DESIGN GUIDELINES FOR ENERGY EFFICIENT COMMERCIAL BUILDINGS IN COMPOSITE CLIMATE

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 ENERGY EFFICIENT COMMERCIAL BUILDINGS IN COMPOSITE CLIMATE"** in partial fulfillment of the requirement for the award of the degree of **MASTERS OF ARCHITECTURE** submitted in the Department Of Architecture And Planning of Indian Institute Of Technology, Roorkee is an authentic record of my own work carried out during the period from August 2005 to June 2006 under the supervision of **Prof P.K Patel.**

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

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CERTIFICATE

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

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ABSTRACT

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

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

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

However it's not too late to retrace our steps. The resource crunch confronting the energy supply sector can still be alleviated by designing and developing our future buildings on the sound concepts of energy efficiency and sustainability. Sustainable environment aims to create environment friendly and energy efficient buildings. This entails actively harnessing renewable natural resources like solar energy and utilizing materials that cause the least possible damage to the global commons like- air, water, forests and soil.

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Roorkee
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ARAFAT HUSSAIN

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INTRODUCTION

THE PROBLEM - WHATS AND WHYS?

THE PROBLEM: WHY ENERGY EFFICIENT BUILDINGS

IDENTIFICATION OF THE PROBLEM

WHY COMMERCIAL BUILDINGS

OBJECTIVES OF WORK

SCOPE OF STUDY

METHODOLOGY

CHAPTER 1

1.0 INTRODUCTION

The importance of energy efficient buildings has assumed great urgency today. In light of fast depleting energy resources, energy scarcity and increasing environmental pollution, innovative ways to cut down energy consumption are necessary. The construction industry is one of the largest energy consuming sectors. In modern buildings significant amounts of energy are also consumed to keep the building environment comfortable.

However it's not too late to retrace our steps. The resource crunch confronting the energy supply sector can still be alleviated by designing and developing our future buildings on the sound concepts of energy efficiency and sustainability. Sustainable environment aims to create environment friendly and energy efficient buildings. This entails actively harnessing renewable natural resources like solar energy and utilizing materials that cause the least possible damage to the global commons like- air, water, forests and soil.

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

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

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

The ignorance in the energy conserving designs of buildings created manifold problems. Because of the inefficient indoor environmental conditions, most of the energy in buildings is being used for physical comfort such as air-conditioning, artificial lighting, heating and cooling etc. By studying the climatic aspects for human comfort and architectural aspects of orientation, topography and microclimate of the site etc., an energy conserving program can be established in building system.

Solar energy as a long lasting energy source plays a vital role in the conservation program. The proper utilization of active and passive solar system can directly curtail the energy demand for day lighting, heating, cooling etc of the building.

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

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

Buildings, as they are designed and used today, contribute to serious environmental problems because of excessive consumption of energy and other natural resources. The close connection between energy use in buildings and environmental damage arises because energy intensive solutions sought to construct a building and meet its demands for heating, cooling, ventilation and lighting cause severe depletion of invaluable environmental resources. However, buildings can be designed to meet the occupant's need for thermal and visual comfort at reduced levels of energy and resources consumption. Energy resource efficiency in new construction can be affected by adopting an integrated approach to building design.

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

1.1 THE PROBLEM......WHATS AND WHYS?

WHATS...

• The continuously and often erratically rising costs of energy headed by the price of oil led to an increasing concern about the limitations of fossil energy resources.

• Buildings, as they are designed and used today, contribute to serious environmental problems because of excessive consumption of energy and other natural resources.

• The close connection between energy use in buildings and environmental damage arises because energy intensive solutions sought to construct a building and meet its demands for comfort cause severe depletion of invaluable environmental resources.

• Buildings are not designed to meet the occupants need for thermal and visual comfort at reduced levels of energy and resource consumption.

• Increased development of housing and other commercial buildings has imposed immense pressure on our dwindling energy sources and other resources like water, thus aggravating the already rampant process of environmental degradation.

WHYS...

1. IGNORANCE

• Buildings are major energy consuming systems and the ignorance in energy conserving designs of buildings created manifold problems.

• The common man who forms a major chunk as the users of the buildings is ignorant about the recent developments taking place in energy efficient measures to be incorporated in buildings .the research is beyond the scope of the users.

2. FEASIBILTY

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

3. LACK OF DESIGN INPUTS EXCESS OF TECHNOLOGICAL INPUTS

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

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

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

4. LACK OF RESOURCES

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

5. UNECONOMICAL

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

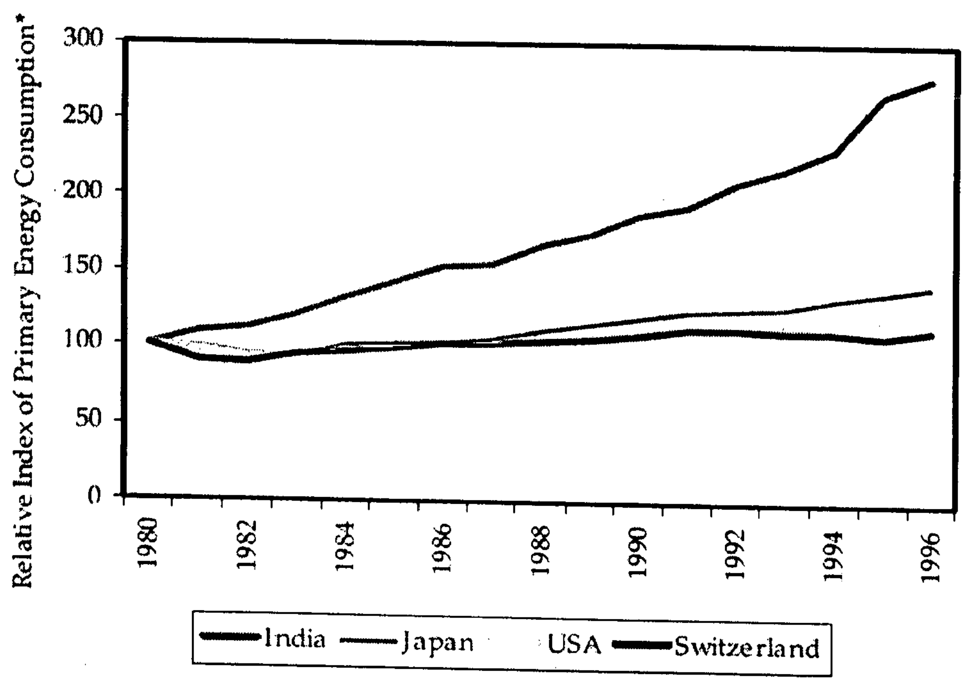
1.2 THE PROBLEM: WHY ENERGY EFFICIENT BUILDINGS

- Limited fossil energy resources
- Rise in cost of oil
- Contribution of buildings to environmental problems
- Close connection between energy use in buildings and environmental damage
- Energy intensive solutions used to help the building fulfill its basic functions.
- Increased development of housing and commercial buildings

