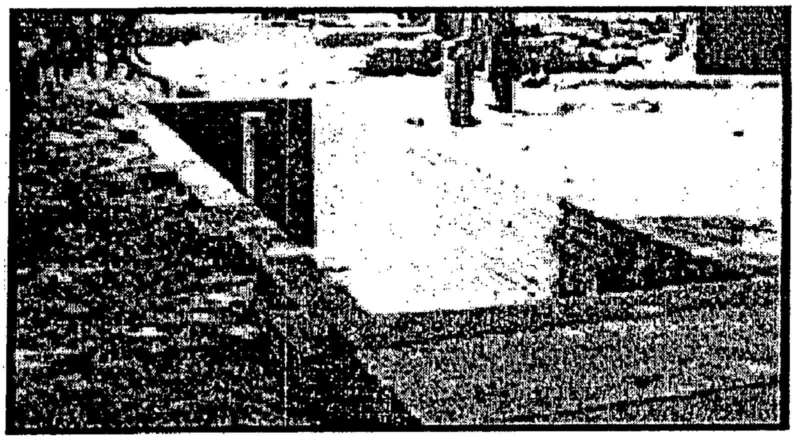


Fig 21Trench for rain water harvesting (10)

Maharashtra Pollution Control Board, Nagpur, is a competent authority in the area of environmental management, pollution monitoring and control of pollution from industrial activities of the Nagpur region. Being regulatory authority for the natural resources MPCB has taken maiden initiative to set an illustrative model for all the industries, Governmental offices, private houses and educational institute to adopt the rainwater harvesting scheme at their respective premises. The inventiveness taken by the **Maharashtra Pollution Control Board, Nagpur** to adopt **Rooftop Rainwater Harvesting System** at their UDYOG BHAVAN Premises, Nagpur is highly commendable.

Globally, the ever-growing population along with rapid industrialization has posed serious threats to the water regime quantitatively as well as qualitatively. **RAINWATER HARVESTING** - the new watchword is being promoted as a solution to the problems arising due to impact of various anthropological activities on the water regime. It is accepted as a measure to collect and store the rainwater locally, for its use during the dry periods of the year. It also helps to check soil erosion, augment the ground water, check water table depletion and improve the ground water quality.

Nagpur, occupying the central part of India receives an ensured, average, annual rainfall amounting to more than 1000 mm. Majority of this rainfall is received from southwest monsoon during June-September every year. The rainfall pattern of the region based on the observations made by the Indian Meteorological Department, Nagpur is graphically depicted below.

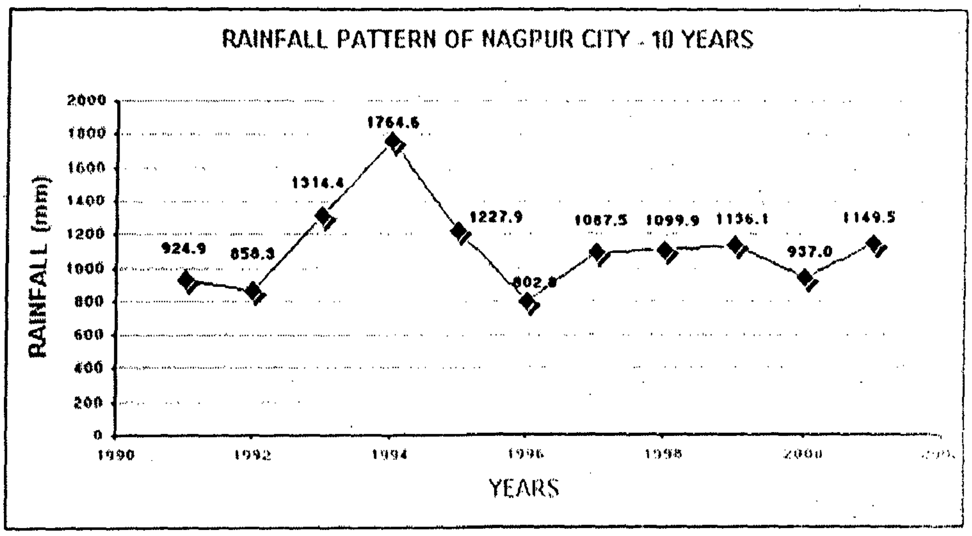


Fig 22 Rainfall pattern of Nagpur city (10)

The month wise rainfall data as compiled below indicates that the maximum rainfall occurs during June-October of every year.

RAINFALL NAGPUR CITY 1991-2001													
YEAR	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUNE**	**JULY**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**TOTAL**
1991	36	3.8	6.9	3.2	0.1	138.7	447.2	278.8	10.1	0.1	0	0	924.9
1992	0	0	0	8.1	8.6	86.6	222.0	373.2	117.3	37.5	4.8	0	858.3
1993	0	25.5	72.9	3.4	29	196.8	412.2	215.7	293.3	63.6	0	2.0	1314.4
1994	37.1	67.4	0	10.1	5.8	152.5	683.9	338.6	295.9	172.8	0.5	0	1764.6
1995	43.2	0.4	99	10.3	6.8	145.8	364.3	266.4	255.3	36.4	0	0	1227.9
1996	0.3	14.1	6.4	60.8	0.2	21.9	259.6	230.0	115.1	69.0	25.4	0	802.8
1997	22.5	0	0	8.4	14.9	87.3	223.3	198.2	216.0	105.0	82.1	129.8	1087.5
1998	27.6	52.2	44.9	11.5	22.5	104.0	202.3	290.9	191.2	52.6	100.2	0	1099.9
1999	0.5	24.9	0.9	0	51.9	115.0	252.1	324.8	236.7	129.3	0	0	1136.1
2000	0	25.9	0	0	54.5	187.4	395.5	175.1	82.7	15.9	0	0	937.0
2001	4.2	0.0	20.1	28.8	46.6	279.8	231.4	253.3	101.2	184.1	0.0	0.0	1149.5
TOTAL	**171.4**	**214.2**	**251.1**	**144.6**	**240.9**	**1515.8**	**3693.8**	**2945**	**1914.8**	**866.3**	**213**	**131.8**	**12302.9**
AVERAGE	**15.6**	**19.5**	**22.8**	**13.1**	**21.9**	**137.8**	**335.8**	**267.7**	**174.1**	**78.8**	**19.4**	**12.0**	**1118.4**

Table 09 showing rainfall data for Nagpur city for 10 yrs. (10)

Note: Further analysis of the available data indicates that the rainfall occurs in approximate 59 days of the year. These rainy days are spread in approximate 51days (out of 122 months) of every year.

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC	TOTAL
1991	2	1	1	1	0	7	15	13	1	0	1	0	42
1992	0	0	0	1	2	5	12	17	4	2	1	0	44
1993	0	1	5	1	3	10	17	13	14	5	0	0	69
1994	2	3	0	2	1	13	21	14	8	4	0	0	68
1995	2	0	5	2	1	10	14	15	9	3	0	0	61
1996	0	2	1	2	0	2	14	18	10	5	1	0	55
1997	1	0	0	1	3	8	14	10	9	6	4	9	65
1998	1	0	0	1	3	8	14	10	9	6	4	9	65
1999	0	3	0	0	5	11	15	12	17	8	0	0	71
2000	0	3	0	0	3	13	11	10	5	2	0	0	47
2001	1	0	3	3	5	10	12	17	5	7	0	0	63
TOTAL	9	13	15	14	26	97	15.0	149	91	48	11	18	650
AVERAGE	1.0	1.0	1.0	1.0	2.0	9.0	15.0	14.0	8.0	4.0	1.0	2.0	59.0

The availability of ensured and adequate amount of rainfall, supportive geo-environmental conditions at the site and the economic benefits expected as a result of the rainwater harvesting are sufficient reasons for the MPCB, Nagpur to think seriously about this scheme.

In order to establish the possibility of conserving the rainfall M/s **SRUSHTI SEWA, Nagpur** conducted a systematic survey. This included study for the estimation of rainwater incident on the Udyog Bhavan office premises, assessment of collection mechanism, existing rainwater disposal system. **SRUSHTI SEWA** is working for protection and conservation of vastly depleting natural resources in rural as well as the urban areas and promotes the rooftop rainwater-harvesting scheme.

Water is a finite; limited and vastly depleting resource as far as quantitative as well as qualitative characteristics are concerned. There is only one source of freshwater, and that is precipitation, which ultimately recharges the groundwater. In the region like central India, we are bestowed with ensured rainfall of at least 1000 mm / annum. However, most of the rainfall reaching the surface of the earth quickly turns into surface-runoff and thus recharging is minimal. On the other hand uncontrolled groundwater extraction is a common phenomenon of recent years. This ground water overdraft has resulted in serious water level depletion all over the country. This is even more serious in urban areas where most of the recharging areas are now converted into concrete buildings or paved areas and hence it has become very difficult to augment the water bearing formations (i.e. aquifers) below the ground by regular recharging mechanism. The water requirements of many major, medium and small industries are met either from the surface water reserves or from the groundwater resource. The industrial requirement being high as compared to the natural recharging pattern, an imbalance is observed in the surrounding regions of industrial operations. On the other hand, the naturally occurring rainwater falling on the premises of industrial unit is disposed off systematically. If this water is collected, stored and /or recharged the enormous stress on the depleted ground water and surface water reserves can be released on an optimum sustainable basis.

Rooftop Rain Water Harvesting is the technique through which rainwater is captured from the roof catchments and stored in surface / sub surface reservoirs. Harvested rainwater can be stored in sub-surface ground water reservoir by adopting artificial recharge techniques to meet the household needs through storage in tanks. Main Objective of rooftop rainwater harvesting is to make water available for future use. In Nagpur city we can collect and store 80 m^3 (or 80, 000 litres) water / annum from 100 m^2 roof area.

The Udyog Bhavan premises consist of many important government offices. Water requirement is met from Municipal water supply scheme, which is adequate to meet their demand. Water is mainly required for non-drinking purposes such as washing, toilets and bathrooms, laboratories, gardening and other domestic purposes. A dug well with 3.0 m dia and 6 m depth is also a supplementary source of the building. However, water requirement is totally dependent on the Municipal water supply.

The total area of the premises being 6047 m^2, the built up area is 5909 m^2 This building is 6 storied and each floor consists of 965 m^2 The total rooftop of this building is measured to be 1002 m^2 **Rooftops** of the buildings have been systematically designed and slope to drain out the rainwater through drainpipes (160 mm diameter PVC pipeline). These drainpipes are interconnected and subsequently open into nearby nala, discharging all the rainwater in the form of surface run off. The rooftop has been divided in two sections, viz., Northern & Southern Sections respectively. These act as catchments, divide and separate each section on rooftop. Amount of rainwater incident on these roof areas along with other roof areas has been estimated as below. As mentioned earlier the roof top area was measured to be1, 002 m^2. Considering 1000 mm. rainfall incident over these rooftops, 802m3 water is received in the form of rainfall every year.

Annual Rainwater

Incident = **Rooftop Area x Annual Precipitation x 0.8**

= 1002 x 1.0 x 0.8

= **802 m^3 or 8,00,200 liters / annum**

Based on the lithological formation and aquifer properties of the lametas, a recharging system is proposed. As can be seen the rainwater incident on the rooftops will be systematically diverted towards a RECHARGING TROUGH TRENCH. This recharging trench would act as a medium to divert the rainwater for recharging the aquifer. The proposed dimension of the trench is designed to accommodate the rainfall incident on the rooftop of the Udyog Bhavan building as estimated in earlier paragraph. The proposed sump will be connected to the dug well. This sump will also be connected to the existing overhead tank from where the water distribution network in all over the building is already established. The overflow from the sump will be sent for recharging. In this method a pit of (3mx3mx2m) dimension will be constructed and it is connected with approved WATIN filter, which filters the water before recharging the aquifer. This filter is to be located near the dug well so that all the filtered water may be allowed to pass into this well. A sedimentation /settling sump is also advisable near the filter in order to arrest all the silt and clay deposited on the rooftop, pipelines etc.

Precautionary Measures

- Rooftop to be kept clean. At least before onset of monsoon it should be thoroughly cleaned.
- Regular maintenance of Sedimentation sump at six-month interval. September End and May end is advisable.
- Digging, excavation near Recharging Trough Trench to be avoided
- The Recharging Filter surface needs to keep free from any load.
- Even garden pots, vehicles, cooler and any miscellaneous household item, which may dig or excavate and disturb the surface of the Recharging Filter, be avoided.

4.5 FINDINGS, INFERENCES FROM CASE STUDIES

Following are the **design features** incorporated to achieve **Green Design** in the case studies and their performance.

4.5.1CASE STUDY 1

RESIDENCE FOR SUDHA AND ATAM KUMAR

4.5.1.1 Design features

- The house has been oriented to face south so that every habitable room has a liberal solar exposure. Shading has been carefully designed to prevent solar gains during summer and allow the same during winter
- External wall and roof insulation help the thermal mass to act in tandem with the inner space
- Reflective finishes of wall and roof for heat reflection
- Multi-directional evaporative wind tower atop stairwell, for cooling of house during dry summer
- South-facing solar chimneys assist air exhaust during summer
- Architecturally integrated solar water heating system and solar cooker
- Compost pits in garden for composting of kitchen wastes
- Low water flush valves without cisterns
- All rooms adequately day lit and artificial lighting is provided with low energy lights
- Overall rationalization of loads done by careful device selection

- An inverter and battery bank back up has been provided with provision for photo-voltaic charging in future.

4.5.1.2 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 over 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.

4.5.2 CASE STUDY 2

RESIDENCE FOR MAHENDRA PATEL, AHMEDABAD

A connected load of 18 kW is used to fulfill the client's need without compromising on any comfort.

Air-conditioning load reduced from 36 to 26 tonnes by passive solar interventions

Fly ash bricks are used for masonry work

External walls and roof are insulated

- Windows are with double glass shutters.
- Walls are finished with white paint, which reflects heat
- There are 1.2 metre projections all round the building that work as service ducts to carry all the utility services like electricity, water supply, fan coil units for air-conditioning, and also as a shading device

- Problem of air and light quality is eliminated by provision of north light and fresh air unit at the top of the entrance hall.
- Solar photovoltaic and solar water heating systems are used.
- Building automation system is used to minimize energy wastage

4.5.3 CASE STUDY 3

CII-SHORABJI GODREJ GREEN BUSINESS CENTRE, HYDERABAD

4.5.3.1 Green features

- Zero water discharge building
- Waste water treatment through root zone treatment system
- Rainwater harvesting
- Low flow water fixtures
- Waterless urinals
- Use of storm water and recycled water for irrigation
- Roof gardens
- Pervious paver blocks
- Use of aerated concrete blocks for facades
- Double glazed windows
- Fly ash based bricks
- Recycled glass, aluminium and ceramic tiles and recycled wood
- Office furniture made of baggase based composite wood
- Harvesting of solar energy through photovoltaics for generating electricity
- Control of air quality through carbon dioxide monitoring

- Fresh air drawn in building through wind towers
- Use of low Volatile Organic Compound carpets, paints, adhesives and sealants

4.5.3.2 Performance

- 50% savings on energy consumption
- 35% reduction in potable water use as compared to conventional building
- Operational savings right from day one
- 90% of building is day lit
- Use of aerated concrete blocks reduces 15-20% load on air conditioning
- Materials selected have no adverse health impact on the occupants
- More than 50% of the construction waste recycled within the building
- 20% of the building energy requirement is catered to by the solar photovoltaics
- The 23.5KW capacity solar photovoltaic generates 100-125 units per day

4.5.4 CASE STUDY 4

<u>RAIN WATER HARVESTING – UDYOG BHAWAN, NAGPUR</u>

4.5.4.1 Features

- Rainwater harvesting through rooftop
- Terraces sloped down to allow rainwater to flow to drain pipes and finally collect to the sump.

4.5.4.2 Performance

- The total roof area for the building is 1002 sq m and the total water harvested is 802 cu m

INTEGRATED ANALYSIS AND INFERENCES

- In the dry summer month of May, the room temperature (in the rooms cooled by the earth-air-tunnel combined with evaporative cooling system) of 28° (average day-time condition) with 45%-50% relative humidity was recorded when the ambient temperature and relative humidity were 40° and 30% respectively.
- In humid summer months, room temperature (in the rooms cooled by earth air tunnel supplemented by ammonia absorption chillers) of 30°C and 65% relative humidity.
- Generally the summer temperatures are lowered by 6-7°C and winter temperatures are raised by 5 °C.
- The users are comfortable round the year and there's no need for additional space conditioning.
- The average units of electricity generated by PV system are 55 units per day on a sunny day.
- The power consumption is inclusive of pumping water for garden (twice a day) and house.
- Maximum artificial light usage is 204kWh per day for an average size residence.
- Optimization of structures to reduce embodied energy.
- Vertically mounted collectors - 12 %increase in total capital cost.

CHAPTER 5

CONCLUSIONS AND GUIDELINES

5.1 CONCLUSIONS

We have an intimate interdependency with nature, so our decisions have to be such that they sustain and can also be sustained by nature. It's needed to set out a more holistic, system based way of thinking about ecologically sustainable buildings that can help people develop an understanding of the relationships between natural systems and built environment and between the decisions we make and the intended outcome.

The result of our attempt to use resources, which have been the products of billions of years of solar energy within what is relatively a mere instant, has been, conversely, to spew more substances and energy into the environment than the planet is capable of digesting, and this has thrown the entire global ecosystem out of balance.

All over the world we are finally beginning to recognize the threat that 963.*- abnormal weather and pollution in the air, water and ground are posing to civilization. Economic development that wastes limited resources and destroys the environment brings only momentary prosperity; it lacks sustainability and threatens the very existence of future generations. Now is the time to change our consciousness in this regard and, focusing on solar energy, to come up with the appropriate means of utilizing our resources

We need to learn to carefully select and then fit together, cells containing the knowledge we need, in a way that allows us to appreciate the whole system that we'll affect when we build. We need to develop solutions that resolve these energy and environmental performance issues while reducing envelope and whole building costs.

Though it is troublesome to make biodegradable goods and to utilize natural energy in our present ways of life, it is not impossible.

5.2 DESIGN GUIDELINES FOR GREEN HABITAT IN HOT DRY CLIMATE

5.2.1 SITE CONSIDERATIONS

5.2.1.1 Topography

- Maintain the natural slope of the site. This helps in taking maximum advantage of the microclimatic conditions and natural energy that is available. For example, even a 10° slope will receive up to 28 percent more sun than a horizontal surface in mid-winter, which is enough to cause spring blooming to occur two weeks earlier.

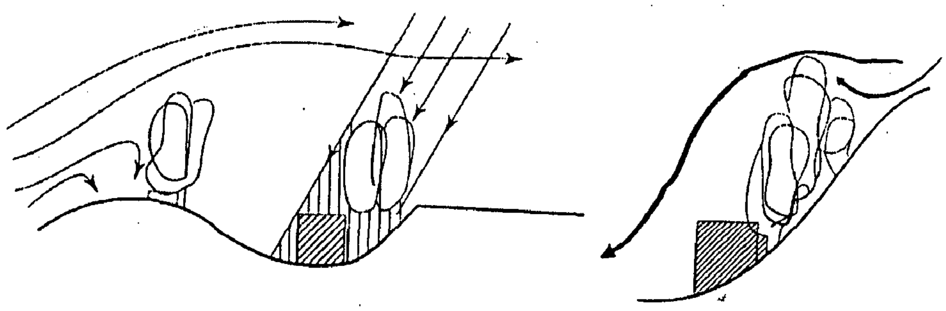


Fig 23 Natural slopes of the site maintained (7)

5.2.1.2 Reduce footprint of the site

- Mark out the limits of construction activity and fence the area to protect all undisturbed soil and vegetation located outside specifically designated construction (e.g. drop cloths, tree barriers).
- Preserve the topsoil from construction area for later use in planting trees.

5.1.2.3 Landscape

- Minimize areas of vegetation disturbance
- Preserve the natural landscape during construction because it is much less expensive and more ecologically sound than subsequent restoration.
- Try to restore native planting patterns when site disturbances are unavoidable. All native plants disturbed by the construction should be saved.
- Use landscape to provide desired microclimate for buildings.

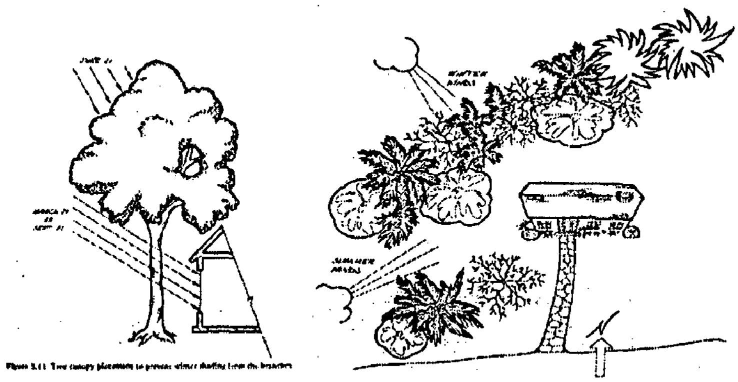


Fig 24 Microclimate created through proper landscaping (8)

- Minimize the use of lawns during dry periods, as they need more water. Drought-tolerant groundcovers should be considered as an alternative to lawn.
- Plant more trees to reduce solar heat gain, cooling energy and increase the attractiveness of outdoor spaces.
- Plant trees with dense canopies and mature height of 40 ft. next to east and west building facades to shade windows and walls from low-angle sun.
- Plant trees at a distance of approximately half the width of the trees mature canopy from the building and spaced at 1/4 to 1/3 the canopy width. For greater shading and cooling, plant a multi-layered composition of shrubs and small trees with a minimum height of 3m and width of 1.2m next to building facades.