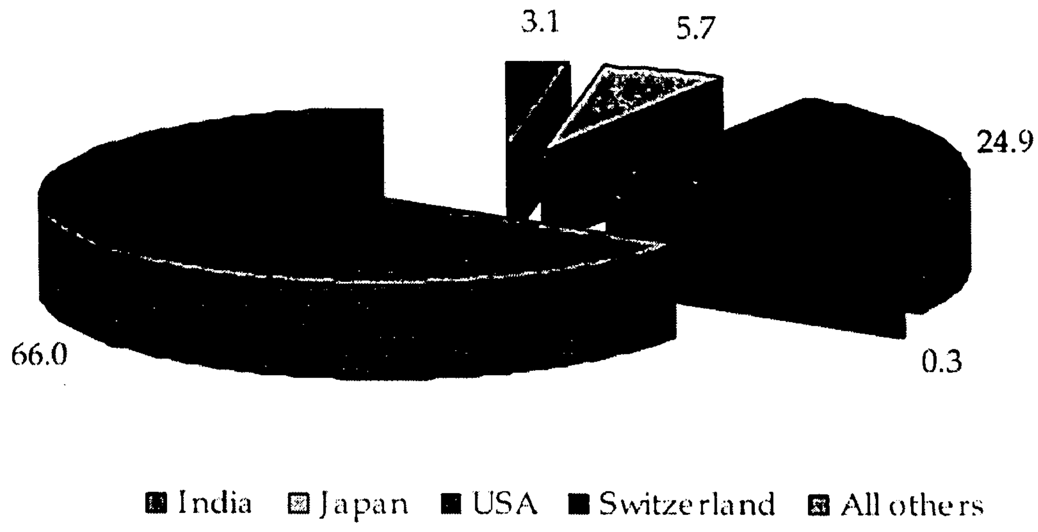
1.3 IDENTIFICATION OF THE PROBLEM

- The residential, commercial and institutional building sector consumed 31 percent of global energy and emitted 1900 mega tons of carbon in 1990. By2050, its share is expected to rise to 38 percent and 3800 mega tons respectively [IPCC 1996].

- In India, estimates suggest that about 20 to 25 % of the total energy demand is due to manufacturing materials required in the building sector.
- While another 15 % goes into the running needs of the building.
- The Ministry of Power estimate indicates that about 20 to 25 % of the total electricity consumed in government buildings in India is wasted because of inefficient design parameters of buildings,
- Which results in an annual energy related financial loss of about 1.5billion Rupees.
- In developing countries like India, rising population, increasing standards of living and rapid urbanization result in an increase in building construction activities.
- India ranks sixth in the world in terms of energy demand accounting for 3.5 % of world commercial energy demand in 2001.
- With a GDP growth rate of 8 % set for the Tenth Five-Year Plan (2001 – 2006), the energy demand is expected to grow at 5.2 %...
- As most of the required energy is currently derived from burning fossil fuels, the building sector has emerged as a major factor impacting on the environment.
- To achieve the collective objectives of energy security and environmental protection, eco-sensitive buildings or 'green buildings' that utilize their resources judiciously,



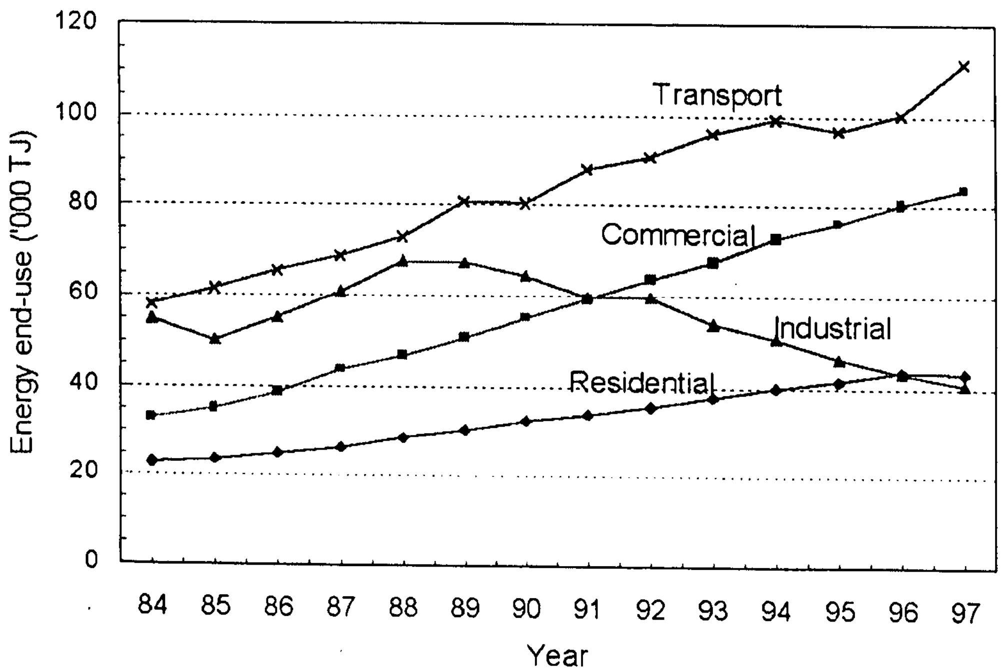
Relative Growth in Primary Energy Consumption from 1980-1996

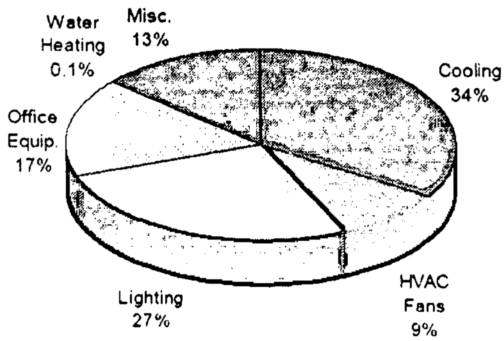


Share in Total World Primary Energy Consumption in 1996

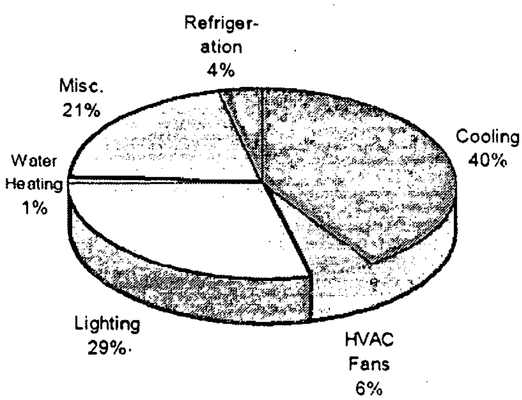
1.4 WHY COMMERCIAL BUILDINGS????

The commercial buildings sector is one the fastest growing energy consumption sector. This is mainly due to the growth of commercial and public activities and their associated demand for heating, cooling ventilation (HVAC) and lighting. Moreover in the new economy, with a wide dissemination of information and communication technologies, information technology appliances are also important electricity consumers..

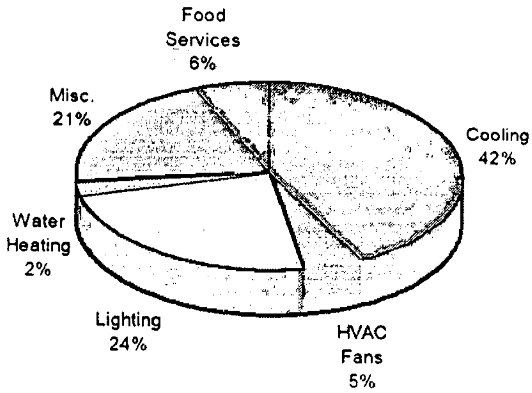




Energy consumption for typical Indian office building; total 23 kWh/yr-ft2.

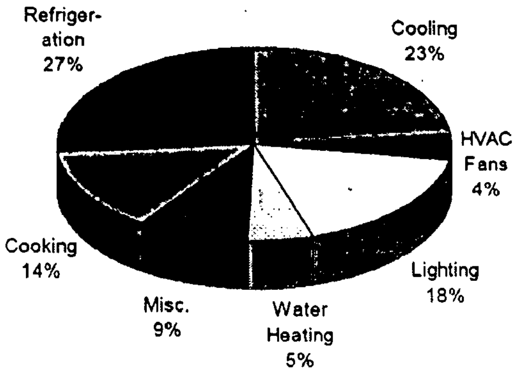


Energy consumption for Typical Indian health care building; total 25 kWh/yr-ft2.

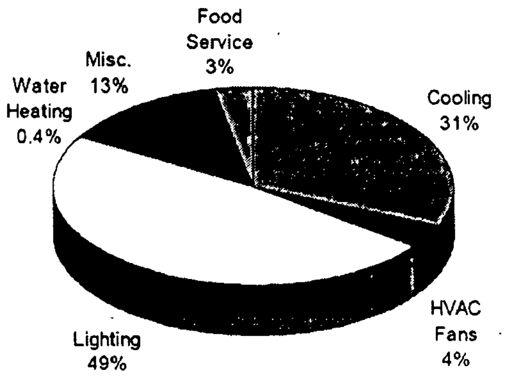


Energy consumption for Typical Indian hotel; total 16 kWh/yr-ft2.

Source: CMIE (2001): Economic Intelligence Service Report 2001, Centre for monitoring Indian economy, Mumbai, India.



Energy consumption for typical Indian restaurant; total 53 kWh/yr-ft2.



Energy consumption for typical Indian retail facility; total26 kWh/yr-ft2.

Source: CMIE (2001): Economic Intelligence Service Report 2001, Centre for monitoring Indian economy, Mumbai, India.

1.5 OBJECTIVES OF WORK

Energy conservation is vitally important to our energy future. It is a topic where opportunities and challenges deserve much more careful analysis and detailed probing than we have been able to do. The study deals with energy conservation in Commercial Buildings and human comfort, the study will provide a very timely insight into the context; techniques and benefits of energy efficient buildings.

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

- Bioclimatic design, **passive cooling, natural ventilation and lighting**.
- Effective insulation for building envelope (roof, external walls, windows, doors, floors), prevent heat transfer between indoor and outdoor of building.
- Integrating **active/passive solar energy system** and shading, for limitation the affects of sun radiation to make the building energy efficient.
- To identify the **planning constraints** in **commercial buildings**
- Guidelines to integrate the building with the **site conditions and microclimate of the area.**
- Studying the climatic aspects for **human comfort** and **architectural aspects of orientation, topography and microclimate of the site**.
- **Advocate** the application of renewable energy systems

1.6 SCOPE AND LIMITATIONS

- The study will only discuss the applications of climatic principles to commercial buildings in composite climates.
- Overview of technologies applicable to energy efficient design.
- Standalone renewable energy gadgets/devices without having an integrated approach to whole design fall outside the purview of this work.

1.7 METHODOLOGY

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

- Identification of the problem.
- Framing Aim & objective and scope & limitations.
- Studying the climatic principles for energy efficient buildings in composite climate.
- Case studies, selected on the basis of their energy efficient approach to design.
- Comparative Studies
- Inferences
- Framing Guidelines for achieving energy efficiency in commercial buildings in composite climates.

ENERGY EFFICIENCY

WHAT IS AN ENERGY EFFICIENT BUILDING

NEED FOR ENERGY EEFICIENT BUILDINGS

ENERGY EFFECTIENT BUILDINGS

CHAPTER 2

2.0 ENERGY EFFICIENCY

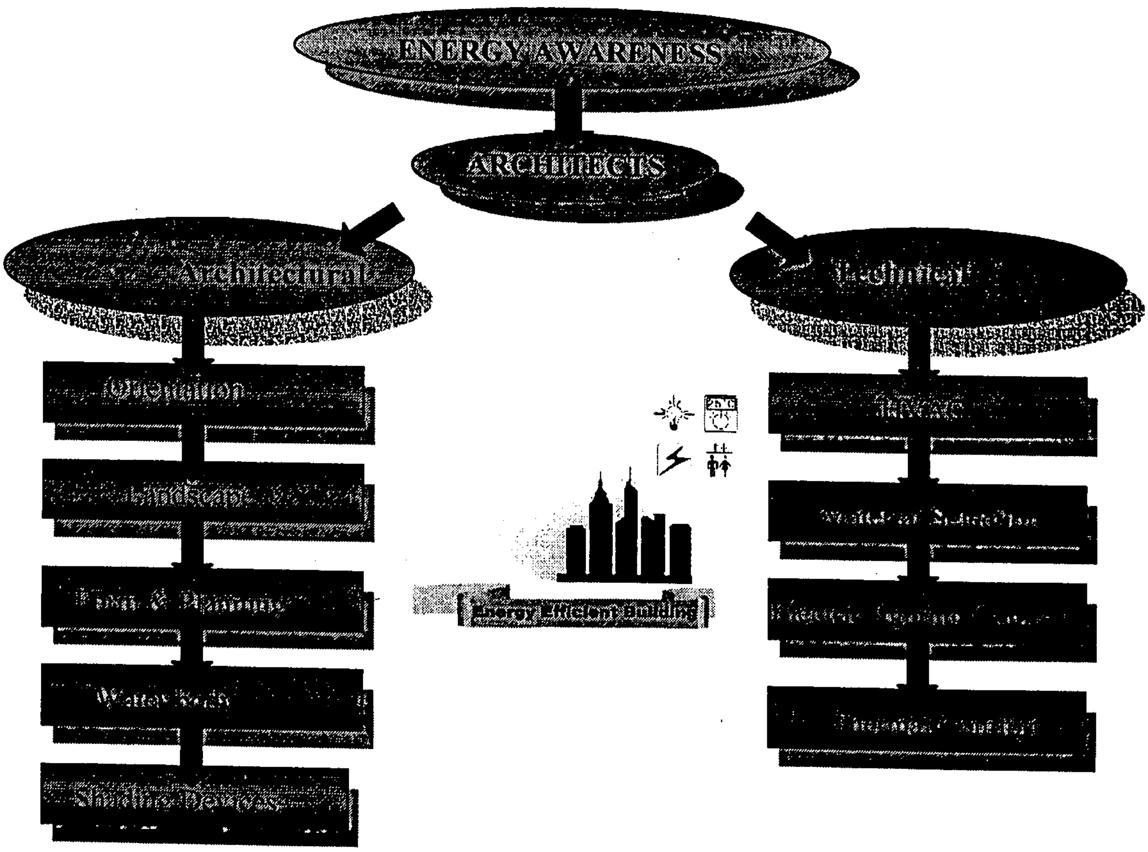
Energy conservation is possible by judicious design of lighting and HVAC (heating, ventilation and air conditioning) systems, controls and operation strategies. Increasing insulation levels in conditioned buildings is regarded as the most cost-effective investment in energy efficiency. Thermal insulation of external walls, roofs and floors, and double-pane windows can reduce energy consumption for space heating by lowering heat losses through the envelope of the building. Energy consumption for cooling is also reduced because of lesser heat gains from outside through the envelope. Energy efficient windows with their high thermal insulating values and spectral selectivity can make air conditioning systems work more effectively. This can lead to reduction in AC loads, lower consumption of electrical energy and reduction in peak load demand.