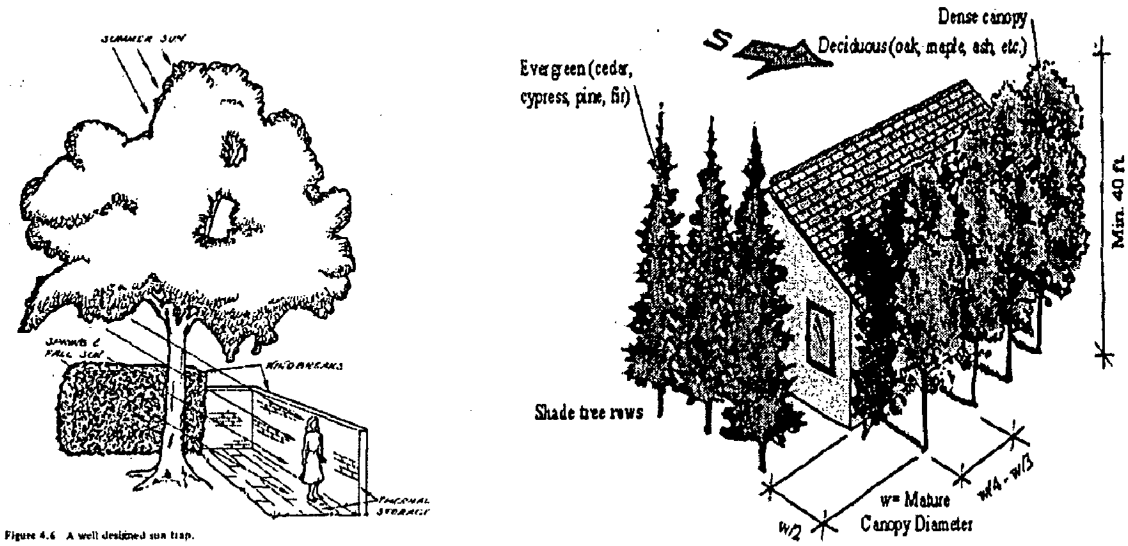


Fig 25 Landscaping to cut down space conditioning loads (8), (12)

- Mount vertical vine lattices 0.3m to 0.9m away from walls, to create a shaded, cool air pocket.

Fig 26 Energy conservation through landscaping (12)

- Cover bare areas with grasses to lower the summer temperatures.
- Locate buildings to benefit from existing vegetation.

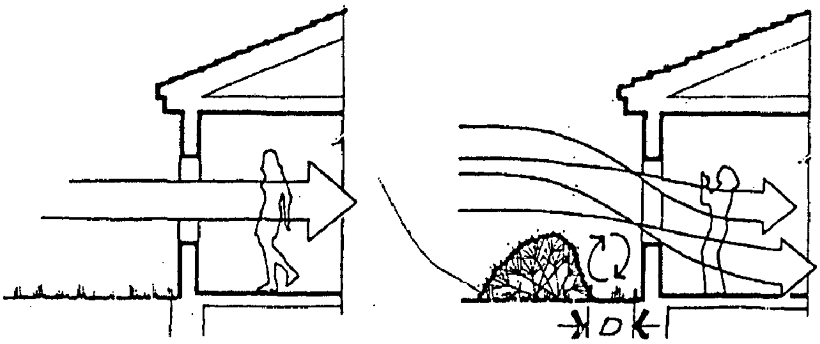


Fig27Shrubs foster down deflection. Effect produced for distances D up to 15-20 ft (13)

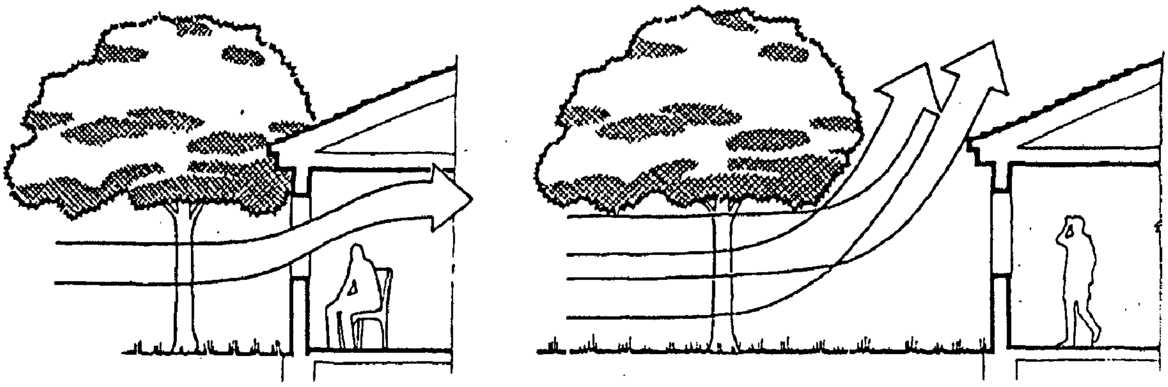


Fig 28 Tree canopy fosters upward deflection (14)

- Plant deciduous trees on the south, the east, and especially the west sides of a building to reduce cooling loads while allowing much solar heat gain in winter.
- Landscape with drought-resistant native plants and perennial groundcovers.
- Use impervious pavement out of recycled concrete and asphalt, only where regular car use is expected otherwise use porous asphalt, paver blocks or large aggregate concrete for parking and highly used bicycle and pedestrian areas.
- Use crushed stone or brick for lightly used pedestrian paths
- Recycled asphalt and recycled concrete where impervious surfaces are required

- Provide "curb cuts" and slope hard landscaping features to allow water to flow to permeable surfaces and oil/water separators.

5.1.2.4 Orientation, Massing And Shape

- Organize building mass, orientation and outdoor spaces to provide efficient access to services; incorporate recreational areas that have multiple functions in addition to visual value. For example, rooftops can be used as gardens and for water collection; a water feature in a playground can provide both cooling and recreation for children.

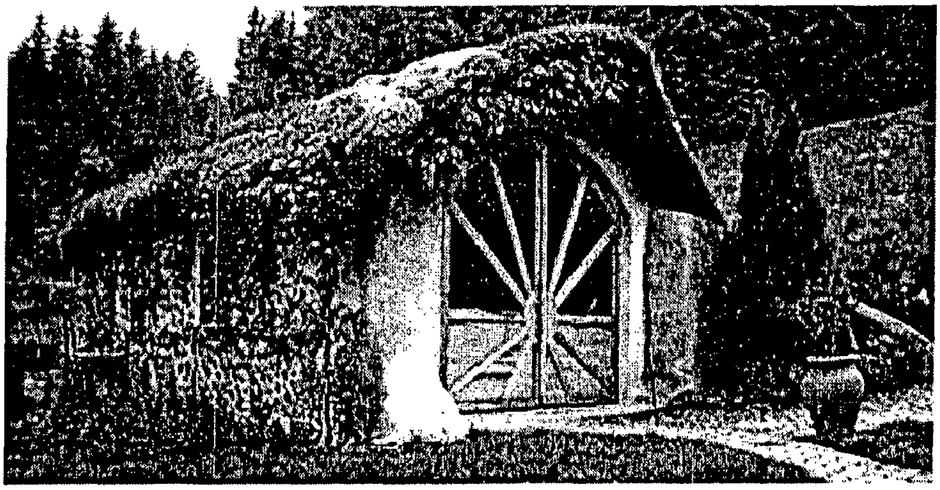
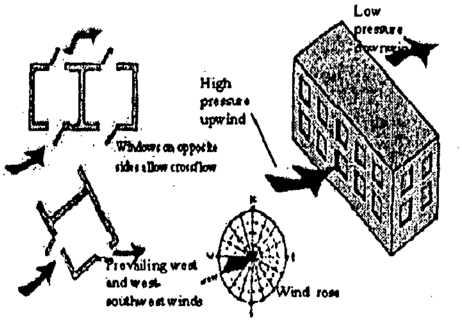


Fig.29Insulation through roof gardening (10)

- Orient buildings with longer axis on East-West than North-South with interior light wells or courtyards for lighting and ventilation.
- Shape buildings with small roof areas to a rectangular form with the major axis lying in the east-west direction.
- Orient buildings with long sides within 15 degrees of south (slightly east gives best heat distribution) with garages and storage on west and east.
- Orient the building to allow for maximum exposure to summer breezes.



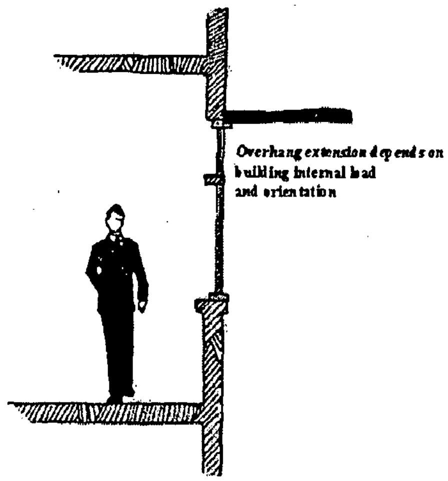


Fig 30 Passive methods to reduce energy loads through orientation and shading (12)

- Layout interior spaces to take advantage of passive cooling.
- Provide overhangs over the south windows to keep the high summer sun out, this type of building will be warmer in winter and cooler in the summer than any other shape.
- Orient building, windows and outdoor spaces in such a way that they work together to take maximum advantage of the light, airflow and interesting views.

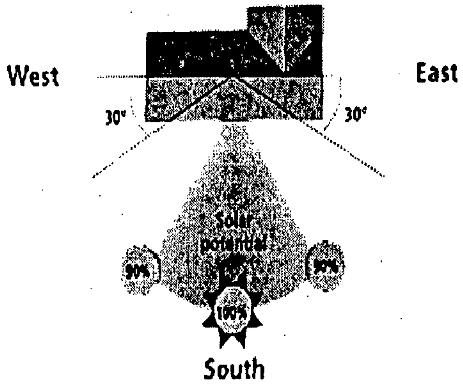


Fig 31 Orientation of longer side on East-West axis

5.1.2.5 Preservation of soil, water, and air quality

- Use mulch to conserve soil moisture, restore soil fertility, and reduce the need for fertilizers. Leave grass clippings, small plant debris, and fallen leaves to decompose on the ground. Use compost for soil amendment in lieu of peat moss (a non-renewable resource).
- Treat the sit with ecological landscaping, which improves local air quality by absorbing carbon dioxide, producing oxygen and filtering particulates.
- Reduce water pollution from pesticides, herbicides, and fertilizers by using plant combinations and maintenance methods that do not require chemicals.

5.2.2 ENERGY CONSERIDERATION

5.2.2.1 Shape size and orientation

- Shape buildings to be conscious of wind catch summer breezes, while lay out the interior to efficiently circulate these breezes.
- Orient building to respond to the local climate and to allow for maximum exposure to summer breezes.

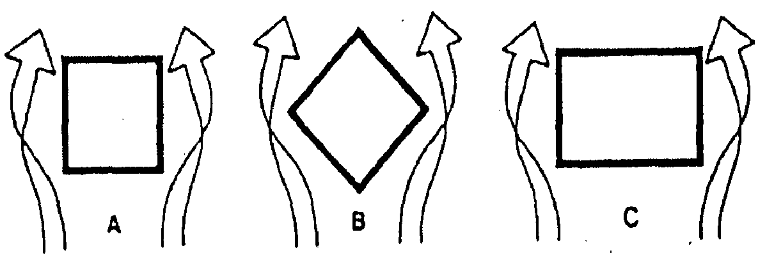


Fig 32 Plan A and B have the same area but B is as exposed C to the prevailing winds (14)

- Design rectangular shaped building elongated on the east-west axis Use a simple house design that will minimize the area of perimeter walls.
- Place living spaces and areas that are the most frequently occupied during daylight hours, to the south.
- Place laundry areas outside of interior living space if possible.
- Take advantage of natural light and ventilation using proper amount of glass and window location.
- Use properly sized overhangs (Reference: Architectural Graphic Standards)
- Plan windows for cross ventilation.
- Optimize the use of interior space with good design so that the overall building size and resources used in constructing and operating it are kept to a minimum.
- Minimize the surface to volume ratio (SVR). As a general rule, the more compact the shape, the greater the heating and cooling efficiency of the building. This is accomplished by minimizing the exterior wall and roof areas.

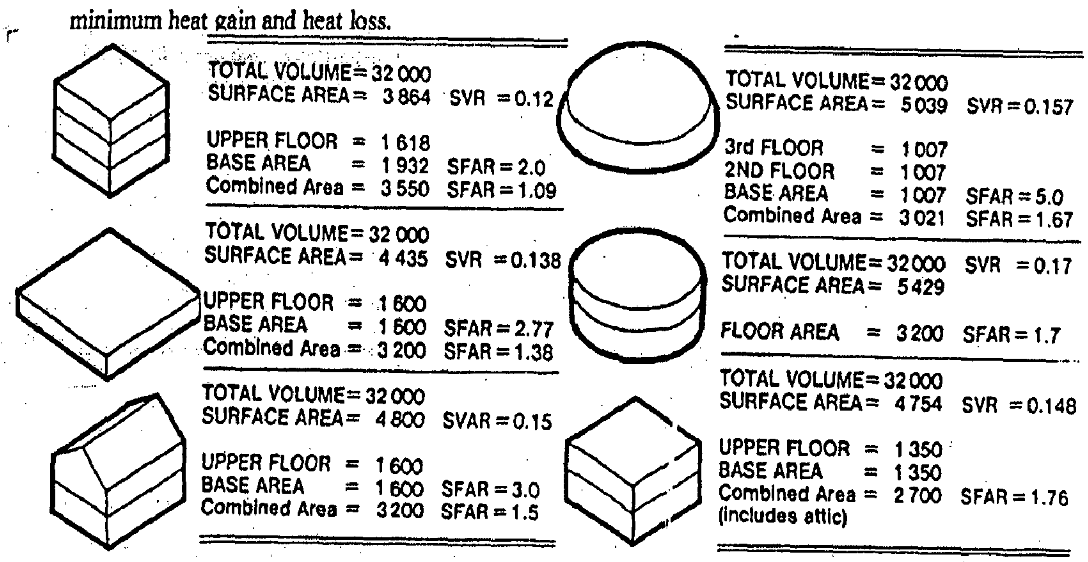


Fig 33 Comparison of different configuration of spaces with different S/V ratio, space volume kept constant (14)

5.2.2.2 Solar Control

- Use high performance glazing or exterior solar controls such as overhangs or awnings, rather than internal blinds for best results.
- Install energy efficient windows with double panes Low-Emissivity (low-E) with low conductivity frames.
- Specify high-performance low-emissive glazing with visible transmissivity greater than 0.6 and solar transmissivity less than 0.4. This can reduce annual operating energy by 20%.

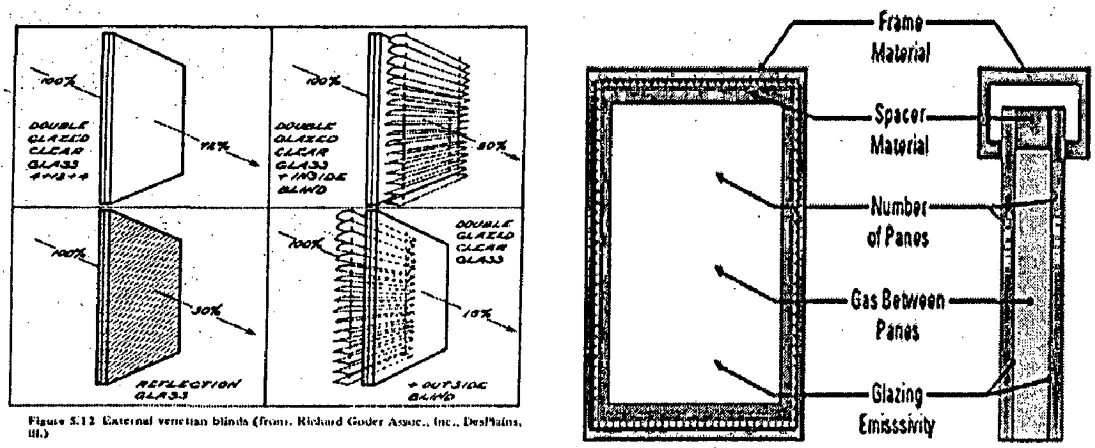


Fig 34 High performance glazing (8), (16)

- Keep window size to minimum and keep total window area equal to 10% of the floor area to reduce heat gain.
- By use of passive techniques admit the sun into the spaces when heating is required in winters and block the midday summer sun. This helps to reduce electrical energy loads for heating and cooling.
- Provide window chajja 0.9m for west and south and 0.6m on east and north to cut down the high altitude sun.

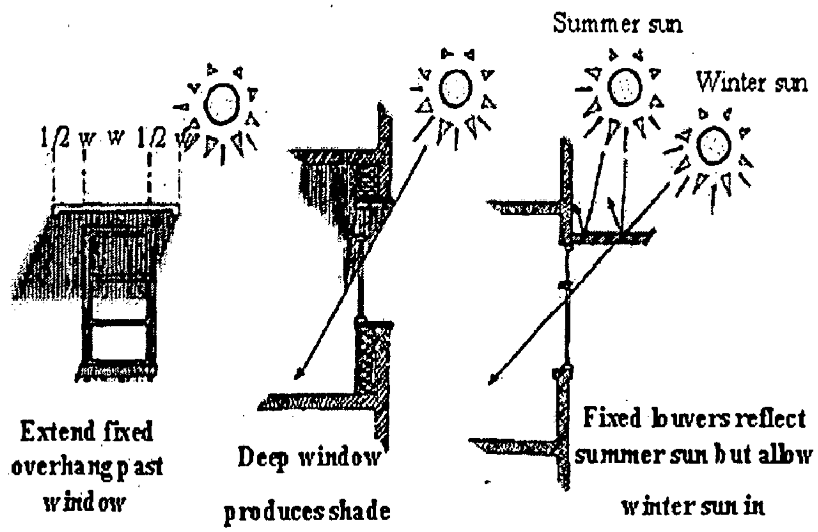


Fig 35 Sun shades (12)

- Limit the amount of glazing on west and southwest orientations where mid-afternoon summer sun is difficult to shade effectively with fixed fins or overhangs.
- Reduce solar heat gain by recessing windows into the wall. Recess windows up to 0.15m. Deeper recesses provide additional shade but may reduce daylight.
- On southern windows, block sunlight greater than 65 degrees.
- Glaze areas of southern façades equal to 7% of total floor areas.
- If thermal mass (ex. tile, masonry, concrete) is used, the glaze south facades up to 12% of floor area.
- Provide reflective and light colour finishes on the terrace to reduce heat gain.

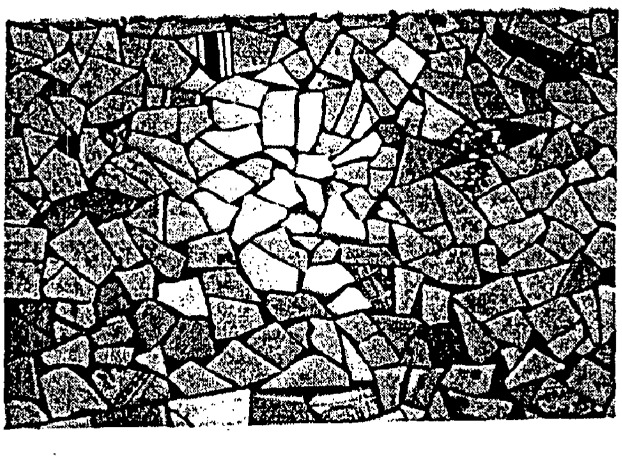


Fig 36 Reflective terrazzo finishes for roof (9)

- Provide extended roofs to shade the entire wall on north and south.

5.2.2.3 Space Planning and Interior Finishes

- The design of the interior must ensure that light and air reach the largest area possible, requiring careful design of interior spaces and partitioning.
- Reduce pollutants like formaldehyde in cabinets, carcinogenic adhesives, and volatile paints and varnishes.

5.2.2.4 Daylight

- Make arrangement for diffuse light from the sky rather than direct sunlight and bring light deep into the building.
- Provide multiple sources of daylight, from at least two sides of every space to reduce glare and shadow problems.
- Distribute daylight, by directing it towards the ceilings, floors, walls for gentler and more diffused light and fewer shadows.