The use of energy efficient glazing helps in minimizing unwanted solar gains in summer and heat losses in winter, while maximizing the amount of useful daylight in buildings. Lighting load constitutes about 10 to 15 percent of the total electrical load of a building, and so energy efficient lighting systems, such as compact fluorescent lamps and fluorescent tubes with electronic ballast, are generally recommended instead of conventional lighting fixtures to reduce the lighting load. Although the initial cost of such installation is high, they last longer and the running cost is also less. As electricity is efficiently converted to light in energy efficient lamps, the amount of heat generated is also less.

2.1 How do we create energy efficient buildings?

Energy efficient and environment conscious building design is essentially an integrated approach. The available options in architectural intervention, building materials and design methodologies need to be carefully evaluated to minimize energy usage, minimize the ecological degradation that may be caused by the construction of the building and provide cost effective solutions. The aim is to achieve the desired comfort with the least input of conventional energy. Though the rules are not very well defined, architects and designers accomplish the task through solar passive design, use of renewable energy technology systems, and/or natural building materials. While designing such buildings, not only new building stock can be targeted but also existing buildings can be retrofitted with energy efficient and eco-friendly technologies, thereby substantially reducing energy consumption. In general, energy efficiency in new buildings can be achieved through:

- Bioclimatic architectural principles
- Load minimization by the incorporation of solar passive techniques in building design;
- Design of energy efficient lighting and HVAC systems;
- Use of renewable energy systems to meet a part of the building load; and
- Use of low energy materials and energy efficient methods of construction.



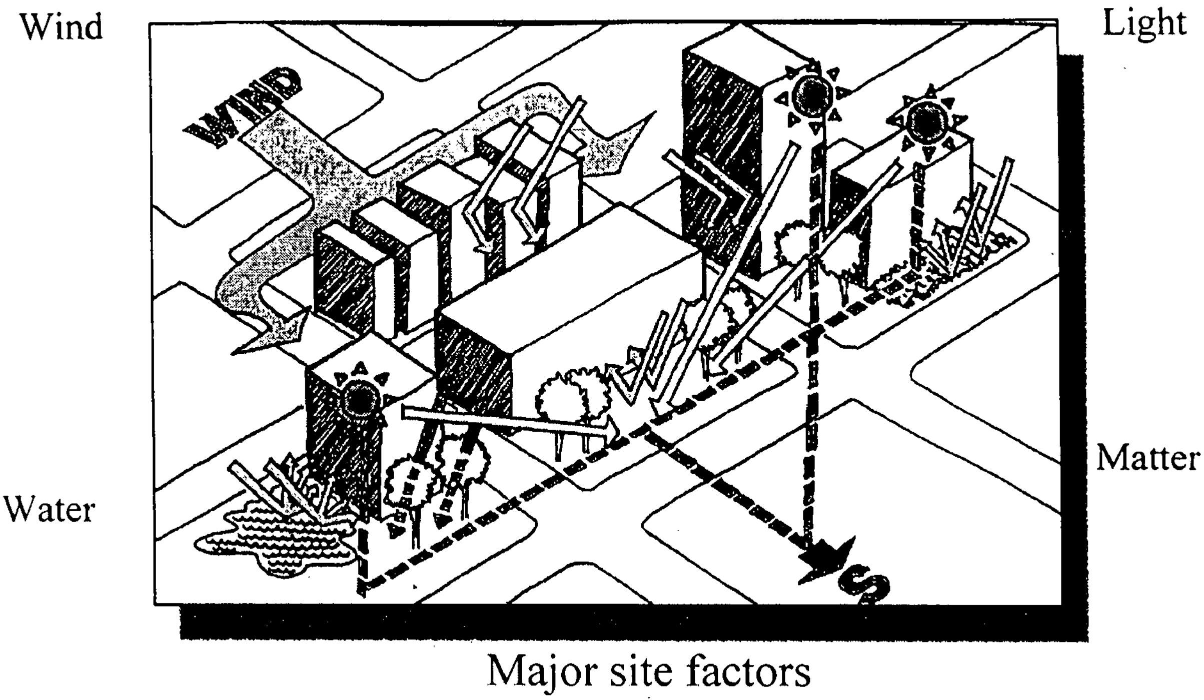


Fig (2.1a): Major site factors

COMMERCIAL BUILDINGS

Commercial Buildings are for the revenue generation, the location of these buildings is in the high commercial areas of the city, where the land prices are very high there fore the energy efficient guidelines should be framed keeping in mind the constrains those are with the commercial buildings.

As the basic motive is the revenue generation the buildings should attracts the tenants in terms of aesthetics, function and the lease rates.

- Energy-efficient buildings provide a marketing edge, making it possible for speculative developers to offer competitive lease rates
- Lifecycle energy saving allow the alternative return on investment for owner builder
- Reduced utility costs offer multiple benefits to property managers. They can, if they wish, pass some of the savings on to the tenant through lower lease rates

coupled with enhanced comfort from better design, can help attract and retain building tenants. The portion of the energy savings retained by the property manager will improve the buildings net operating income.