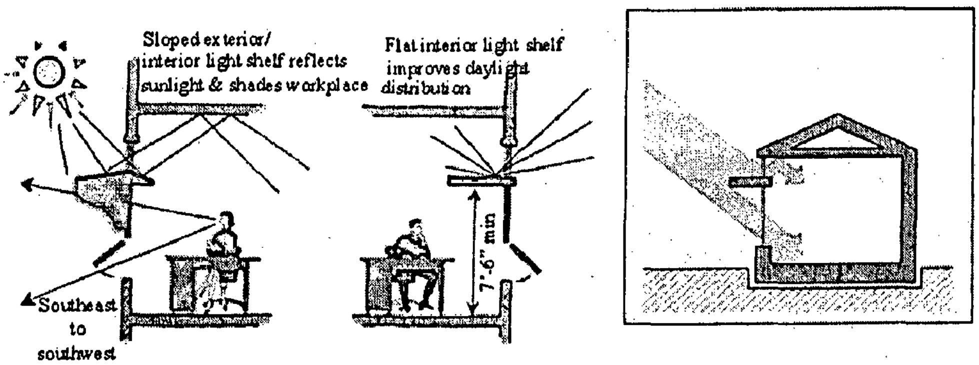


Fig 37 Natural lighting through light shelves (12)

- Use light coloured interiors surfaces to reflect more light and brighten the space more.
- Limit the amount of glazing on west and southwest orientations where mid-afternoon summer sun is difficult to shade effectively with fixed fins or overhangs.

- Provide more of window area and glazing visible transmissivity on north- and northeast-facing walls to admit more daylight.
- Avoid heavily tinted or reflective glasses that reduce solar heat gain but also reduce daylight and exterior views.
- Separate the window into upper and lower portions, to independently control daylight, natural ventilation and view.
- Use light colors on interior surfaces, especially walls and ceilings, to increase the daylight that reaches areas remote from windows.
- Use splayed, light-colored windowsills and reveals to reduce contrast and glare.

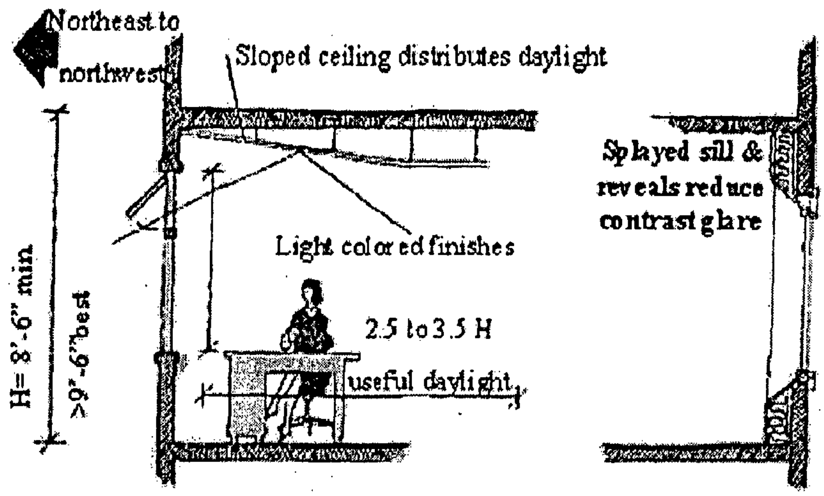


Fig 38 Splayed sill to reduce glare (12)

- Align interior partitions perpendicular to windows to avoid blocking daylight.
- Shape the ceiling and use secondary reflecting surfaces to further diffuse daylight.
- Increase window area and glazing visible transmissivity on north- and northeast-facing walls to admit more daylight.

- Avoid heavily tinted or reflective glasses that reduce solar heat gain but also reduce daylight and exterior views. Make use of passive cooling and heating methods to reduce energy loads.
- Shape the roof monitor to admit only daylight from the north only and the skylight area should be around 4% to 8% of the floor area.

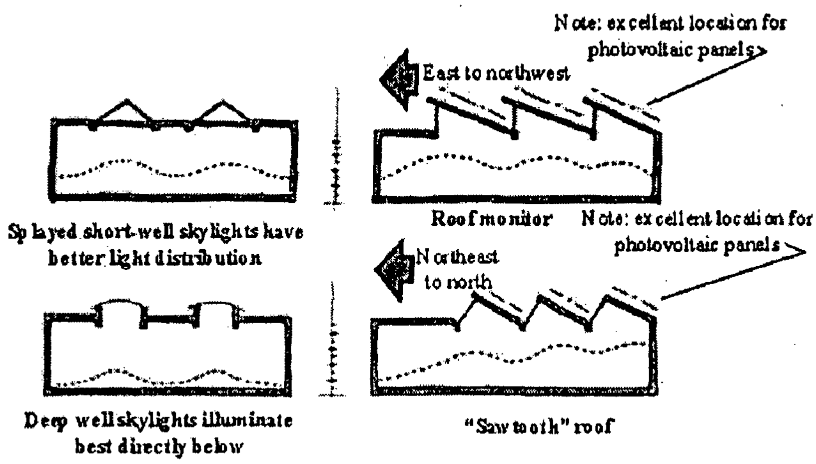


Fig 39 Roof lighting (12)

- Skylights can be energy costly, and should generally be minimized unless treated with a Sky Lid or other form of movable insulation.
- Integrate photovoltaic collectors on south-facing sides of the monitor.
- Splay the walls and use matte white reflecting surfaces around the monitor to improve light distribution and reduce glare.
- Avoid using horizontal skylights, which result in excessive solar gains in summer.
- Brighter sky visible through skylights can cause glare problems.
- Use a translucent glazing, to reduce glare. If using clear glazing, use a ceiling diffuser at the bottom of the skylight shaft to improve light distribution.
- Provide an exterior shading system over the skylight during the summer.

- Provide recessed windows with depth of the recesses less than 6 in. as deeper recesses provide additional shade and control glare, but may reduce day lighting.
- Provide light helves to take advantage of the clear sly conditions.
- Use a combination of exterior and interior shelves on southeast, south and southwest orientations:
- Use light coloured, sloped external shelves for best daylight penetration.
- Use interior shelves on north orientations to improve light distribution in spaces with high floor-to-ceiling dimensions and deeper illumination in the building. Integrate light shelves and ceiling design.
- Combine light shelves with flat, light-colored ceilings free of obstructions for better light penetration.
- Slope the ceiling down from the window side to enhance light distribution, and reduce contrast and glare.

5.2.2.5 Natural Ventilation

- Design windows to admit natural ventilation and provide windows on at least 2 sides of the space for cross-ventilation to interior spaces.

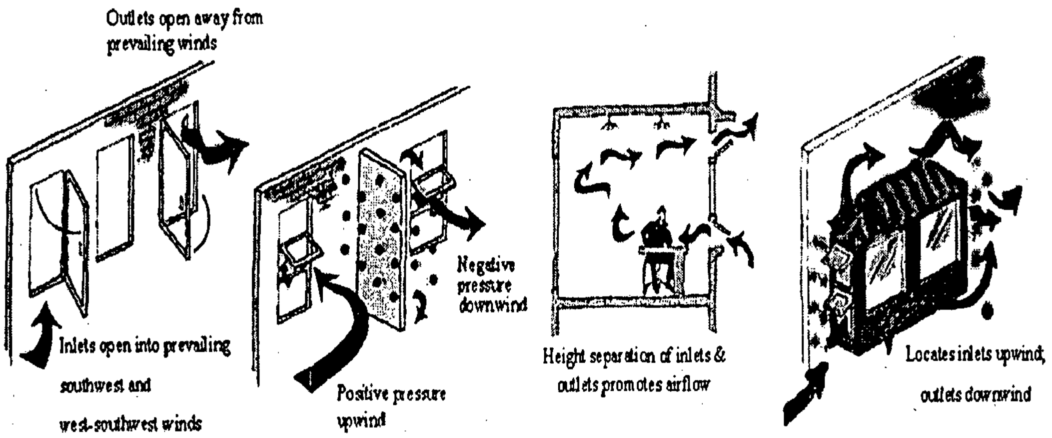


Fig 40 Natural ventilation though windows (12)

- Place windows strategically to efficiently circulate the breezes. Use walls, overhangs and other built elements to assist in channeling breezes through the building.
- Open-plan layouts are ideal, but where spaces are subdivided, design the rooms to allow airflow in and out, between rooms and through occupied areas.

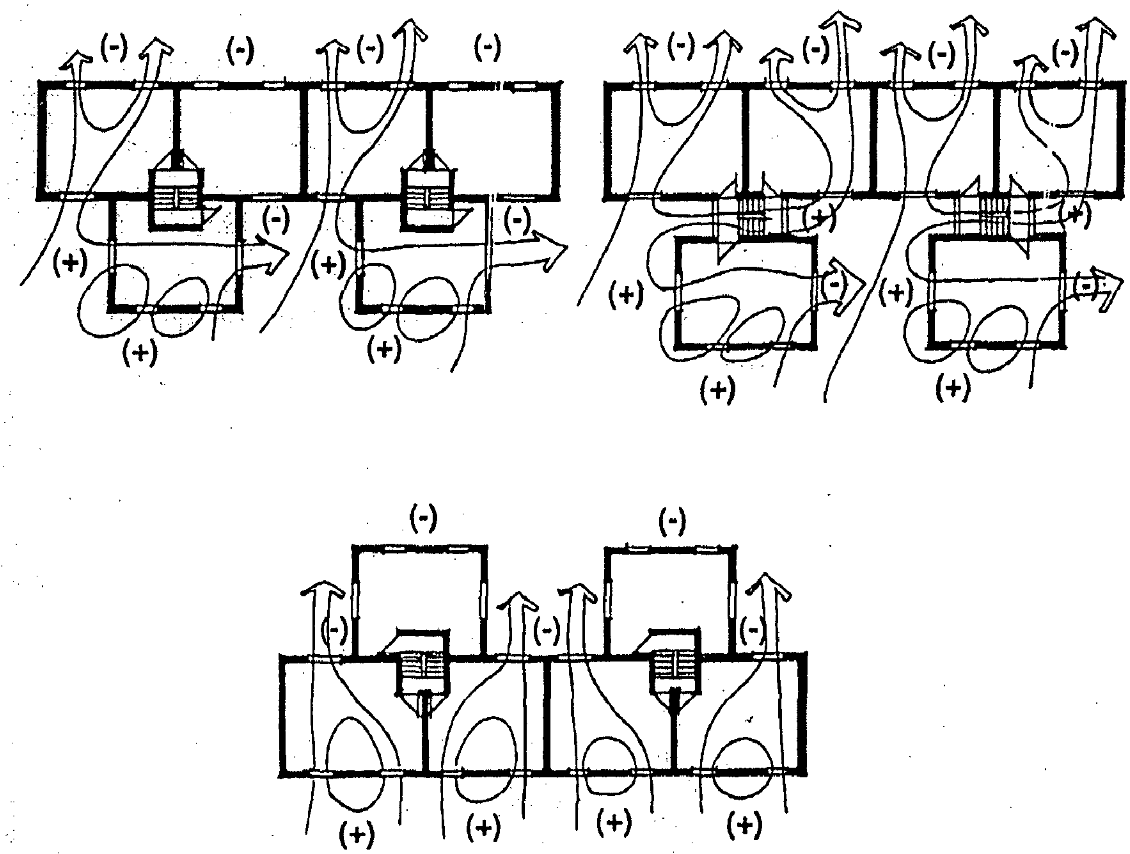


Fig 41 Different ventilation potentials for different configuration of spaces of the same size (5)

- Provide horizontal pivot windows for higher ventilation capacity.
- For single-sided ventilation, place windows as high as possible to exhaust warm air at ceiling level.
- Locate larger spaces on the windward side of the building. This provides improved air distribution in all linked interior spaces.

- Provide wind towers, which take the hot air from outside and cool it. As this air-cools, it settles down and enters into the spaces through the openings and the warm air escapes out.
- Provide internal courtyards with roofs sloping towards the courtyard. The cool air sinks into the courtyard and enters the living spaces through low-level openings.
- Take care that the courtyard does not receive intense solar rays.

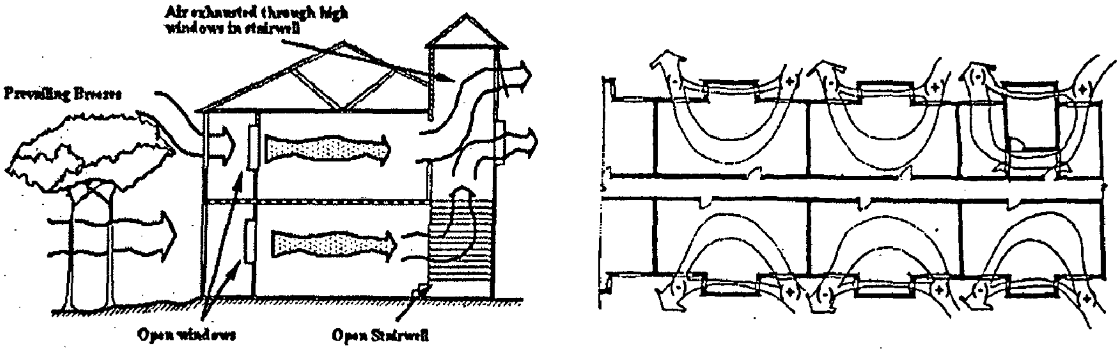
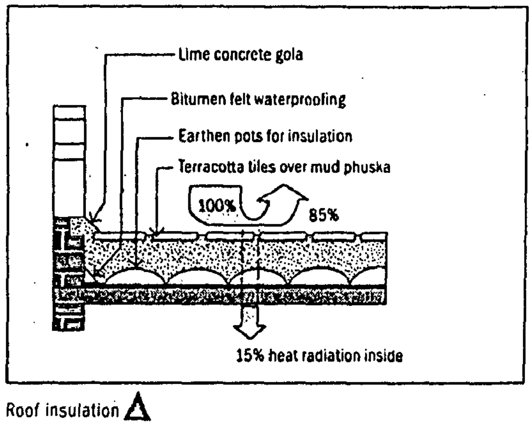


Fig 42 Ventilation through open stairwell (5)

- Use operable transom windows in walls to permit a free flow of air and daylight.
- Use high ceilings to allow heated air to rise out of occupied zones.
- Provide vertical airshafts such as cupolas and roof monitors, which serve to efficiently remove hot air through stack-effect ventilation.

5.2.2.6 Insulation and Massing

- Insulate the roof to minimize the cooling loads in summer, when the roof receives as much as 50% solar radiations. A traditional cost-effective system can be used where the entire roof is covered with densely packed inverted earthen pots laid in mud phuska. This arrangement provides an insulation cover of still air over the roof, which impedes heat flow within the building.



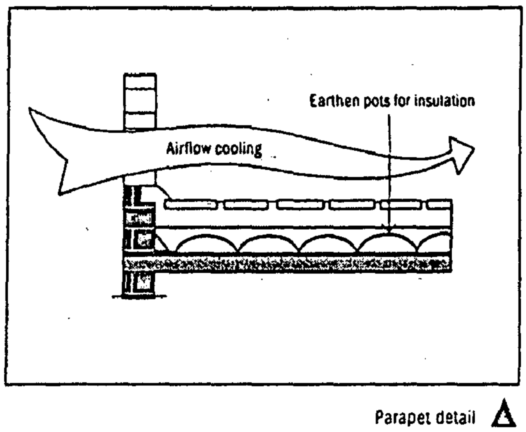


Fig 43 Insulation by inverted earthen pots (9)

- Provide at least double pane windows, with insulated shutters or curtains inside.
- Double up inexpensive single pane windows to make double pane windows. A one-to-two inch gap filled with inert gas like neon, between these panes is sufficient, which allows only light and cuts down the heat from the sun.

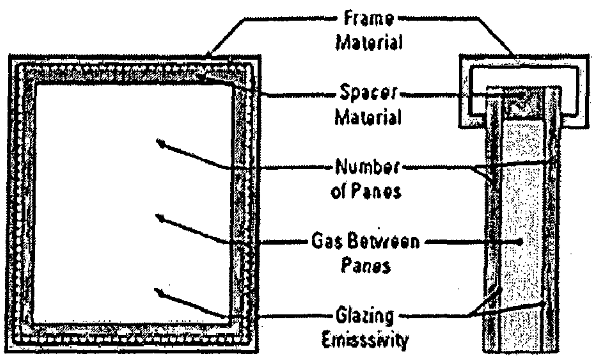


Fig 44 Double glazing to allow only light and cut down sun (16)

- Provide special heat saving windows with energy control films (such as Heat mirror™) and argon gas.
- Use expanded polystyrene (25-mm thick) insulation 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 can be provided over the roof slab. Both these provide for a highly inert house with high thermal mass and high insulation.

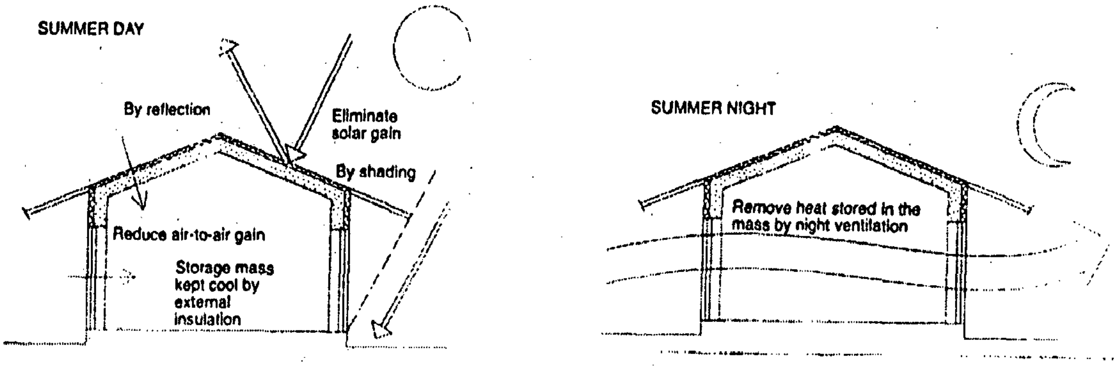


Fig 45 Envelope for hot climates (7)

- Use high-density concrete provides more thermal mass than low-density concrete.
- Provide terrace gardens to reduce upon the cooling loads.

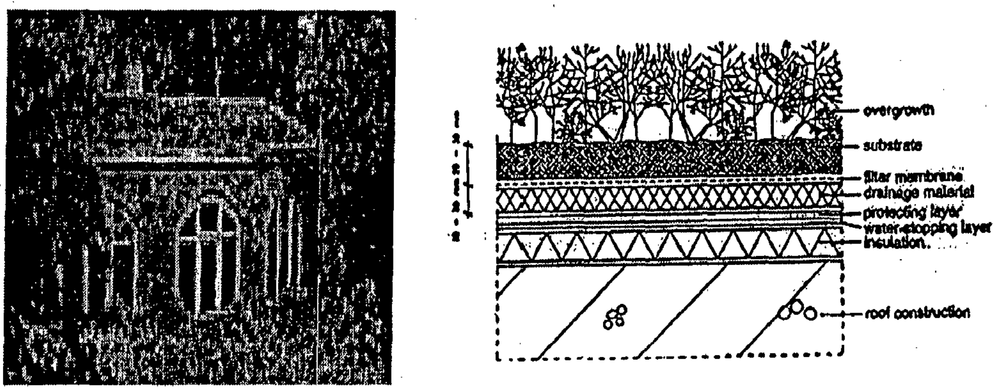


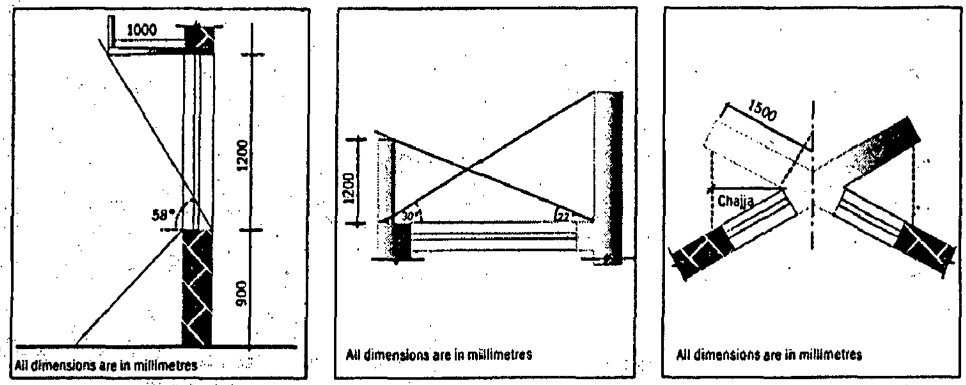
Fig 46Roof gardens to reduce space conditioning loads (10), (15)

Caution

- Structural loading design must be taken into account for the extra loads that are added thru insulation and massing.
- If using gravel ballast for roof insulation, fit gravel stops around rainwater drains and the roof perimeter.

5.2.2.7 Passive techniques

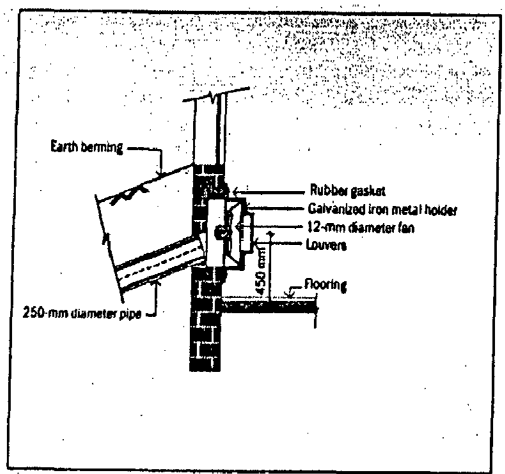
- Design for open floor plan to optimize passive system operation.
- Use shading to prevent summer sun entering the interior.