- Comfortable, attractive, energy-efficient workspaces will bring benefits to tenants as well. Businesses not only incur reduced overhead costs, but are likely to see improved employee morale and productivity

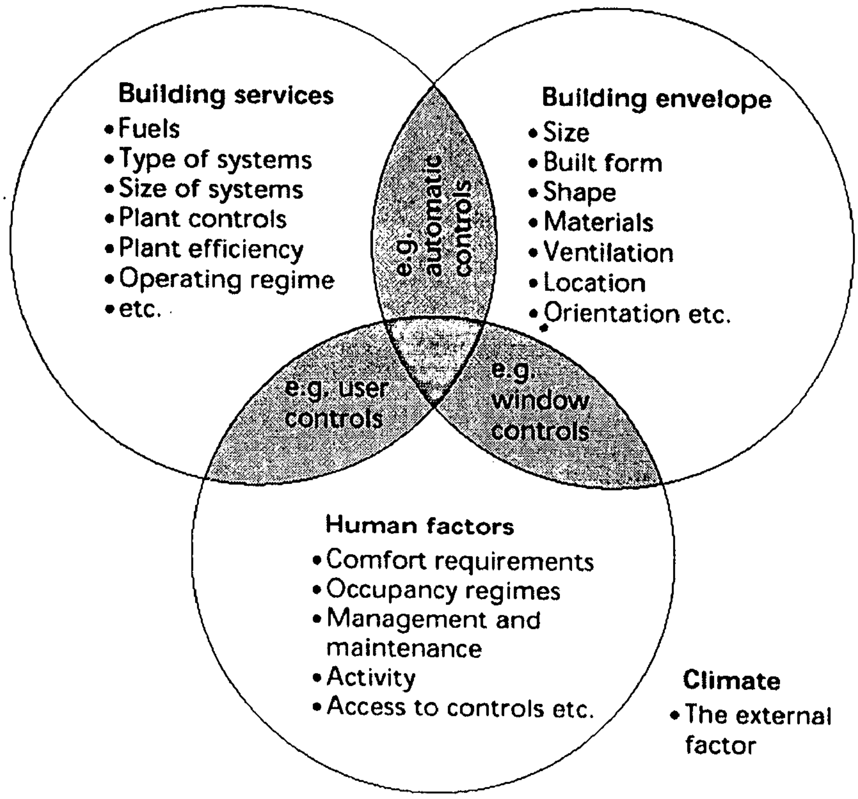


Fig (2.1b): Key factors influencing energy consumption

2.2 ENERGY-EFFICIENT BUILDING...

What we once called *"Building for all seasons"* has now been christened as *"energy-efficient"* or "climate conscious" or "sustainable architecture". *"An energy-efficient building is the one which balances all aspects of energy use in a building-* lighting, space conditioning, and ventilation by providing an optimized mix of passive solar design strategies, energy efficient equipment and renewable sources of energy. Use of materials

LITERATURE REVIEW

COMFORT FACTORS
THE BODY'S HEAT PRODUCTION
REGULATORY MECHANISMS
THE COMFORT SCALE

CHAPTER 3

relative humidity levels of 30% to70%. These ranges apply when people are dressed in light clothing, are in the shade, and are relatively inactive.

Our perceptions of comfort and tolerance for changes in environmental conditions are affected by whether we have enjoyed the benefits of a naturally cooled environment or become dependent upon air conditioned spaces. Recent research sponsored by the American Society of Heating, Refrigeration and Air Conditioning Engineers indicates that people in naturally ventilated buildings are comfortable over a wider range of temperature and humidity conditions than people accustomed to air conditioning. Perceived comfort in naturally ventilated buildings is affected by local climatic expectations and higher levels of personal control (occupants can choose appropriate clothing, open windows, or turn on fans).

3.2 THE BODY'S HEAT PRODUCTION

Excess heat, whether from the environment or our own metabolism, must be removed to maintain a constant body temperature and thermal comfort. Mild air movement (less than 100 feet per minute) improves comfort levels when temperatures and humidity are high, aiding convective cooling and increasing the evaporation of perspiration. Air movement above 100 feet per minute can begin to be less effective and may be experienced as draft, and above 200 feet per minute (2 to 3 mph) can be annoying.

Our bodies eliminate excess heat through convection, radiation, and evaporation. *Convective cooling* occurs when air that is cooler than the body moves across the skin. *Radiant cooling* occurs when heat is radiated to the air from the skin. *Evaporation* of perspiration from the skin and in the respiratory tract also helps cool the body.

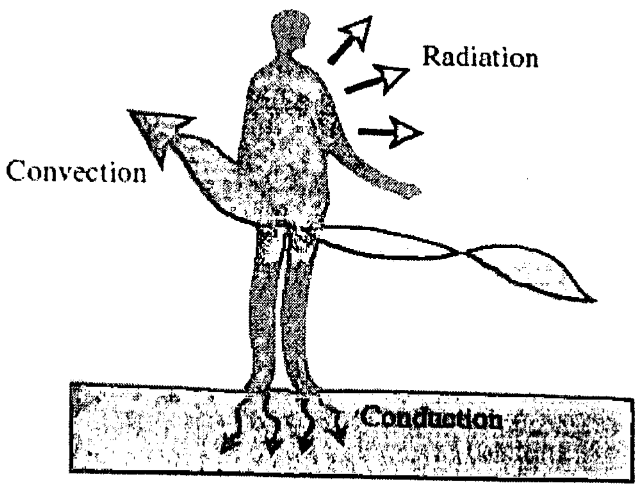


Fig (3.2): The Body's Heat Production

3.3 REGULATORY MECHANISMS

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

$$Met - Evp \pm Cnd \pm Cnv \pm Rad = 0$$

Where,

GAIN :-

Met.=metabolism (body heat)

Cnd.=conduction (contact with warm bodies)

Cnv.=convection (if air is warmer than skin)

Rad.=radiation (from sun, sky & hot bodies)

LOSS :-

Met.=metabolism (body heat)

Cnd.=conduction (contact with cold bodies)

Cnv.=convection (if air is cooler than skin)

Rad.=radiation (night sky & cold surface)

Evp.=evaporation (of moisture &sweat)

3.4 THE COMFORT SCALE

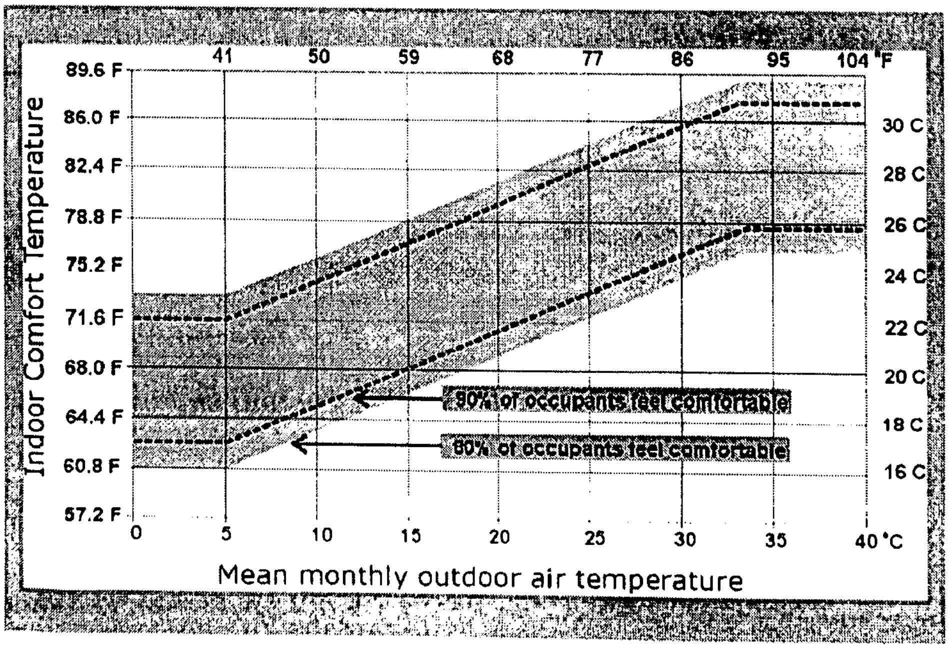


Fig (3.4): The Comfort Scale

Thermal comfort model proposed by Gail Brager. The shaded area shows indoor temperatures at which 80% of occupants feel comfortable as out door temperature varies. The area between the dotted lines shows the in door temperatures at which 90% of occupants feel comfortable.