Shading of walls - South section ▲ Louvre design of north wall typical plan ▲ Louvre design of south-east wall typical plan ▲

Fig 47 Various types of shading devices(9)

Make direct contact with the earth to create better comfort levels than evaporative cooling, as it does not increase the humidity within the rooms. Since it is not possible to build a totally earth-sheltered building, an earthberm, can run along the external periphery of the structure.



▲ Details of ducting of earth air tunnel

Fig 48 Earth berming (9)

- South-facing thin-walled and dark-colored shafts assist air exhaust in the summer days.
- Plan to put the house on photovoltaic charging and progressively make it less dependent on the grid.
- Use light colours for roof as they increase reflectivity to reduce solar gains.
- Increase the roof reflectivity to 0.7 or more can reduce solar heat gains by 80% compared to typical dark roofs. This can be achieved by a variety of techniques, such as covering the exterior surface of the roof with white gravel ballast, light-colored tiles or reflective paint.
- Provide water body like a small pond or fountain for evaporative cooling.

5.2.2.8 Recycling of Waste

- Make it easy for occupants to recycle waste by making provisions for the processing of recyclables such as recycling bins near the kitchen and under-sink compost receptacles.
- Make provisions for on-site composting to reduce the amount of organic waste deposited in landfills (approximately 15% to 25% of solid waste for a typical household).
- Use single-chamber, wood or plastic compost bins as, they are less expensive but also less efficient, requiring proper mixing and layering of green compost (vegetable and fruit scraps, plant clippings) and brown compost (dried leaves, shredded newspapers).

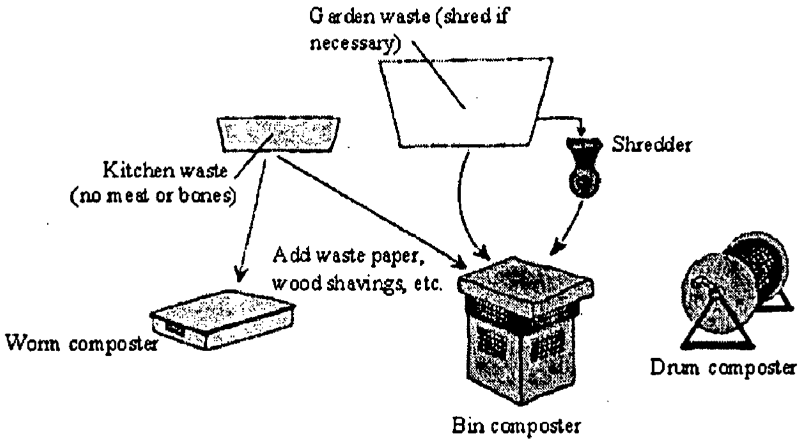


Fig 49 Recycling of domestic waste (12)

- Avoid open compost piles, as they are the least efficient, attract vermin and require considerable space and maintenance.

5.2.2.9 Artificial Lighting

- Low voltage lighting with photovoltaic collectors should be considered as an energy-efficient alternative. Light fixtures should remain close to the ground, avoiding glare from eye level fixtures.
- Use high-efficiency lights and appliances. .
- Install compact fluorescent light bulbs as fluorescent lighting has improved aesthetically and is much less expensive than incandescent.
- Install lighting controls using sensors and timers for use during times when lighting is not needed.

Electric lighting power (Watts per sq. ft.)			
	Conventional Building	Green Building	Percent saving
Day	1.5	0.45	70%
Night	1.5	0.85	43%

Table 10: Energy saved by efficient lighting

5.2.3 MATERIAL CONSERVATION

5.2.3.1 Eco friendly materials

- Use environmentally sensitive building materials that require low amounts of energy to get from raw material to delivered product (low embodied energy).
- Use stabilized rammed earth for foundations (with five per cent cement) and CEB (compressed earth block) (with five per cent cement) walls, vaults, and domes.
- Extract soil for building from the wastewater treatment pond and the garden tank.
- Choose products made of recycled and recyclable materials.
- Use locally produced materials.
- Choose products based on their total life-cycle cost, including durability and embodied energy.
- Use products with a high-recycled material content.
- Specify products that can be recycled or reused.

Make use of Earthen Materials like:

- Cob (earth/straw mixture, sculpted into walls)

- **Adobe** (earth bricks)
- Various **Rammed Earth** systems
- **Ceramic** structures
- **Earth ships** (earth-sheltered structures made of soil-filled tires)

5.2.3.2 Composites as building materials

- Use FRP Doors and Windows as an alternative to the fastly depleting timber resources.
- Use Natural fibre composites (NFC as a substitute for timber as well as for a number of other applications.
- They can be used as a substitute for wood, metal or masonry for partitions, false ceilings, facades, barricades, fences, railings, flooring, roofing, wall tiles etc.
- Use jute-coir composites as another economic alternative to wood.
- Use composite boards namely, coir-ply boards (jute + rubber wood + coir) as plywood substitute and natural fibre reinforced boards (jute + coir) in place of wood for partitioning, false ceiling, surface paneling, roofing, furniture, cupboards, wardrobes etc.
- These boards can be employed as doors & doorframes as an alternate to conventional material like wood, steel etc.
- Use bamboo laminates to replace timber in many applications such as furniture, doors & windows and their frames, partitions, wardrobes, cabinets, flooring etc

5.2.3.3 Use of waste materials

- Use crushed batch concrete waste, window glass wastes as an aggregate substitute, and coal fly ash as a partial cement replacement for the floor slab.

- Use coal fly ash as a replacement to cement component of the concrete mix used in the manufacture of conventional concrete.
- This results not only in a reduction in the cost of cement but also the reduction in the use of precious raw materials and the reuse of by-products and waste materials, which otherwise would have been used as landfill.
- Install recycled content carpet (made from recycled plastic bottles).
- Make use of carpet tiles rather than carpet rolls. By this way the warn out piece of tile can be remade by extracting 80% material from it and helps in great saving of materials.
- Install natural Linoleum over Vinyl Flooring. Unlike vinyl, linoleum is made from natural materials like, linseed oil from flax seed, sand stone, cork, wood and jute.

5.2.4 WATER CONSERVATION

5.2.4.1 Rainwater harvesting

- Collect and store rain water through rooftop rainwater harvesting method to reduce stress on the depleted ground water and surface water reserves.
- Provide surface / sub surface reservoirs for storing this rainwater by adopting artificial recharge techniques to meet the household needs through storage in tanks.

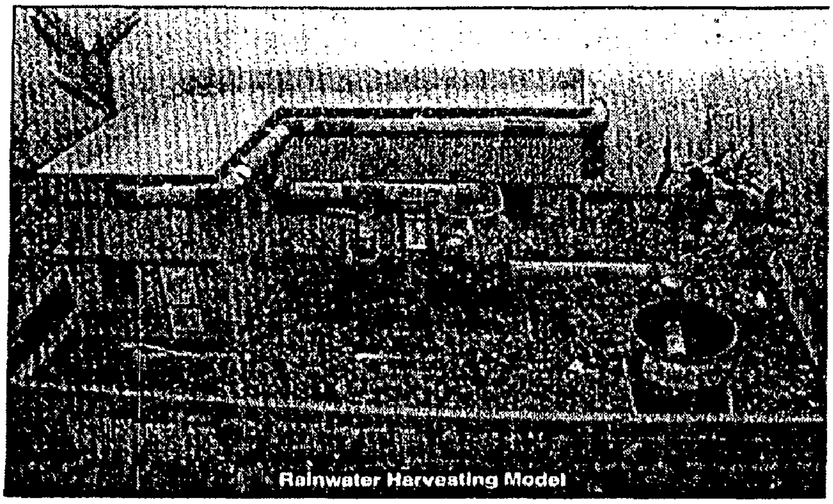


Fig 50 Rainwater harvesting model

5.2.4.2 Waste water management

- Recycle gray water from kitchen, bathrooms, and wash etc. by collecting this water in a pond and applying root zone water treatment method.
- Use this treated water for irrigation purpose and use water efficient irrigation.
- Install plumbing fixtures and appliances that conserve water.

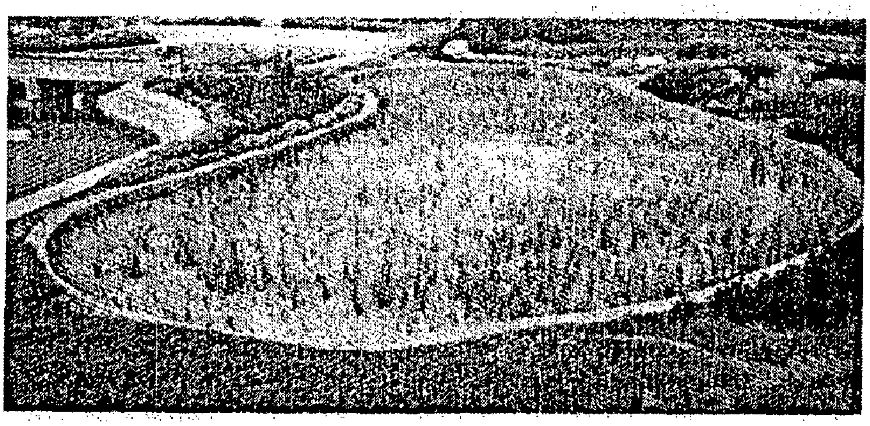


Fig 51 Waste water recycles through root zone treatment

5.2.4.3 Water budget

- Make a water budget to better understand the amount of water you use and how you use it.

5.2.4.4 Use water-efficient equipment

- Use water-conserving toilets, showerheads, and faucet aerators not only reduce water use, they also reduce demand on septic systems or sewage treatment plants.
- Locate the fixtures centrally to reduce hot water costs.
- Install flow reducers in faucets and showers to save excess water from flowing to the drains.
- Use water less toilets and urinals.

5.2.4.5 Reduce Run-off

- Minimize the creation of impervious surfaces when possible.
- Reduce paved areas and use porous materials such as sand, shells, rocks or wood chips for walks and driveways to allow storm water infiltration.
- Eliminate curbs along driveways and streets if possible, so that water can run directly into grass or landscaped areas and does not become concentrated.

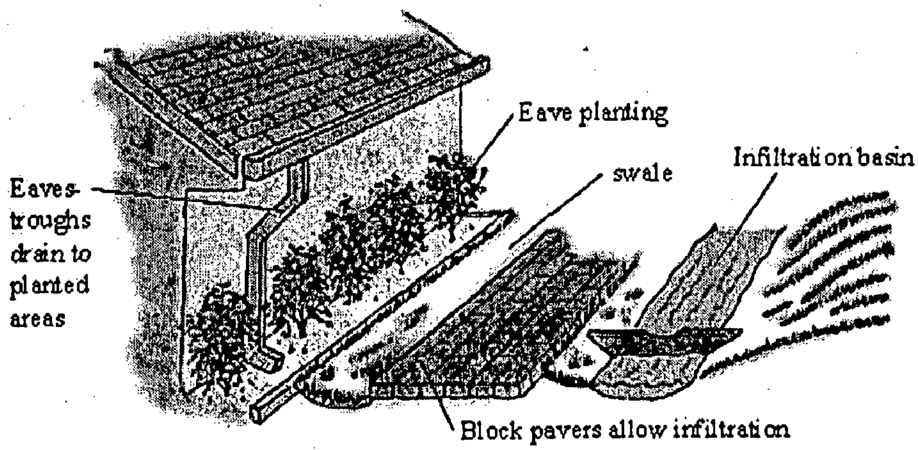


Fig52 Reducing run off (12)

- Plant trees, shrubs and groundcovers to encourage infiltration.
- Provide at least 20% permeable area.

- Provide oil/water separators, catch basin inserts, sand filters, detention basins, ponds, vaults, trenches, dry wells, roof downspout infiltration, porous pavement, grid pavers, grass swales and strips, etc. to prevent storm water pollution.
- Achieve long-term soil stabilization by permanent growth of native vegetation, including but not limited to native grass, sod, tree planting, shrubs, vines and /or other ground covering.

5.2.4.6 Retaining water on site

- Retaining water on-site will help replenish the existing water table. It will help to reduce erosion and the associated sediment deposits in streams.

5.2.4.7 Eliminate gutters

- Eliminate gutters from the edge of a roof to allow storm water to flow evenly off all sides of the building. This way the storm water absorb into the ground where it lands rather than being forced to a few points.

5.2.4.8 Rain barrels

- Place a rain barrel under downspouts to harvest rainwater. The barrels will hold nutrient rich rainwater for plant use.

5.2.4.9Install dry wells

- Install dry wells to allow rainwater to percolate slowly into the soil. Dry wells are small pits, usually two to three feet wide and deep, filled with gravel. These pits hold storm water and allow it to slowly infiltrate into the ground at a slow rate.

5.2.5 INDOOR AIR QUALITY

- To improve upon the indoor air quality always go for informed material selections as the best method to control the quality of indoor air is to reduce or eliminate pollutants at their source.
- Avoid materials, which emit formaldehyde, organic solvents, VOC's, found in adhesives, paints, and binders, finishing products.
- Avoid alkyd-based, or alcohol-based paints as they contain higher levels of VOC's than do latex or water based paints.
- Use non-solvent adhesives that have 99% less hazardous emissions than solvent adhesives. Preferably use yellow and white glues.
- Consider using only silicone sealants in interior areas. All other sealant types, especially the butyl sealants, emit VOC's and other toxic compounds.
- Choose water-based finishes whenever possible.
- Coordinate eco friendly material selection with other strategies such as better ventilation and mechanical systems to produce higher indoor air quality.

5.3 POLICY

Green buildings are our dire necessity today. Though a green building costs 15-20% more than the conventional building, the cost can be recovered well within 2-3 yrs. Incorporation of green features should be made compulsory by making them a part of the byelaws. To make green architecture a regular feature government can offer subsidy or float schemes that attract people towards green building. Evolve local or national green rating system to create awareness about the idea of green architecture.

6 REFERENCES

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8 APPENDIX

1. SOLAR CHART AND SHADOW ANGLES

The position of the sun is described by its altitude and azimuth angles. These angles can be easily determined with the help of a solar chart. The shadow angles defined later are used to work out the sizes of shading devices. These are determined by overlaying a shadow protractor on the solar chart.

SOLAR CHART

The solar chart is a graphical representation of the paths of the sun in the sky for various days in the year. Fourteen such charts, one for each of the 14 latitudes, viz. 9°, 11°, 13°, 15°, 17°, 19°, 21°, 23°, 25°, 27°, 29°, 31°, 33° and 35° N covering India are presented. The radial lines depict the solar azimuth and the concentric circles indicate the solar altitudes. The centre of the chart represents the zenith and the outermost circle, the horizon. The radial graduations marked on the circumference denote the azimuthal angles measured from north. Series of curved lines running from east to west depict the sun's path for selected days of each month, including the days of solstices and equinox. These lines are crossed by another series of curved lines which represent the hour lines. The hours are integral values by the local solar time. The point of intersection of the sun's path line and the hour line shows the position of the sun at that hour of that particular day. The figure marked on the concentric circle passing through this point gives the altitude of the sun and the reading of the point where the radial line through the aforesaid point meets the scale marked on the perimeter will be the azimuth of the sun. The position of the sun for dates other than those given in these diagrams can be determined by interpolation.

Sunrise and sunset are depicted by the intersection of the sun path curve with the outermost circle. Hours of sunrise and sunset can be determined from the relative positions of hour lines.

The Indian Standard Time corresponding to solar noon at various places in the country is shown in Fig. 3-1. Using this figure, equivalent solar time can be determined for any station on any desired day of the year.

SHADOW ANGLES

The shadow angles may be defined from the following considerations. A pin of unit length fixed normally on a wall will, in general, cast an inclined shadow when the sun is shining on the wall. The horizontal component of this shadow through the foot of the pin is called horizontal shadow-throw, and the angle subtended by it at the tip of the pin is known as horizontal shadow-angle. Similarly, vertical component of the shadow through the foot of the pin is called vertical shadow-throw, and the angle subtended by it at the tip of the pin is known as vertical shadow-angle.

SHADOW ANGLE PROTRACTOR

Shadow angle protractor is a special protractor which is used as an overlay with the solar charts to find out vertical and horizontal shadow-angles at any time and day, on a vertical wall, situated on any latitude and facing in any direction. The protractor is drawn on a transparent material, to the scale as the solar chart on which it is to be used. Such a protractor is shown in Fig. 3.2. The base line represents a vertical surface and the curved lines represent vertical shadow angles at 5° intervals. The radial lines correspond to horizontal shadow angles.

USE OF SHADOW ANGLE PROTRACTOR

Determination of Shadow Angles

To determine the vertical and horizontal shadow angles on a wall, the protractor is placed centre to centre on the solar chart of the particular place, such that the base line coincides with the direction of the wall and the centreline lies in the direction to which the wall faces. Then the location of the sun at the desired time and day is fixed on the solar chart. The curved and radial lines passing through the position of the sun provide the values of vertical and horizontal shadow-angles. Once the shadow-angles are known, the shadow-throws may be calculated using the equations:

$$\tan H = b \tan V - v$$

where H and V are the horizontal and vertical shadow-angles and h and v are corresponding shadow-throws.

The above description assumes that the pin of unit length is fixed normally on the wall. In case the pin is inclined downward at $a°$ away from the normal, the vertical shadow throw will get enlarged and can be worked out using the equation

$$\textbf{Sin } (V + a) \textbf{ Cos } V$$

When the pin is inclined in horizontal direction towards the shadow at $a°$ away from the normal, the horizontal shadow-throw can be determined using the equation

$$\textbf{Sin } (// + a) \textbf{ Cos } H$$

It is worth mentioning that the length of the shadow cast by an inclined louver of given length will be maximum when the inclination angle is the compliment of the shadow angle.

Determination of Possible Sunshine Hours on a Wall

To find out the possible sunshine hours on a wall, the protractor is overlaid on the solar chart in the manner discussed above. Then the intersection of the base line with the sun's path would provide sun's arrival and departure times on different days for that orientation of the wall. Thus sunshine hours on the wall can be easily worked out.