Air velocity (feet per minute)	**Probable impact on occupants**
Up to 50 fpm	**Unnoticed**
50 to 100	**Pleasant**
100 to 200	**Generally pleasant but causing a constant awareness of air movement**
200 to 300	**From slightly to annoyingly drafty**
Above 300	**Requires corrective measures if comfort and productivity are to be maintained**

ARCHITECTURAL ASPECTS

WHOLE BUILDING DESIGN
SPECIAL SITE CONDITIONS
BUILDING ORIENTATION AND SHAPE
SOLAR CONTROL STRATEGY
DAY LIGHTING AND VISUAL COMFORT STRATEGY
THERMAL COMFORT STRATEGY
INDOOR AIR QUALITY STRATEGY:
NATURAL VENTILATION
DAY LIGHTING

CHAPTER 4

4. ARCHITECTURAL ASPECTS OF BUILDING DESIGN

4.1 WHOLE BUILDING DESIGN

Whether a building is naturally ventilated or air conditioned, the odds of success improve dramatically if the project team employs an integrated design — or *whole building design* — approach. This is especially true when considering a building's energy efficiency. The operating costs of energy-consuming systems such as lighting and air conditioning are highly dependent on the architectural design. For example, a well-shaded building will not only consume less energy but will likely have a smaller and less expensive cooling system. With adequate attention to cross-ventilation design, the building may need no cooling at all. In addition, a well-designed fenestration system will reduce the need for electric lighting and save large amounts of energy. From an energy efficiency perspective, the following design issues should be addressed at the same time and as early as possible in the design process:

- Solar Control Strategy
- Thermal comfort strategy
- Day lighting and Visual Comfort Strategy
- Indoor Air Quality Strategy

Sometimes design strategies may seem to be in conflict with one another. For example, using reflective glass for solar control limits the amount of visible light available for daylighting. Natural ventilation for thermal comfort may not always maintain the indoor temperature and humidity necessary for special equipment. But if these issues are considered early in the design process, then conflicts can be resolved and energy-efficient design options can be developed.

These general design strategies influence many specific design decisions, including:

- Siting and orientation
- Building form (shape, number of stories)

- Fenestration design (glass type, window area, shading design, operability)
- Roof construction and surface type
- Lighting system design (luminaire type, controls)
- Mechanical system type (including ceiling fans)
- Interior space zoning
- Material selection (moisture resistance, light color, thermal mass)

4.2 SPECIAL SITE CONDITIONS

Local site conditions play an important role in building design. To achieve optimum interior comfort at a given site, local variations or "micro-climate" conditions should be considered when identifying specific strategies for building and site design. These variations are largely the result of differences in elevation above sea level, topography, and orientation to the prevailing trade winds.

4.2.1 Sunlight and Temperature

Solar radiation levels, average air temperature, and daily temperature range vary with elevation, exposure to the trades and cloud cover. Cloud cover is substantially more common on windward coasts and over lower mountain areas. Leeward coasts and high mountain areas receive the most sunlight.

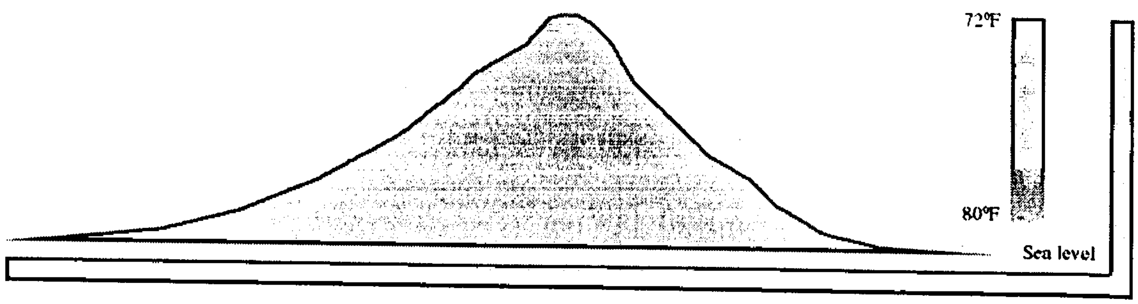


Fig (4.2.1): Air Temperature Variation with Altitude. Air temperatures decrease about 30 F per thousand feet of rise above sea level

4.2.2 Rainfall and Humidity

Variations in rainfall are primarily due to differences in elevation, topography, and exposure to prevailing and seasonal winds.

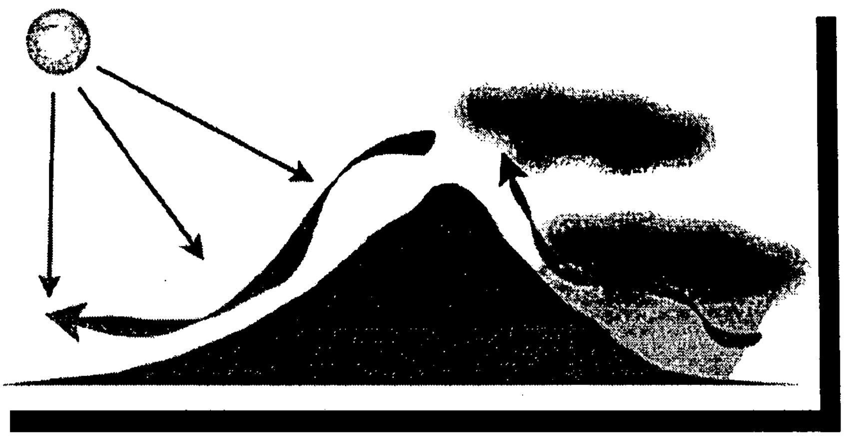


Fig (4.2.2) Rainfall Pattern

Mountains deflect the prevailing trade winds upward, cooling the air and trapping rain. Windward areas get substantially more clouds and rainfall than the nearby open sea and leeward areas. Leeward regions, where air that has lost its moisture over windward slopes descends, tend to be sunny and dry.

4.2.3 Wind

Mountains and valleys affect airflow. Winds that normally rise on encountering mountain slopes may deflect around larger mountain masses. Wind flowing over ridges, around headlands, and through valleys often accelerates and becomes turbulent.