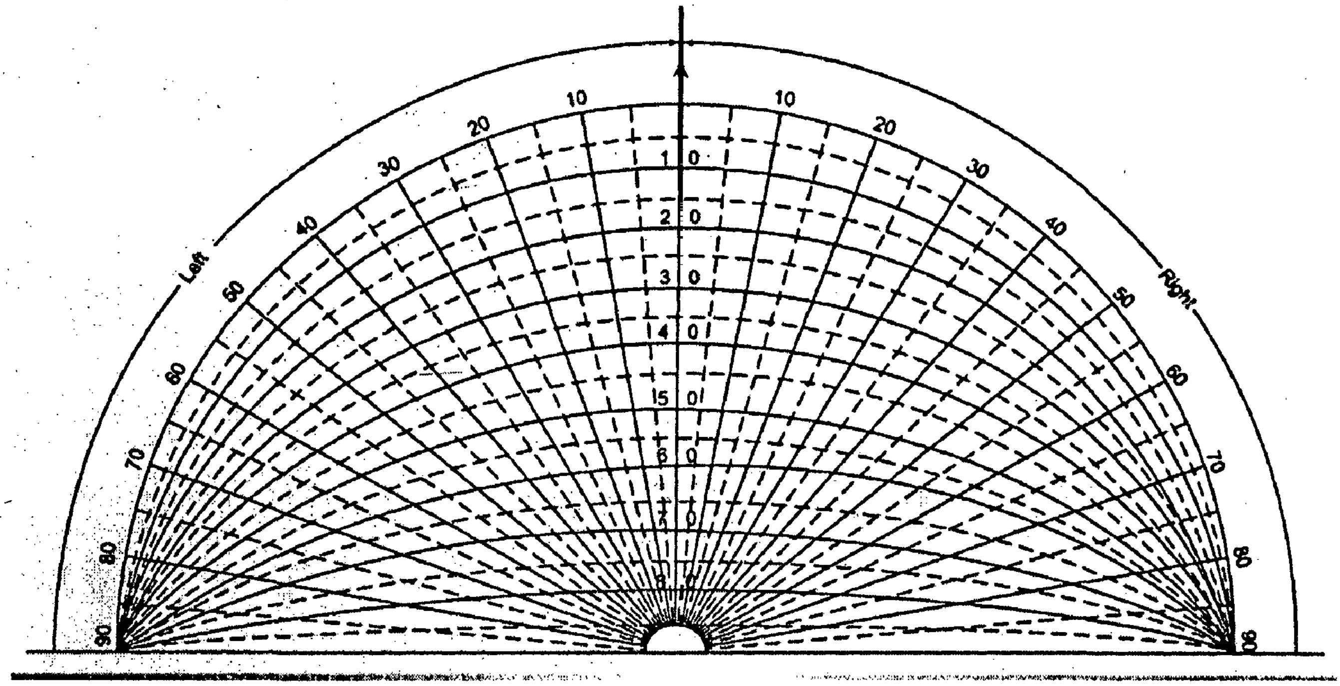


Fig53 Shadow Angle Protractor

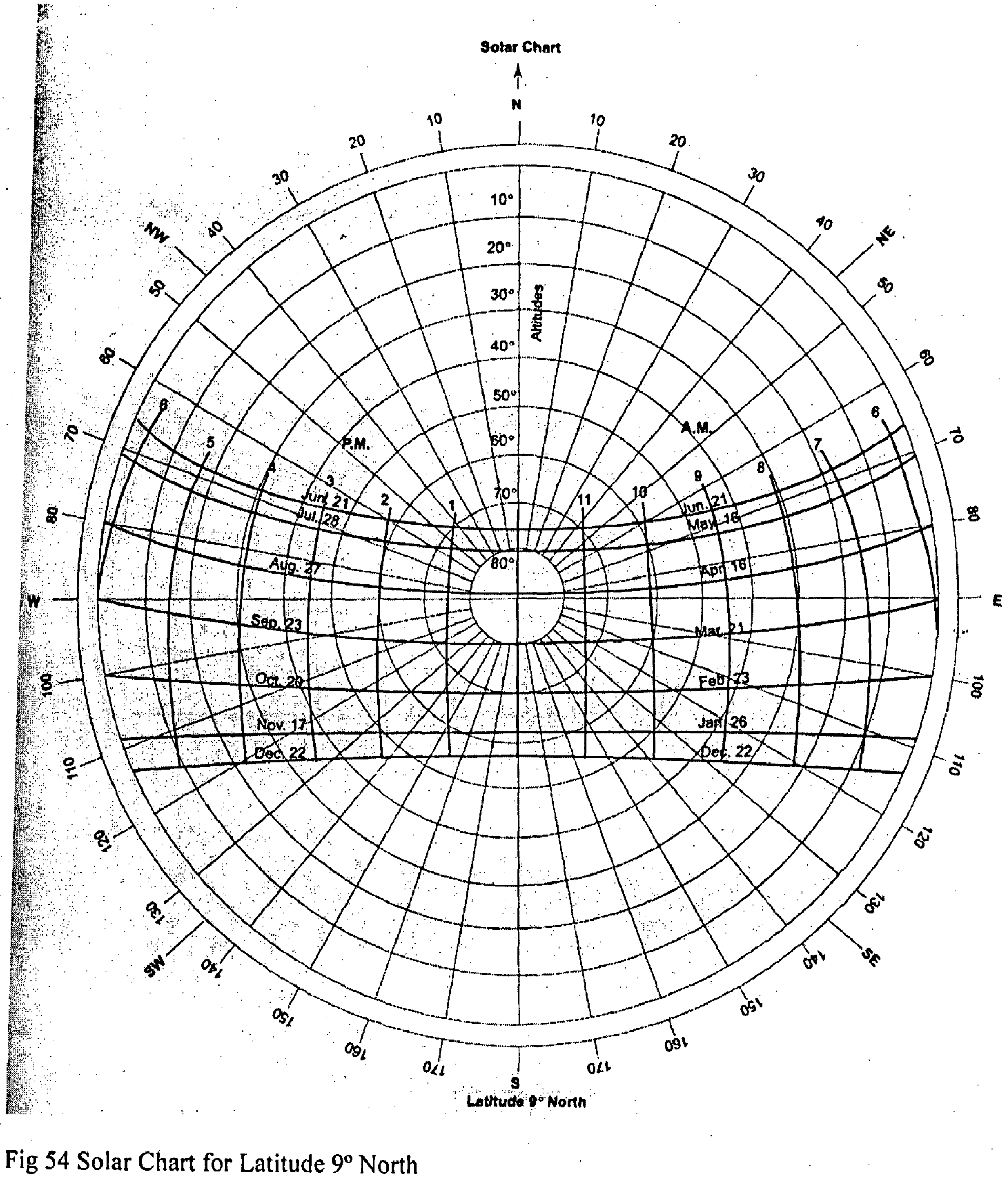


Fig 54 Solar Chart for Latitude 9° North

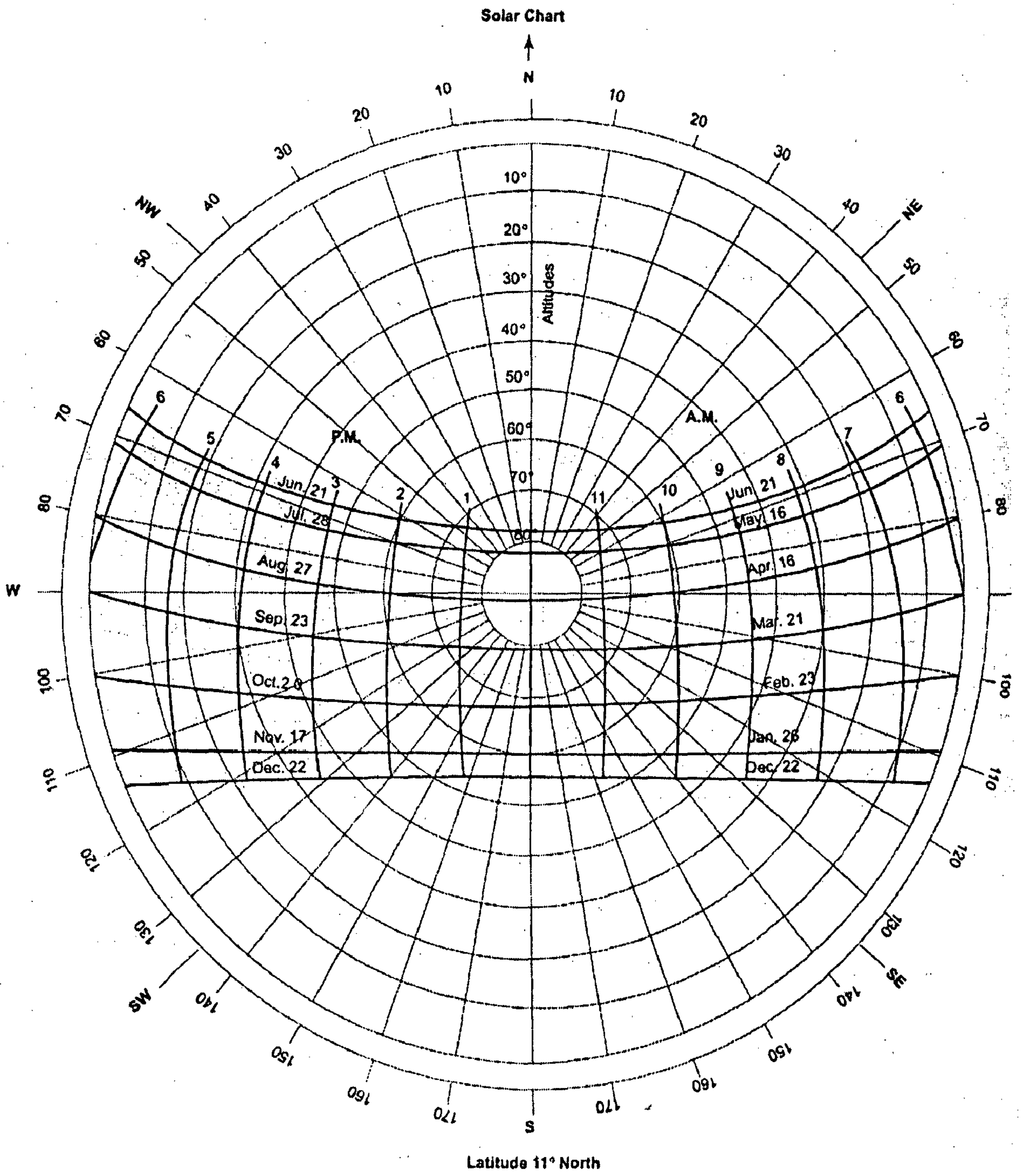


Fig 55 Solar Chart for Latitude 11° North

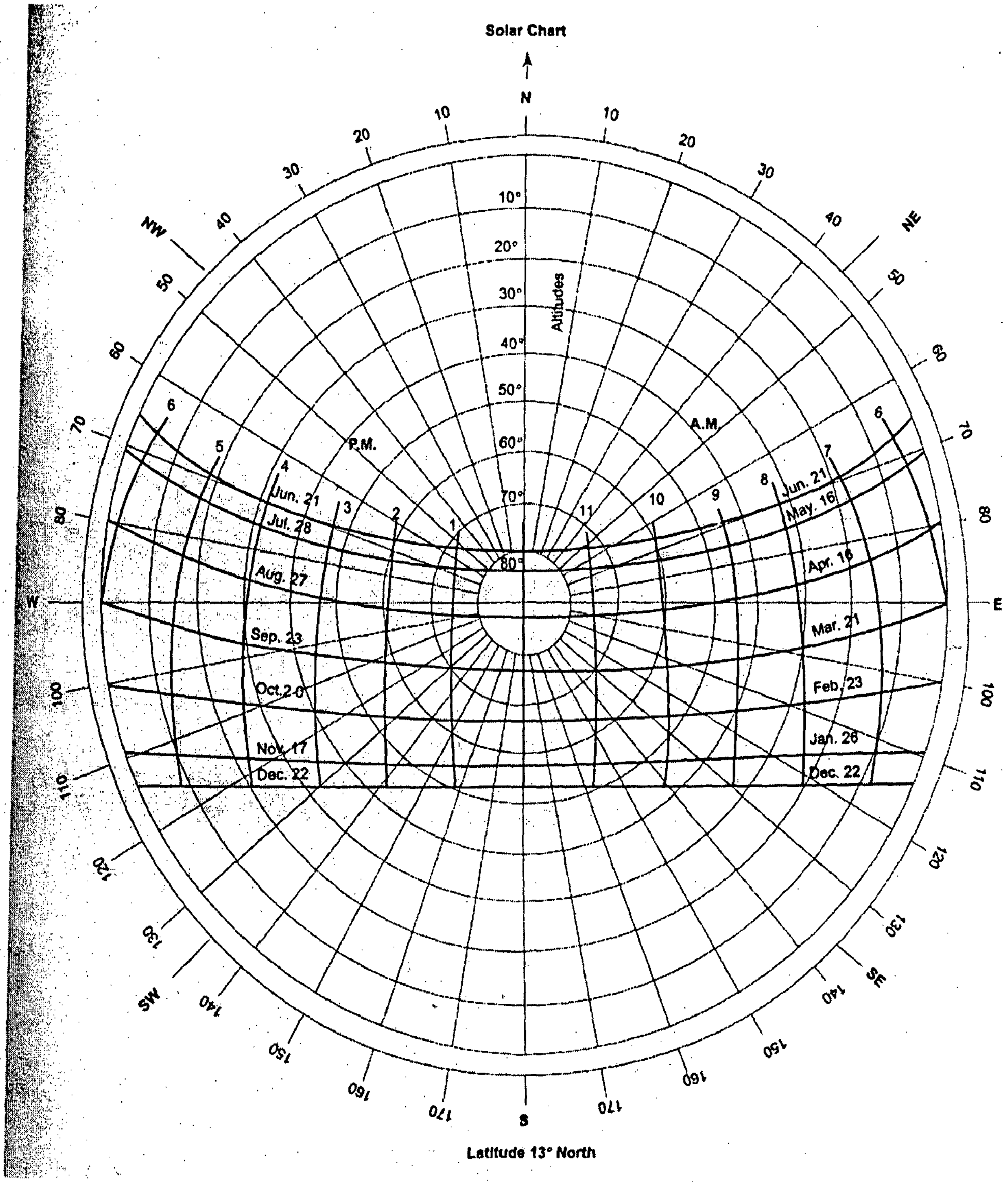


Fig 56 Solar Chart for Latitude 13° North

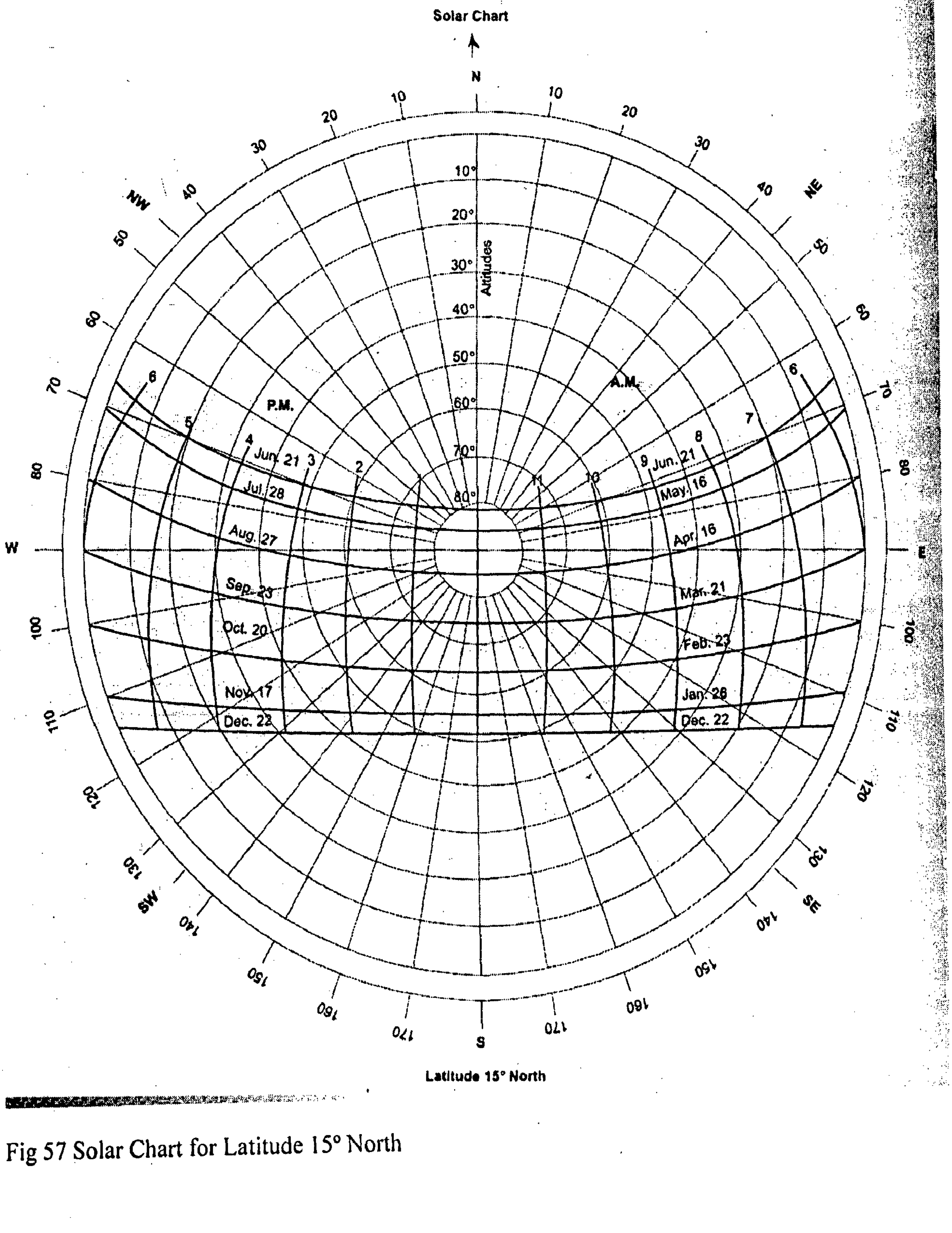


Fig 57 Solar Chart for Latitude 15° North

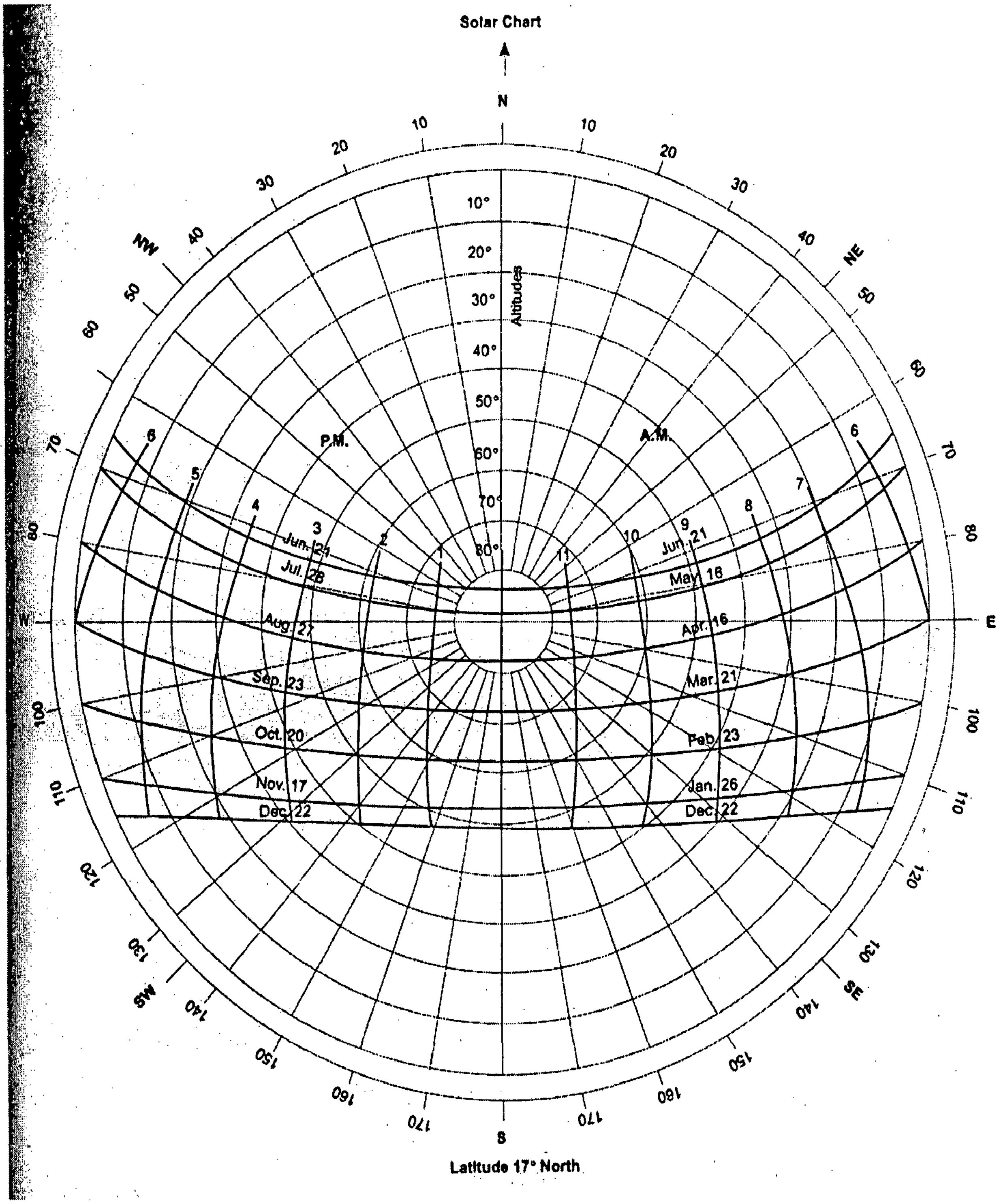


Fig 58 Solar Chart for Latitude 17° North

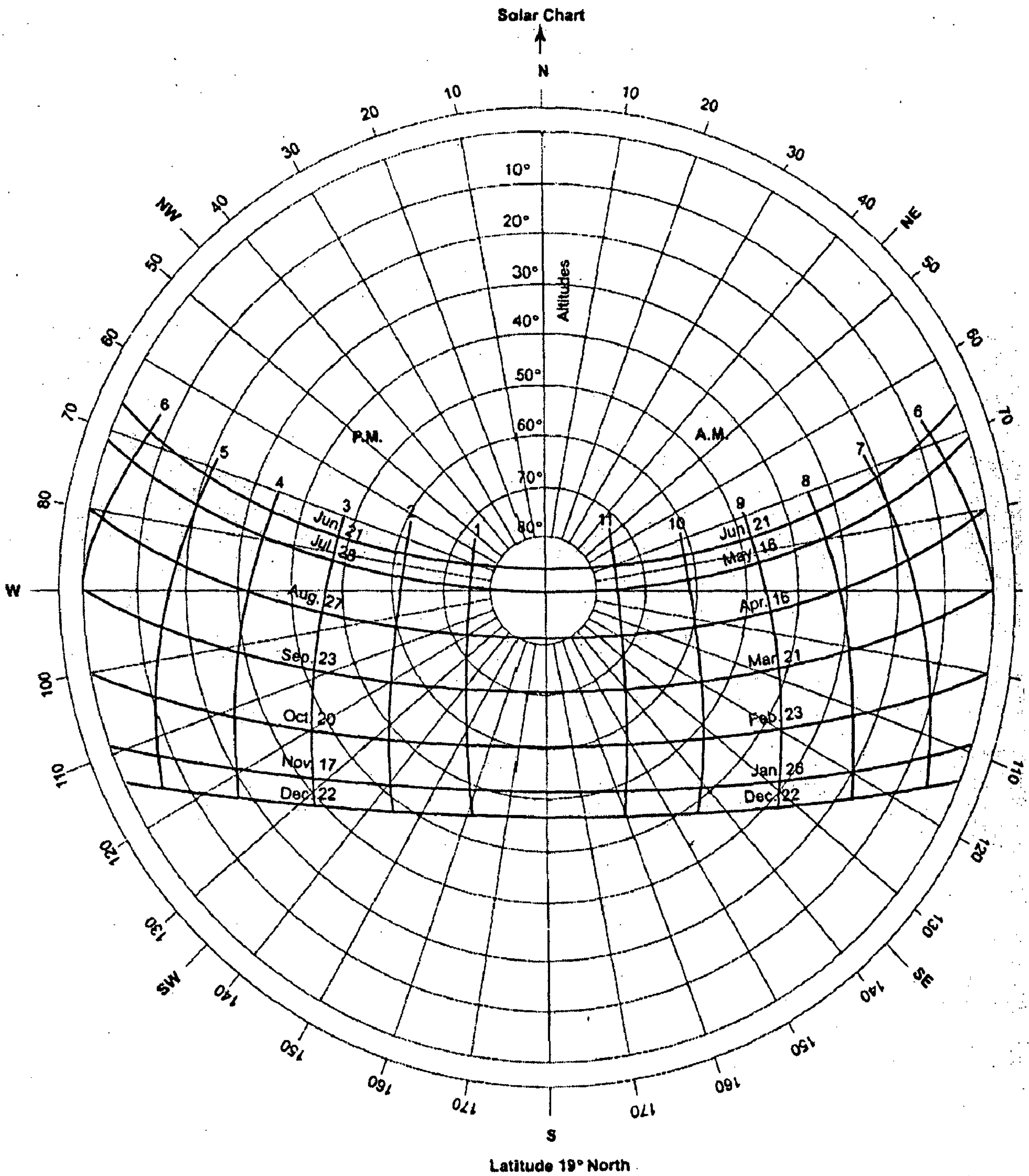


Fig 59 Solar Chart for Latitude 19° North

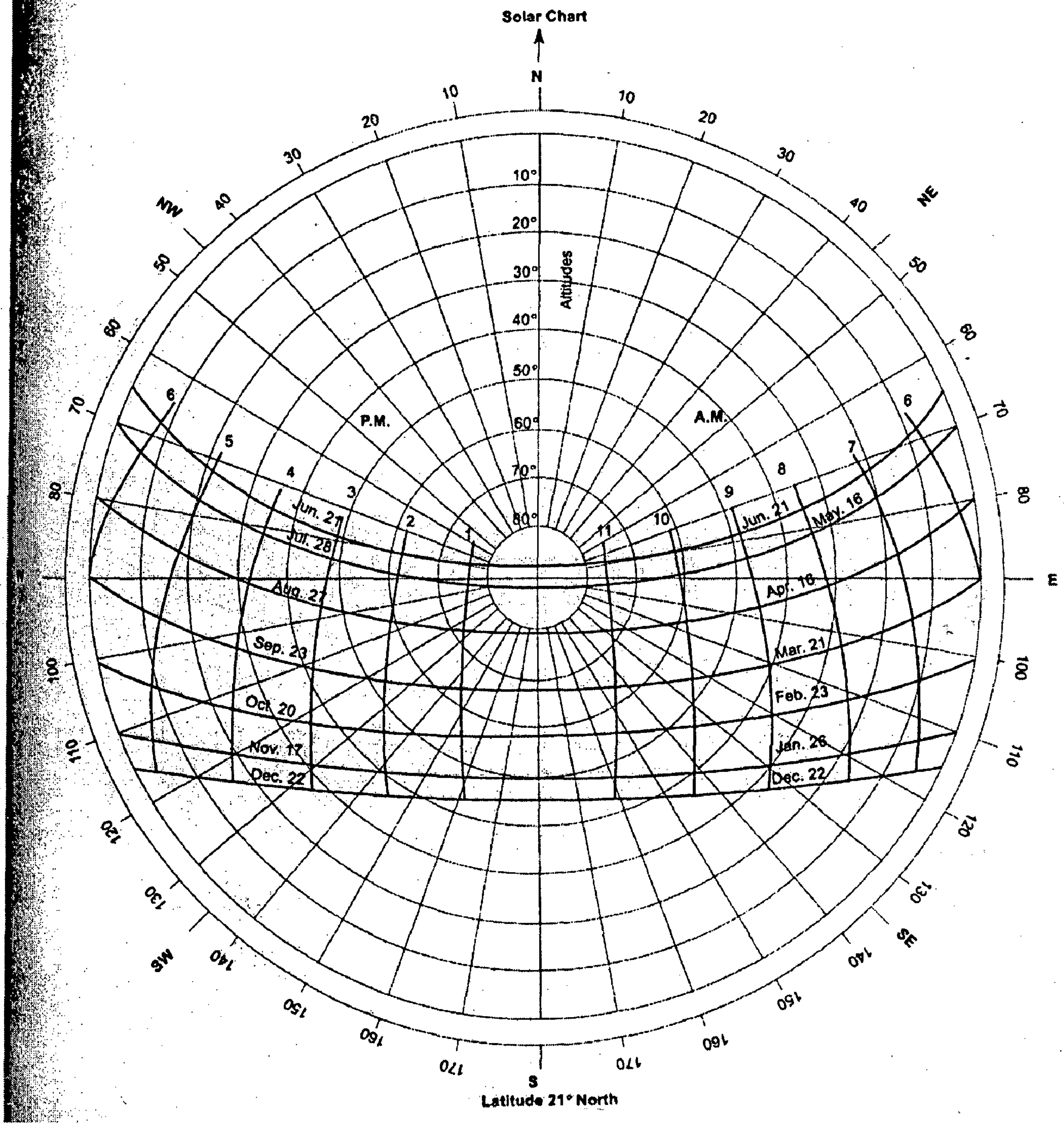


Fig 60 Solar Chart for Latitude 21° North

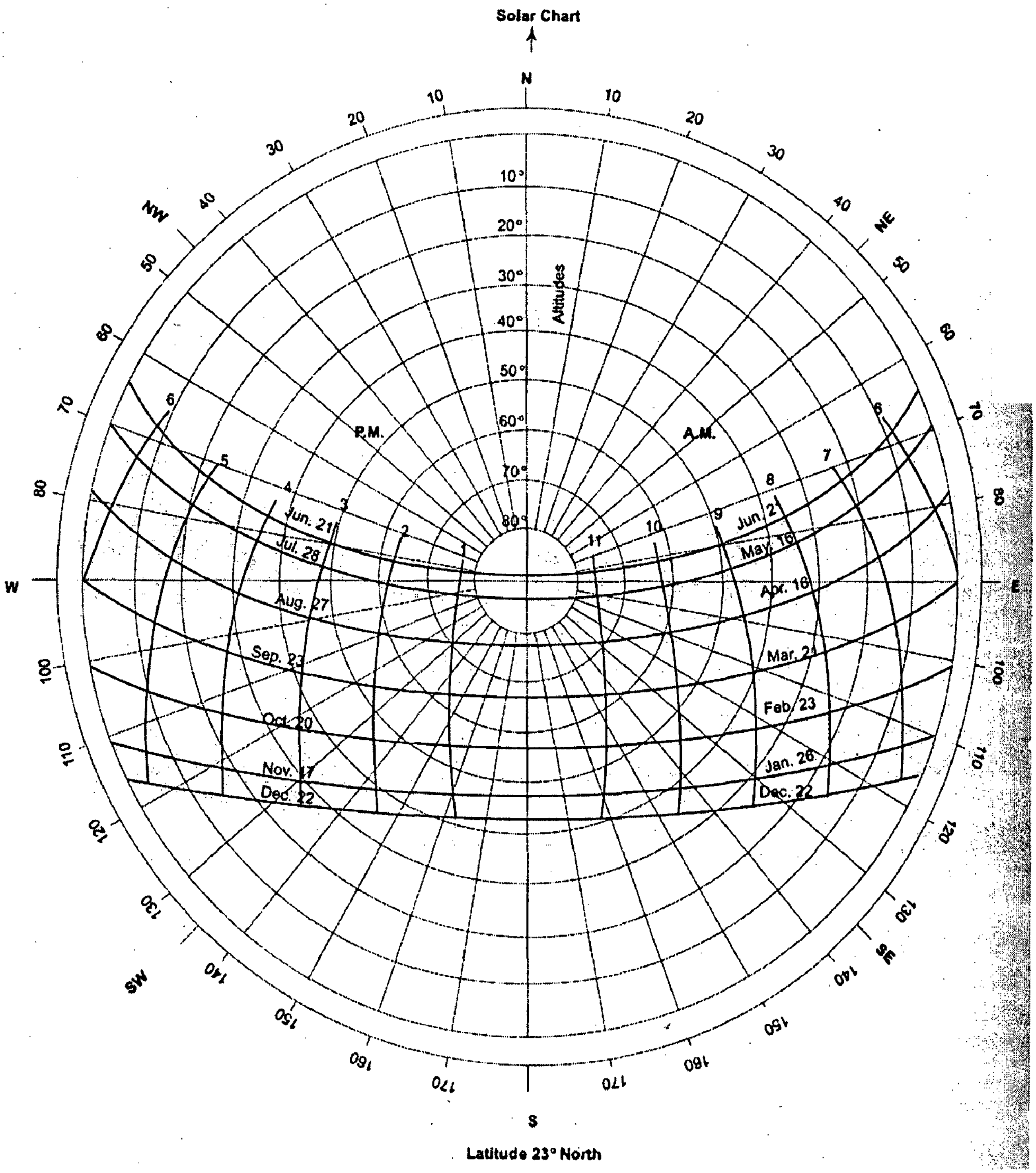


Fig 61 Solar Chart for Latitude 23° North

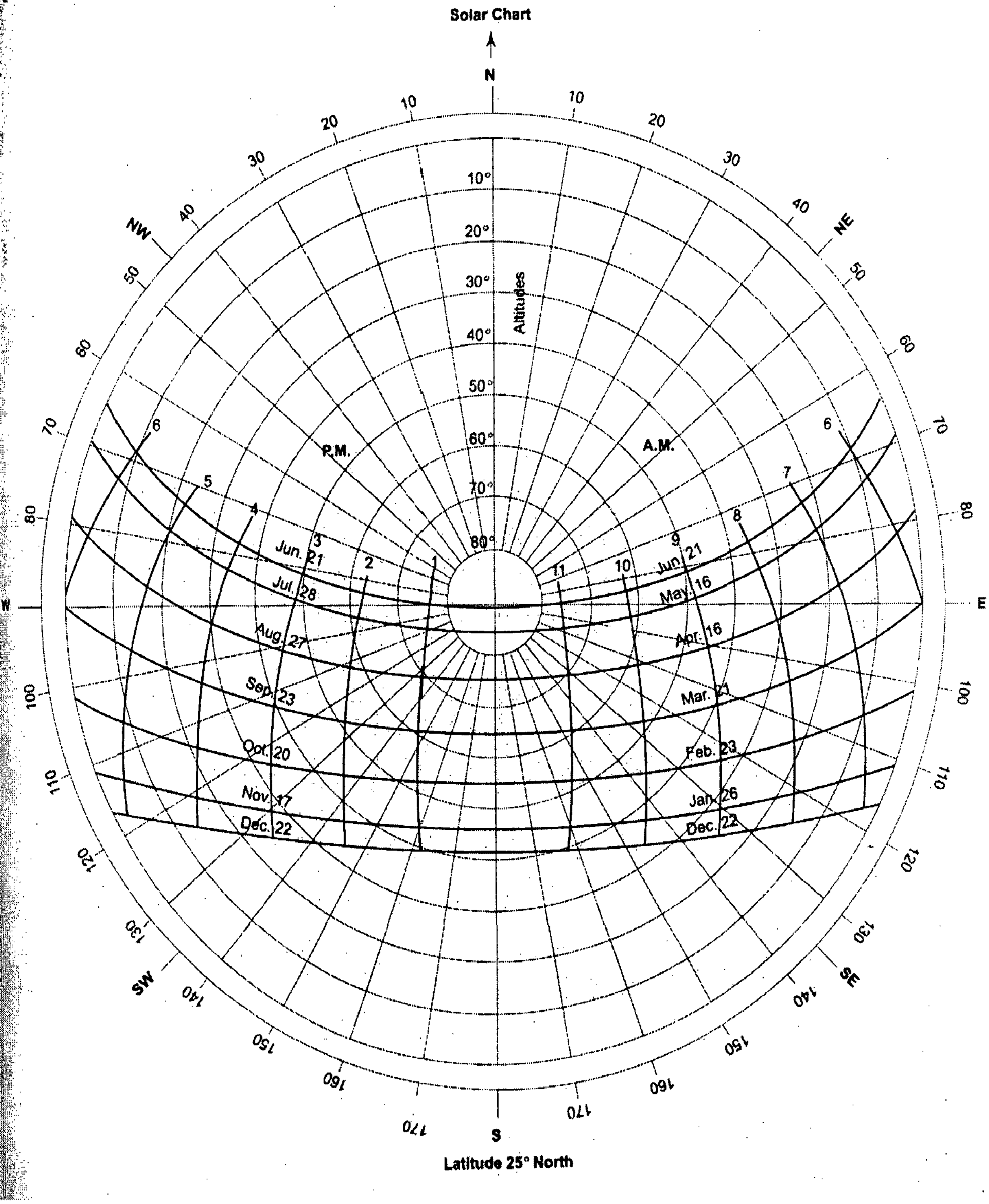


Fig 56 Solar Chart for Latitude 25° North

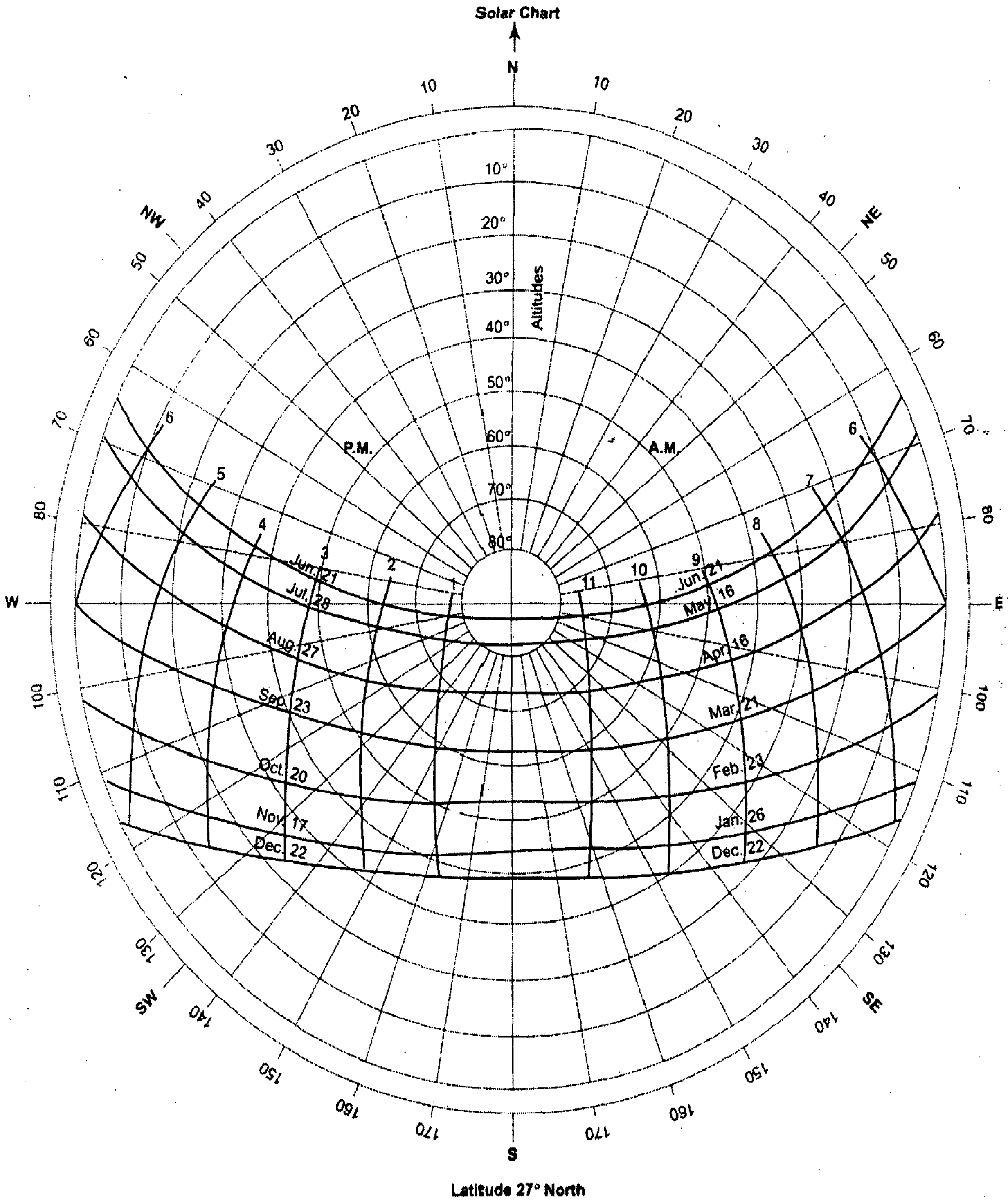


Fig 57 Solar Chart for Latitude 27° North

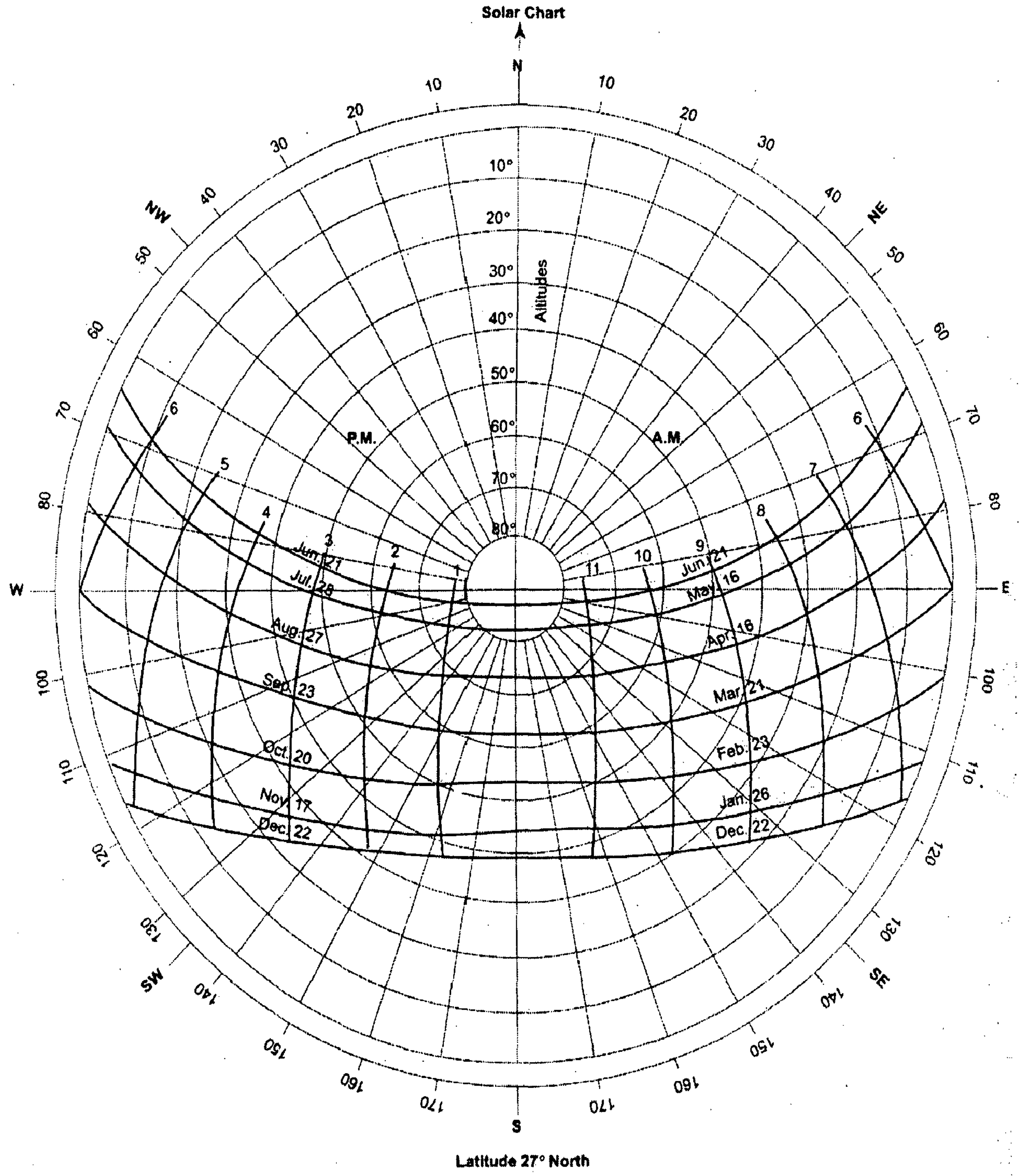


Fig 58 Solar Chart for Latitude 27° North

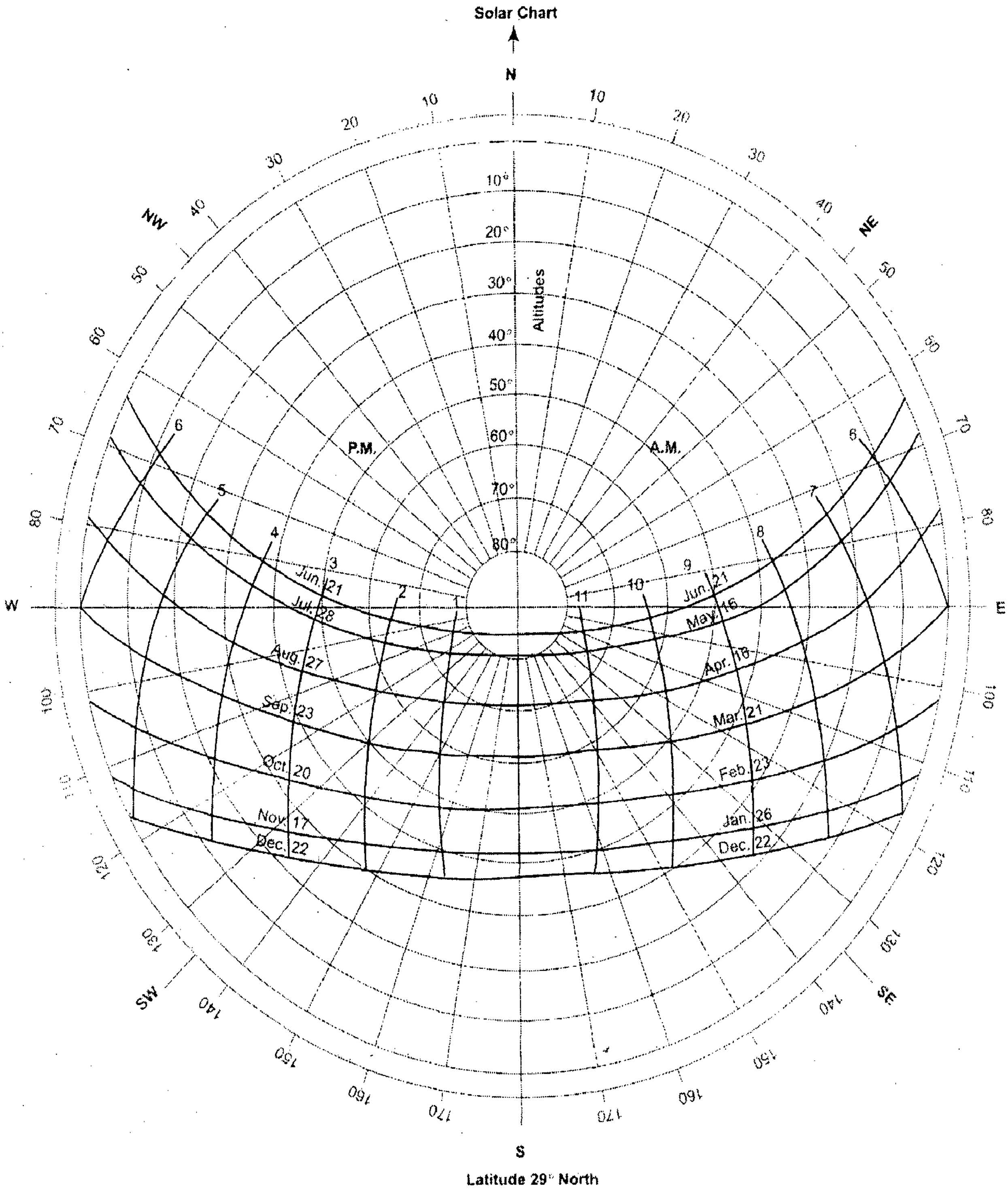


Fig 59 Solar Chart for Latitude 29° North

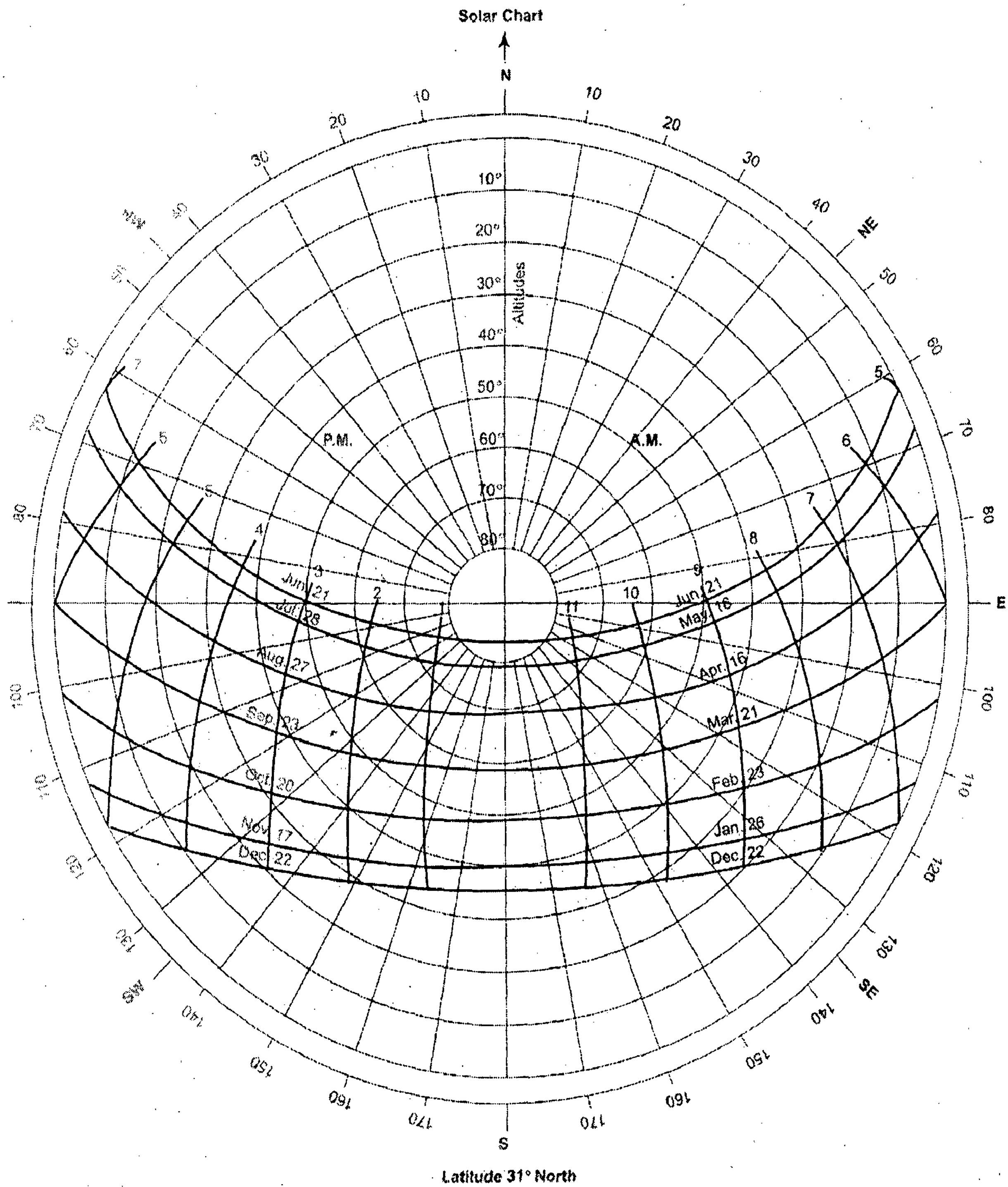


Fig 60 Solar Chart for Latitude 31° North

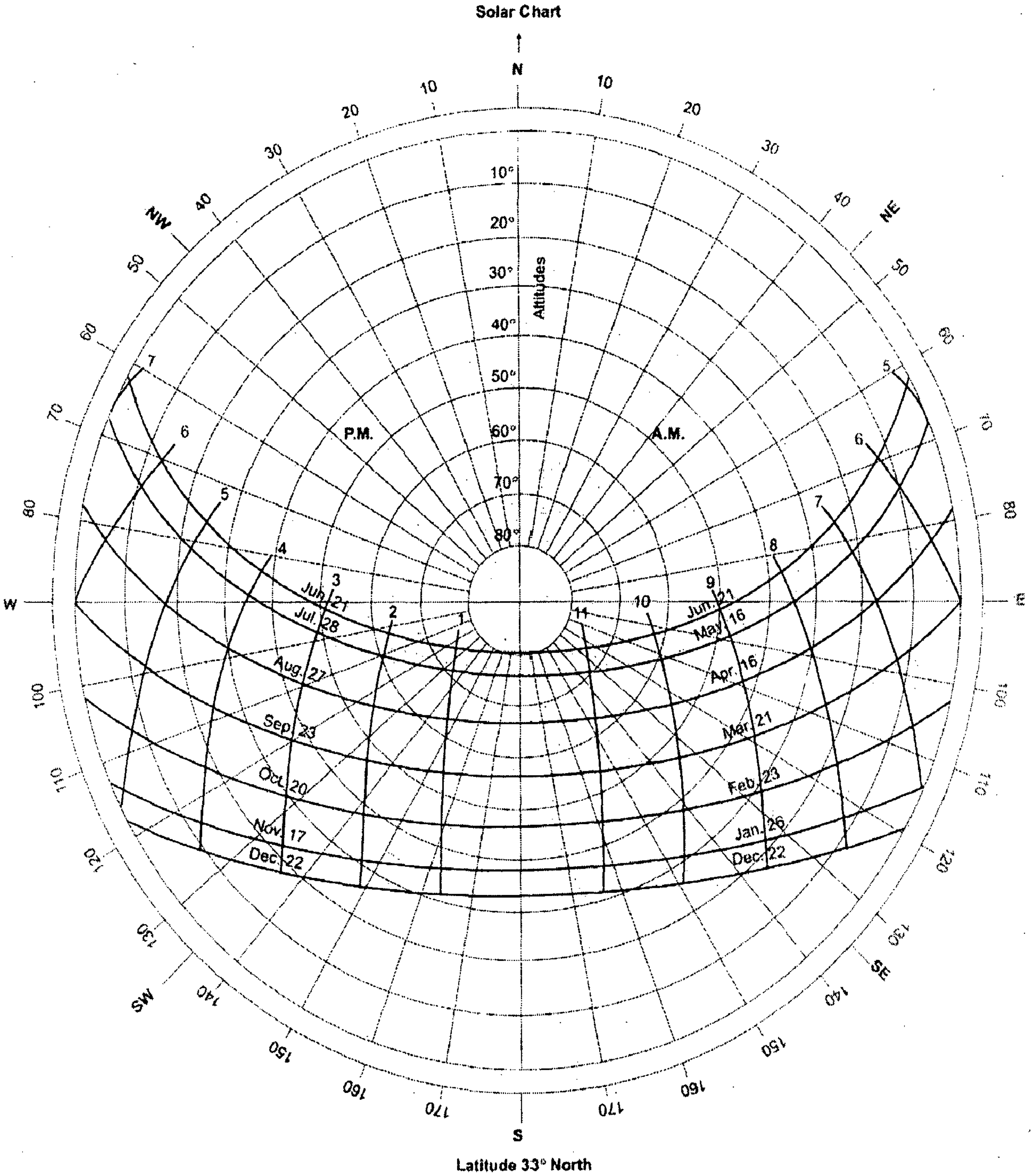


Fig 61 Solar Chart for Latitude 33° North

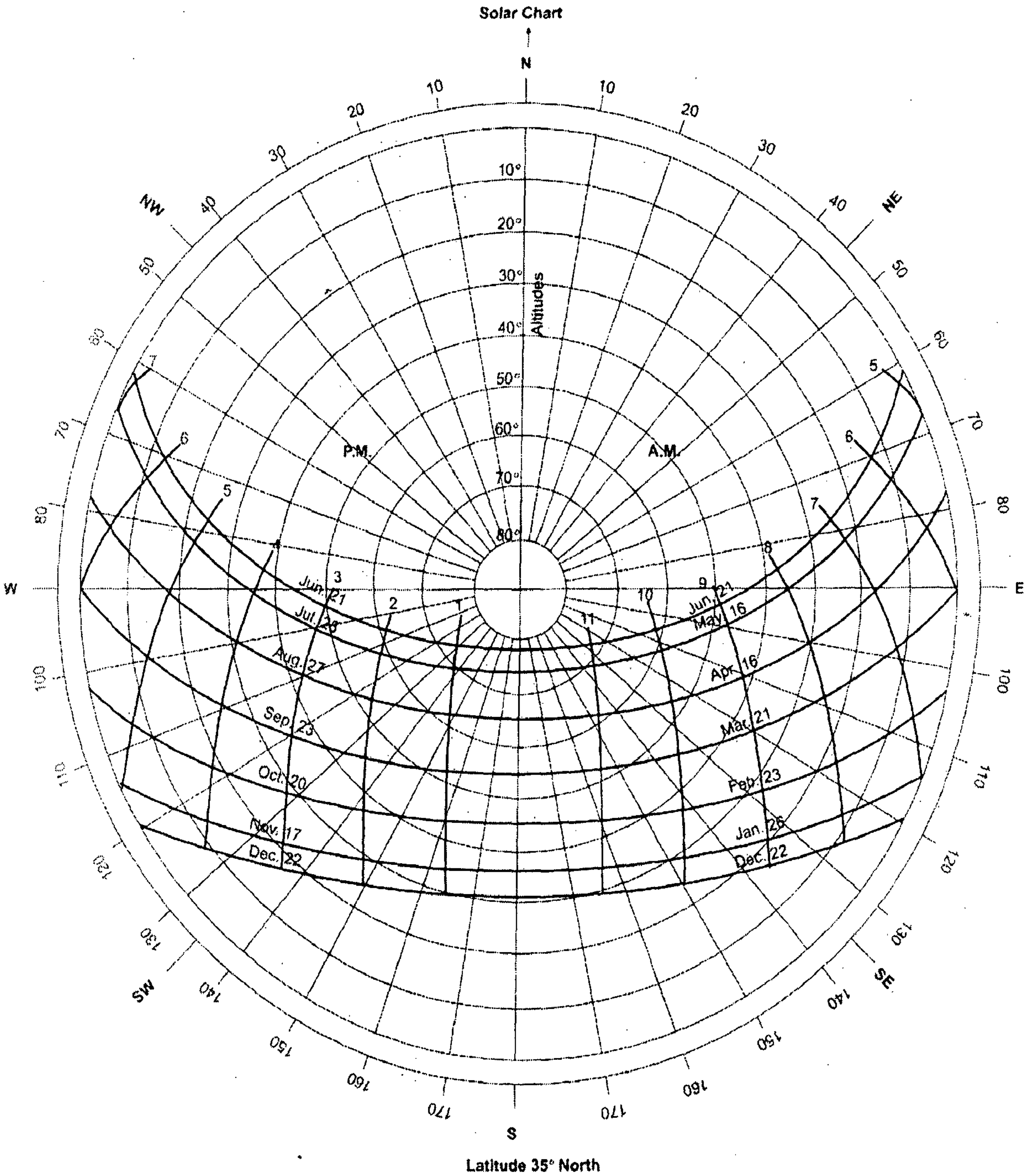