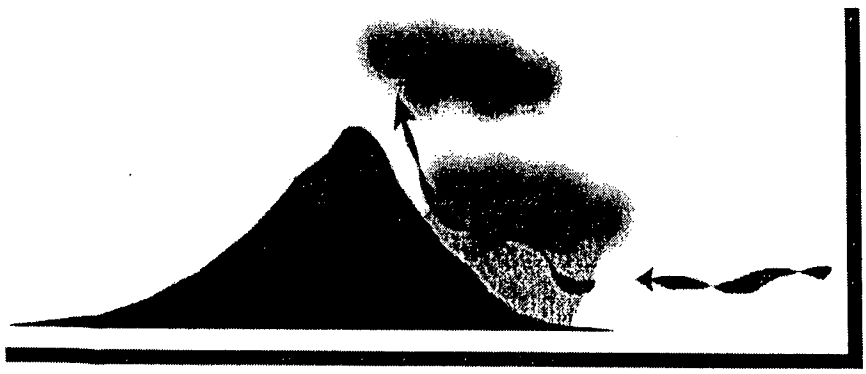


Fig (4.2.3a): Warm onshore breezes during the afternoon and early evening hours can bring rain.

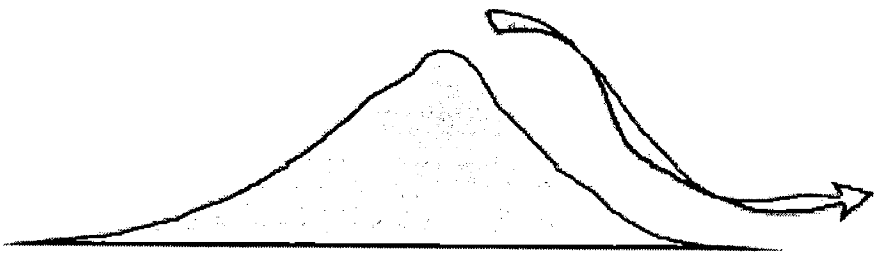


Fig (4.2.3b): Offshore breezes at night and in the early morning hours can bring cooler temperatures.

4.3 BUILDING ORIENTATION AND SHAPE

Solar heat gain has the largest impact on surfaces perpendicular to the sun's rays.

Limit heat build-up by orienting longer sides of the building north and south.

Oriented with the narrow sides facing East-West will reduce low sun angle exposure and provide the best shading opportunities.

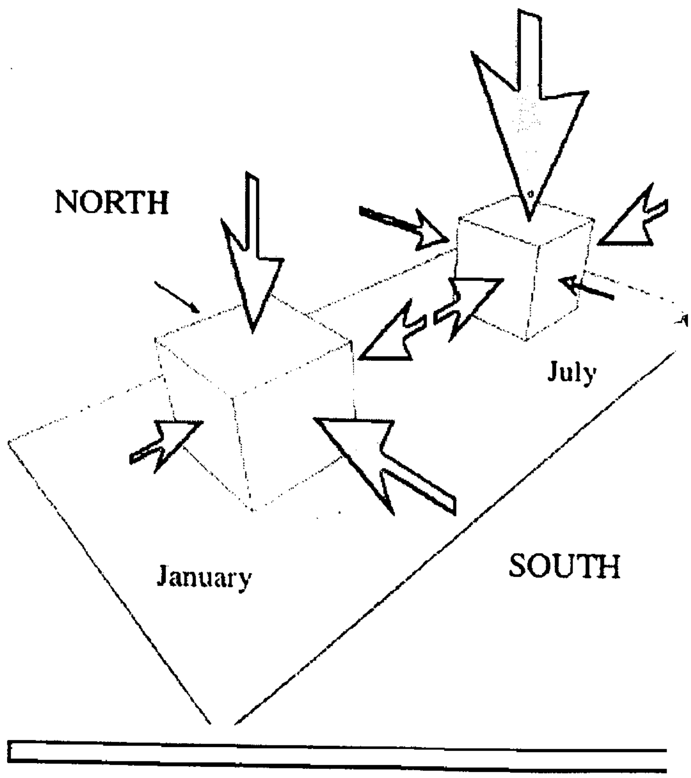


Fig (4.3): Building Orientation and Shape

4.4 SOLAR CONTROL STRATEGY:

To achieve a comfortable and energy-efficient building, controlling the amount of sunlight and heat from the sun that enters the building is key. Good solar control offers several benefits:

- Lower energy cost
- Smaller and less expensive cooling system
- Greater occupant comfort because of cooler interior surfaces
- More usable interior space because of improved comfort near windows

Effective solar control is not always easy or inexpensive.

4.4.1 Orientation

Proper orientation is the most important strategy. Whenever possible, limit the amount of window and wall area on the east and west facades. Sunlight is easier to control on the north and south sides of a building.

4.4.2 Fixed Shades

The best strategy for solar control is to keep direct sunlight off the windows. Overhangs are typically the best choice and are especially effective on the north and south facades. The combination of overhangs and vertical fins can nearly eliminate direct solar gain for most of the year.

4.4.2 Operable Shades

Automatic or manually controlled operable shades can replace or supplement fixed shades. When the sun is obscured by clouds or is on the other side of the building, operable shades can be adjusted to allow more light into the space and to give occupants a better view. However, operable shades are less likely to provide full long-term energy efficiency benefits compared to fixed shades because operable shades require more maintenance and their effectiveness depends on occupant behavior. Exterior shades provide greater solar control because they block more heat from entering the building. However, interior shades may last longer, especially in areas close to the ocean or subject to harsh weather.

4.4.3 Windows

Windows are critical in the battle against the sun. A designer's first choice should be to minimize the amount of direct solar radiation that reaches the windows. If direct sunlight can be kept off the windows, then inexpensive clear or lightly tinted glass can be used. However, if it is not possible to completely shade the windows from direct sunlight, then solar-control glazing should be specified.

The most important glazing characteristic for windows is solar heat gain coefficient (SHGC). A low SHGC can be provided through several different technologies:

Heat-absorbing tints. These tints are available in a range of colors. Some tints, typically blue or green in color, offer better visible light transmittance while providing equal or better solar control than gray or bronze tints. Consider using these blue or green tints in daylighting designs. All heat-absorbing tints get hot in direct sunlight — an important consideration for buildings where occupants sit close to windows.

Heat-reflecting coatings. Several types of coatings are available. Some appear reflective; others are designed to reflect as much heat as possible while also appearing as clear as possible. The latter type of coating is called "spectrally selective" and is the best choice for simultaneously providing daylight and solar control.

Laminates. These consist of plastic films sandwiched between two sheets of glass. Both heat-absorbing and heat-reflecting films are available. Heat-absorbing glass can be used to create the laminated glass sheet, providing further solar control.

Films. Plastic films similar to those used to create laminated glass can be applied to the surface of the glass after the window is installed. This should be considered only as a retrofit measure because the exposed film is not as durable as glass.

4.4.4 Walls

As with windows, the first choice for controlling heat gain through a wall is shading. If shading is not possible, consider a lightcolored exterior wall, radiant barrier, insulation and/or thermal mass to reduce heat flow. Rather it is solar radiation hitting the wall and heating the wall's surface. Therefore, a white uninsulated wall can be as effective as a dark wall with insulation.

4.4.5 Landscaping

Landscaping can provide excellent solar control. Place trees and shrubs in strategic locations, especially on the east or west sides where they can block morning and afternoon sun. But even if plants do not directly shade a building, they can help keep the local environment cooler. Pay special attention to shading asphalt roads and parking lots.