Fig 62 Solar Chart for Latitude 35° North

2. SUN CONTROL STRATEGIES

CONTROL STRATEGIES		CONDUCTION	CONVECTION	RADIATION	EVAPORATION
WINTER	PROMOTE GAIN			Promote Solar Gain	
	RESIST LOSS	Minimize Conductive Heat Flow	Minimize External Air Flow; Minimize Infiltration		
SUMMER	RESIST GAIN	Minimize Conductive Heat Flow	Minimize Infiltration	Minimize Solar Gain	
	PROMOTE LOSS	Promote Earth Cooling	Promote Ventilation	Promote Radiant Cooling	Promote Evaporative Cooling
	HEAT SOURCES		Atmosphere	Sun	
	HEAT SINKS	Earth	Atmosphere	Sky	Atmosphere

Table Sun control strategies

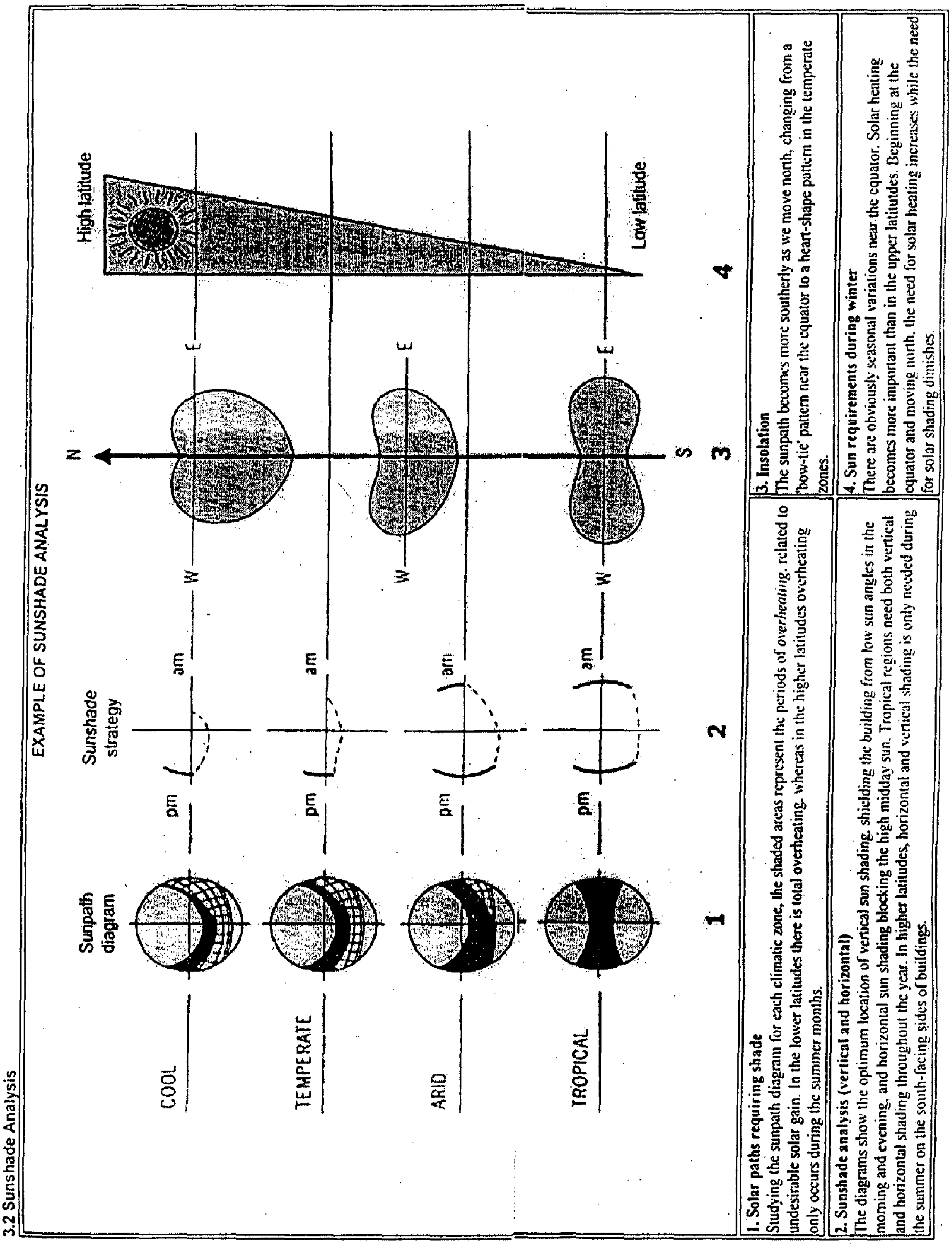
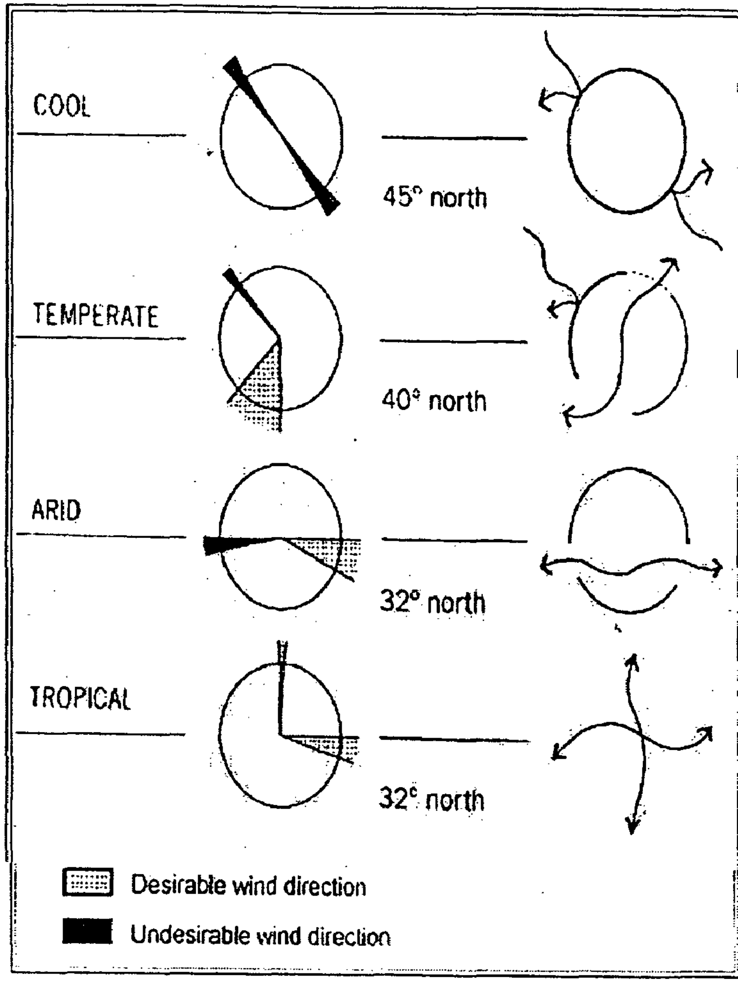


Fig 63 Sunshade analysis for various climatic zones

4 WIND ANALYSIS



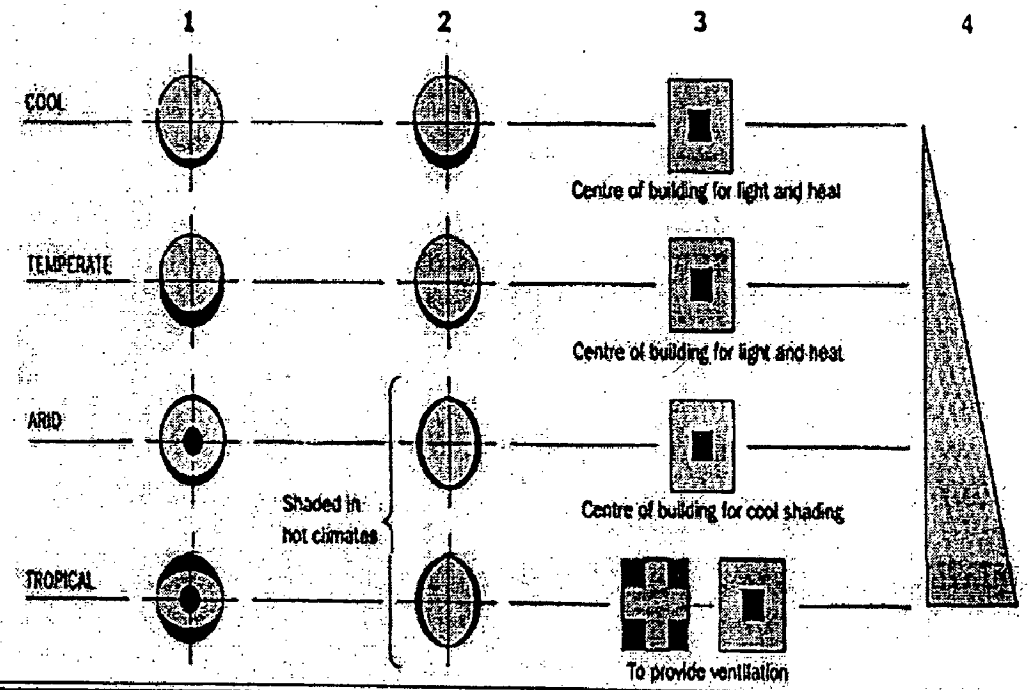
Wind direction

Desirable and undesirable winds in each the climatic zones depend largely on local conditions. Any breeze ir the lower latitude (tropical and arid climates) is beneficial for most of the year whereas in higher latitudes most wind is determental and has to be screened. There is also a small percentage of the time in a year (spring and/or autumn) when comfortable conditions can be achieved naturally, without any need for wind screening or additional breezes.

Cross ventilation

Cross ventilation is far more important in the tropics than in temperate zones. The theoretical strategy for blocking or inducing wind flow into a building is based on local *prevailing wind conditions*. Genrally, for the tropical zones as much ventilation as possible is desired. For the arid zone cross ventilation is required, but care has to be taken to filter out high-velocity winds. In the temperate zone, cross ventilation and shielding are both necessary (for summer and winter, respectively). In the cool region, the building should be protected from cold, high-veolcity winds, although cross ventilation is still required.

Fig64 Wind analysis for various zones



1. Zoning for trasitional spaces

The black areas represent the traditional spaces used for lobbies, stairs, utility spaces, circulation, balconies and any othe areas where movement take place. These areas do not require total climatic control and natural ventilation is sufficient. For the tropical and arid zones, the transitional spaces are located on the north and south sides of the building where the sun's penetration is not as great. An atrium can also be used a transitional space. In temperate and cool zones the transitional spaces should be located on the south side of the building to maximize solar gain.

2. Zoning for solar gain

The black areas are spaces that can be used for solar heat gain. They follow the varying path of the sun in each of the climatic zones: in the tropical and arid zones the east and west sides; in the temperate and cool zones the south side.

3. Use of atrium

The diagram show the optimum position for atrium spaces in each building form in each of the climatic zones. in the tropical zone the atrium should be located so as to provide ventilation within the built form. In the arid zone the atrium should be located at the centre of the building for cooling and shading purposes. For the cool and temperate zones the atrium should be at the centre of the building form for heat and light.

4. Potential of roof/ground floor as useable exterior space

The distance of the angled line from the vertical represents the potential of each zone's roof and ground planes to be used a exterior spaces. In tropical and arid climates there is a high potential to make use of all external spaces, whereas moving towards the northern latitutdes the external spaces have to be covered to be used.

Fig 65 Influences on built form

6 CLIMATICALLY RESPONSIVE ARCHITECTURE

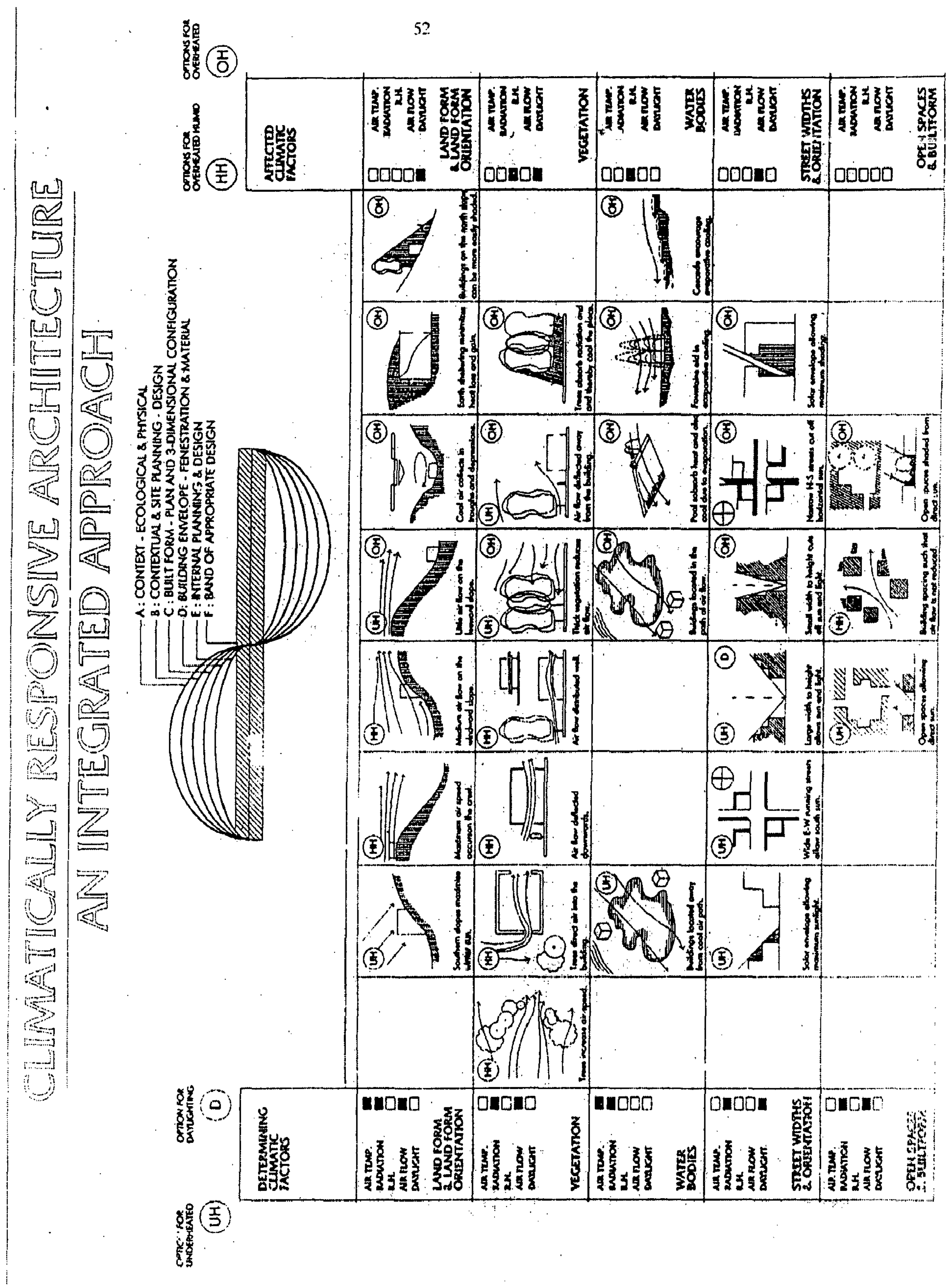


Table: Climate responsive architecture (contd.)

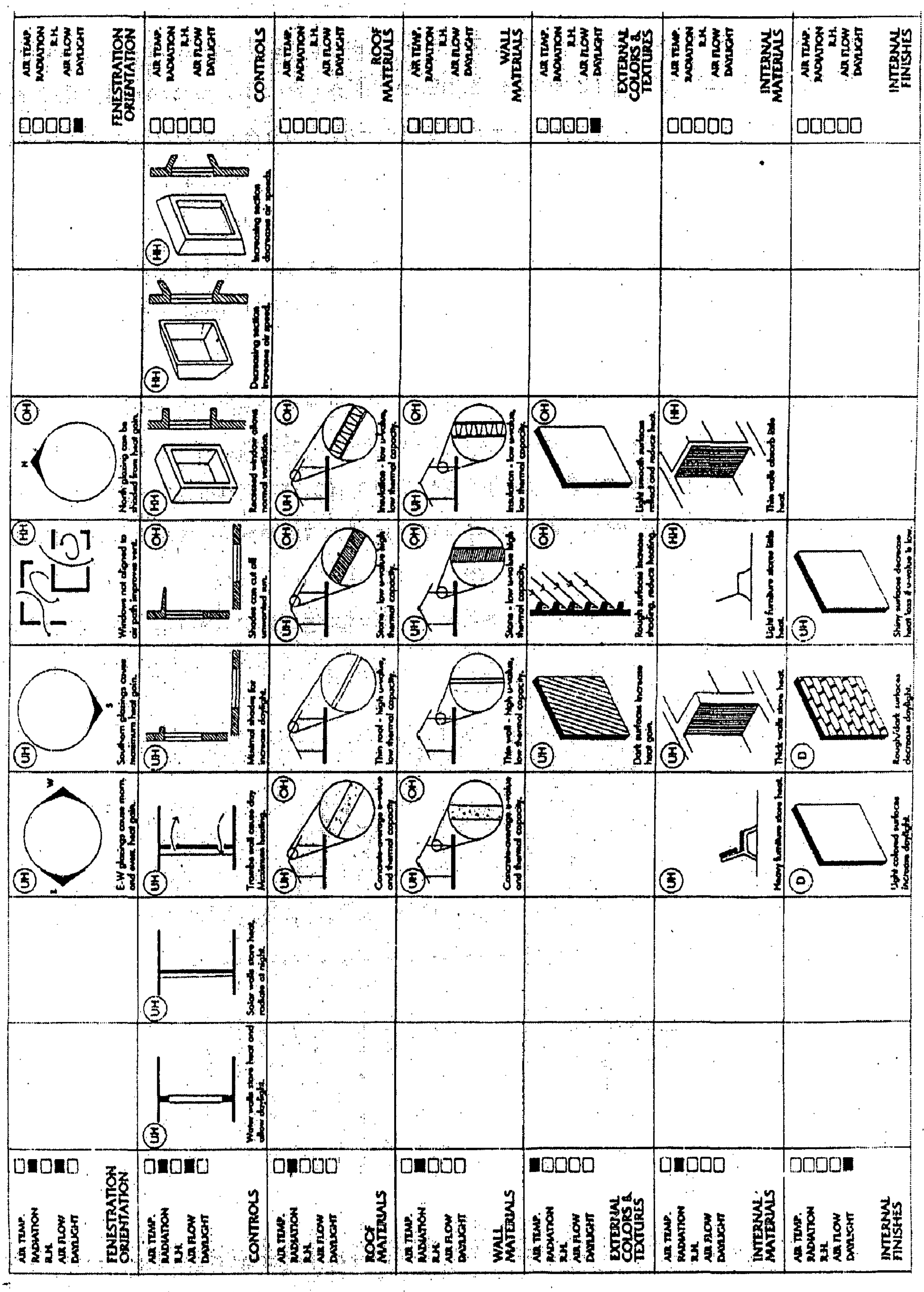


Table: Climate responsive architecture (contd.)

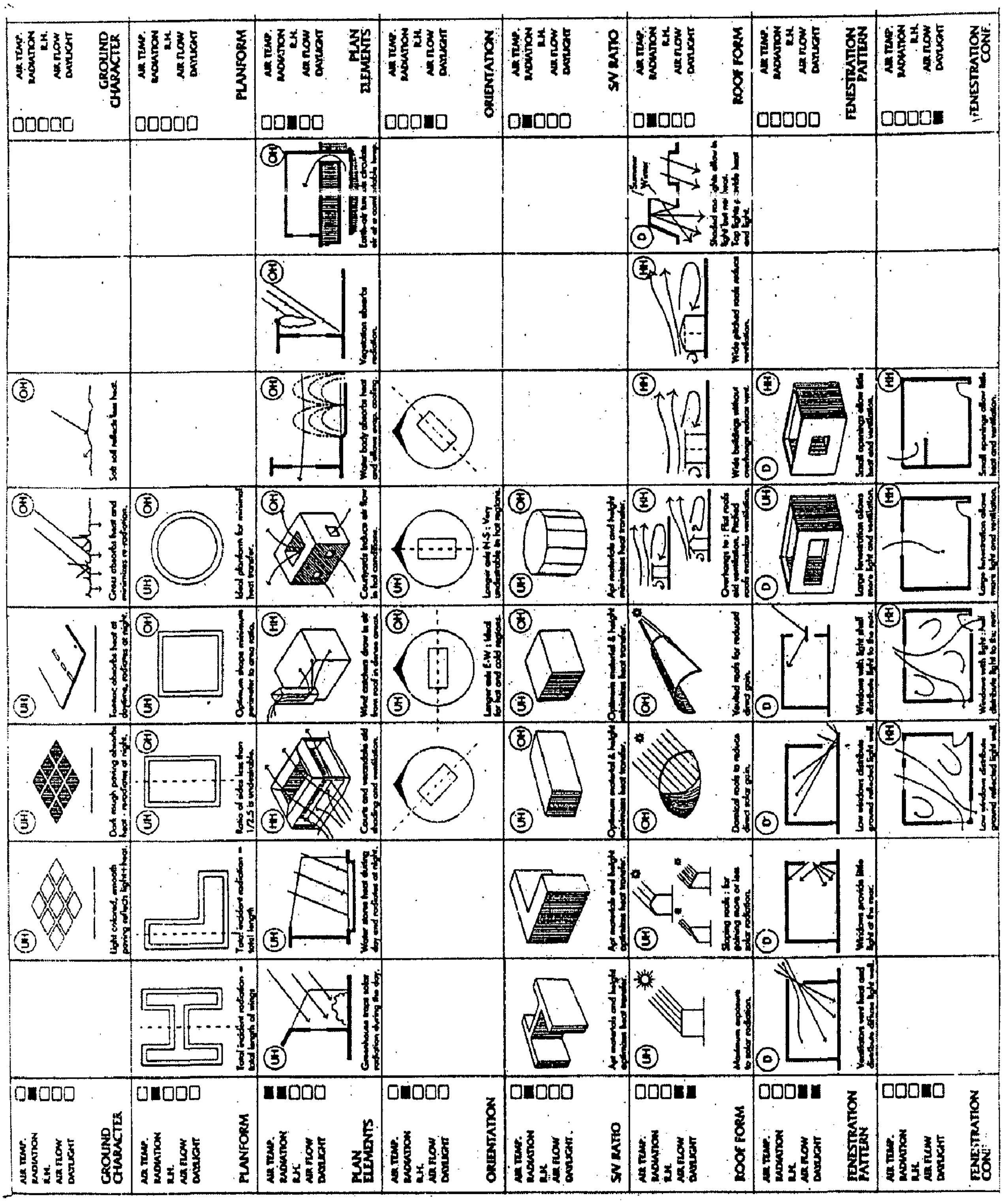


Table: Climate responsive architecture

7 VEGETATION AT NAGPUR CITY

EVERGREEN TREES

Sr.	Botanical Name	Classification	Colour of Flower	Flowering Season
1	Acacia aunculiformis	E	Rich Yellow	Conspicuous in
2.	Alstonia scholaris	E	White	July-Sept.
3	Azadirchta indica	E	White	March
4	Aracuria cookii	E	-	-
5.	Acacia catechu-	E	-	
6	Bauhinia purpurea	E	Purple	Oct to Feb.
7	Cassia siamea	E	Red spiked	April May
8	Callistemon lanceolatus	E		Sept to Feb
9	Cassia siamea	E	Bright yellow	Perennial
10	Casuarina equisetifolia	E	-	-
11	Cupressus	E	-	-
12.	Eucalyptus	E	White	March-April
13	Ficus benegalensis	E	Bright Crimson	-
14	Ficus elastica	E	-	-
15	Ficus benjamma	E	-	March-April
16.	Ficus religioba	E	-	March-April
17	Grevillea robusta	E	Orange	Nov-Feb
18	Kigelia pinnata	E	Purple	April-June
19	Melia azaderacha	E	Liliac	April-June
20	Mimusops elengi	E	Pale white	April-June
21	Michalea champaca	E	Golden yellow	April
22	Millingtonia hortensis	E	White	Nov-Dec.
23	Plumeria alba	E	White, yellow	Perennial
24	Polyalthia longifolia	E	-	Perennial
25	Saraca indica	E	Orange / Red	Jan-May
26	Spathodia companulata	E	Orange scarlet	Feb-March
27	Thespea populnea	E	Yellow	Perennial
28	Tabebuia spectabillis	p	Yellow	March
29	Tamarindus indica	E	-	-
30	Tabernaemontana coronaria	E	White	Perennial

SHADE LOVING PLANTS

In addition to the list given above some plants are listed below which grow /ell in shady condition.

They are listed as follows -

1) Aglaonema 2) Alpinia 3) Ananas 4) Anthurium with flowering 5) Asparagus 6)

Egonia 7) Chlorophytum 8) Coleus 9) Diffenbachia 10) Fittonia

2) Pepromia 13) Schefflera 14) Syngonium 15) Ficus nuda 15) Ficus bengamma

DECIDUOUS TREES

.Sr.	Botanical Name	Classification	Colour ofi	Flowering Season
1	Albizzia lebbek	D	Greenish White	April May
2	Butea frondosa /	D	Red	Feb - March
3	Cassia javanica	D	Bright pink	April Mav
4	Cassia nodosa	D	Rose pink	April - July
5	Cassia renigera	D	Bright pink	April - May
6	Cassia altata	D	Yellow colden	Perennial
7	Delonix regia	D	Scarlet red	April June
8	Eivthria indica	D	Scarlet red	Feb - April
9	Jacaranda	D	Light Blue	March - June
10	Lagerstromia thorelli	D	Lilac / purple /	May - July
11	Peltaphorum	D	Yellow	Feb-May
12	Plum aria rubra	D	Yellow	Perennial

PALMS

Sr. No.	Botanical Names	Classification E = Evergreen D= Deciduous	Form of the Plant
1.	Chamaecrop humilias	E	Ornamental
2	Cycils revolta	E	Flexible thin spiked
3.	Ravenela madagascensis (Travellers palm)	E	Fall shaped

MATERIALS FOR SINGLE GLAZING

Material	*Thickness*	*Initial normal solar transmission %*	*Mechanical lifetime in years*	*Index of Refraction*	*Maximum Use Temperature °F*
SHEET					
Glass	0.125	88	--	1.526	400
F.R.P.	0.040	85 to 88	20	1.580	300-350
Acrylics	0.125	89	20	1.491	180-200
Polycarbonates	0.125	87 to 89	12	1.580	250
Cellulose acetate Butyrate (UVEX)	0.125	89	20	-	150
FILM					
acrylic/polyester	0.011	87.5	20	1.64	270
FEP Teflon	0.002	96	OO	1.34	400
Polyvinyl fluoride	0.004	90	12	1.42	300
Polyethylene	0.004	90	1	—	200
Polyester	0.001	85	10	1.64	300

Table 12 Ordinary Single Glazing Materials

COLOURS FOR WALLS AND THEIR LIGHT REFLECTANCE

WALLS *Color*	*Light Reflectance*
Polar Sky	72
Wisteria Blue	53
Rose Morn	76
Mission Beige	75
Old Linen	71
Vanilla Ice	83
Sunny Beige	79
Cream Supreme	81
Sun Yellow	70
Orange-Glow	62
Deep Chrome	50
Ebony Black	5
Gypsum	86

Table 13 Showing light reflectance values for various colours