4.5 DAY LIGHTING AND VISUAL COMFORT STRATEGY:

Lighting accounts for about 40% of the energy cost for commercial buildings Therefore, buildings designed to take advantage of daylight provide dramatic energy savings. Several day lighting strategies are available, and more than one may be applied in a single project. Two broad categories of day lighting design are top lighting and side lighting. Top lighting employs skylights or roof monitors to illuminate a space from above. Side lighting designs use daylight from windows.

To be effective, a daylighting design must consider visual comfort. If glare is excessive, occupants may resort to using window shades, which may reduce the energy savings of the daylighting design. To take advantage of the potential energy savings, the designers must develop a daylighting strategy early in the design process. Once decisions such as the number of stories and basic floor plan are made, many daylighting options may be eliminated.

4.5.1 Building Form

The most basic design decisions have a big impact on daylighting potential. Single-story buildings have the greatest number of options: they can take advantage of toplighting, sidelighting or both. Multi-story buildings can achieve nearly complete daylighting through several means. A narrow floor plan, like that of many high-rise hotels, allows most indoor space to be illuminated by sidelighting. A courtyard or atrium can also allow daylight to reach interior zones of lower floors.

4.5.2 Orientation

Orientation has an impact on daylighting effectiveness. As with solar shading design, daylight is more easily controlled on the north and south sides of a building. Whenever possible, the long sides of a building should face north and south, minimizing the east and west exposures. Good daylighting design is more difficult on the east and west sides because of glare created by direct sunlight in the morning and afternoon.

4.5.3 Skylights

Overhead skylights can be a very cost-effective means of providing pleasant and even illumination to an interior space. And in a single-story building, skylights can meet all the daytime lighting needs. Skylights are common in large spaces such as warehouses and factories, but they have also been used with great success in smaller spaces such as offices

4.5.4 Windows

It's usually desirable to provide separate vision fenestration (windows that provide views) and daylighting fenestration (glass that provides daylighting). Vision glass should have lower light transmission to reduce glare and maintain the visual comfort of occupants close to the window. Daylighting glass, positioned higher on the wall, should transmit more visible light to provide better daylight penetration for occupants further from the window.

4.5.5 Lightshelves and Other Shading Devices

Lightshelves or similar shading devices help improve the daylighting performance of windows. A good shade design serves two purposes: it blocks direct sunlight penetration and reflects diffuse light deeper into the room.

4.6 THERMAL COMFORT STRATEGY

Thermal comfort depends on several factors, including air temperature, relative humidity, air movement and the temperature of surrounding surfaces. Therefore, several approaches to maintaining comfort are possible.

4.6.1Natural Ventilation

From an energy efficiency and air quality perspective, natural ventilation is usually the best choice. Natural ventilation should be considered in all spaces without special indoor environment constraints (see Special Indoor Environment Requirements section). Of course, the feasibility of natural ventilation also depends on the building location. For a successful naturally ventilated building, designers need to pay greater attention to the surroundings. Obstructions, landscaping and microclimate issues are important. Nearby sources of noise or dust can also be a constraint. The Natural Ventilation Guidelines discuss thermal comfort and natural ventilation strategies.

4.6.2 Hybrid Design

Many successful designs employ natural ventilation and air conditioning in separate portions of the same building. For example, spaces with very high equipment loads or occupant density can be mechanically cooled, while areas such as open offices, private offices, corridors and lobbies can be naturally ventilated. A good hybrid design requires careful space planning from the start.

4.6.3 Building Envelope

Regardless of the choice of natural or mechanical ventilation, the building shell should be designed to prevent the occupants from being exposed to hot interior surfaces. Insulation reduces the interior wall and ceiling temperatures. Window shading, coated glass or both help keep windows cool. Avoid tinted glass where it will be exposed to direct sunlight. Tinted glass absorbs solar radiation and can reach very high temperatures, causing discomfort for people close to the windows.

4.7 INDOOR AIR QUALITY STRATEGY:

Good indoor air quality is best achieved through a system approach that considers:

- Reduction of indoor pollution sources, and
- Monitoring and maintenance.

Natural Ventilation refers to the process of exchanging warm building air for cooler outside air without the use of energy-consuming mechanical devices, such as fans and air conditioners. To maximize opportunities for natural ventilation in the home, you must orient the building for maximum access to outside breezes, and your design must provide openings that will encourage cross-ventilation inside the home.

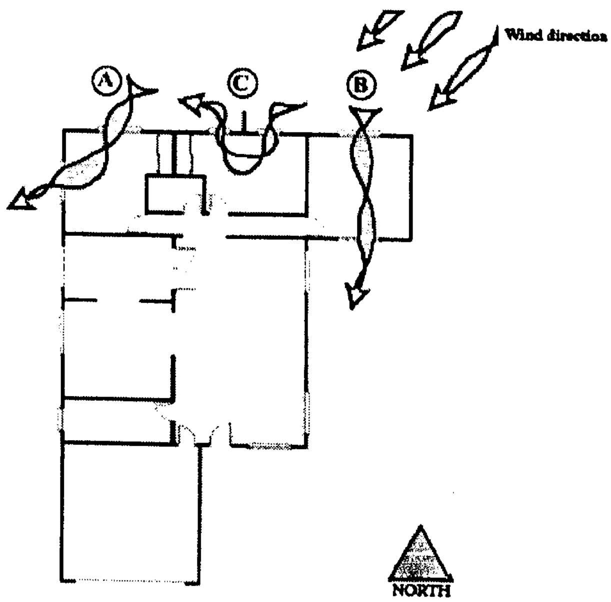


Fig (4.7): Basic Natural Ventilation Strategies.

The primary strategies for creating effective cross ventilation inside the home are:

- Provide an adequate number of windows
- Design for optimum window type, size, and placement
- Use ceiling fans where required to improve airflow.

Floor Plan Design and Orientation

For adequate ventilation, there should be at least two operable openings to the outside in each space. Operable openings include operable windows and entries (doors). Entries should have screen doors. Solid doors should be provided with a door catch to hold them open. Two common window configurations are: openings on adjacent walls (A), and openings on opposite walls (B). Spaces with only one exterior wall are difficult to ventilate effectively. In this situation casement windows or a wing wall may be used to improve ventilation (C).

- Use open floor plans with a minimum of interior partitions to improve air circulation throughout the home.

- Use louvered doors and shutters to allow air to circulate freely through spaces while maintaining visual privacy.

- Rooms that produce heat and humidity such as kitchens, laundry rooms, and bathrooms require special planning. They should be well ventilated and placed on the leeward side of the house to prevent hot humid air from spreading into other living spaces.
- Protect exterior doors from rain with generous eaves and screens if they are to be used for natural ventilation. Hinged doors should have stops and hold-open devices.

- Use louvers or catches on interior doors.

- Install a ceiling fan for every 400 square feet of floor space to improve comfort levels when breezes are light.

- Separate garages or place them on the leeward side of the home so they do not block needed airflow.

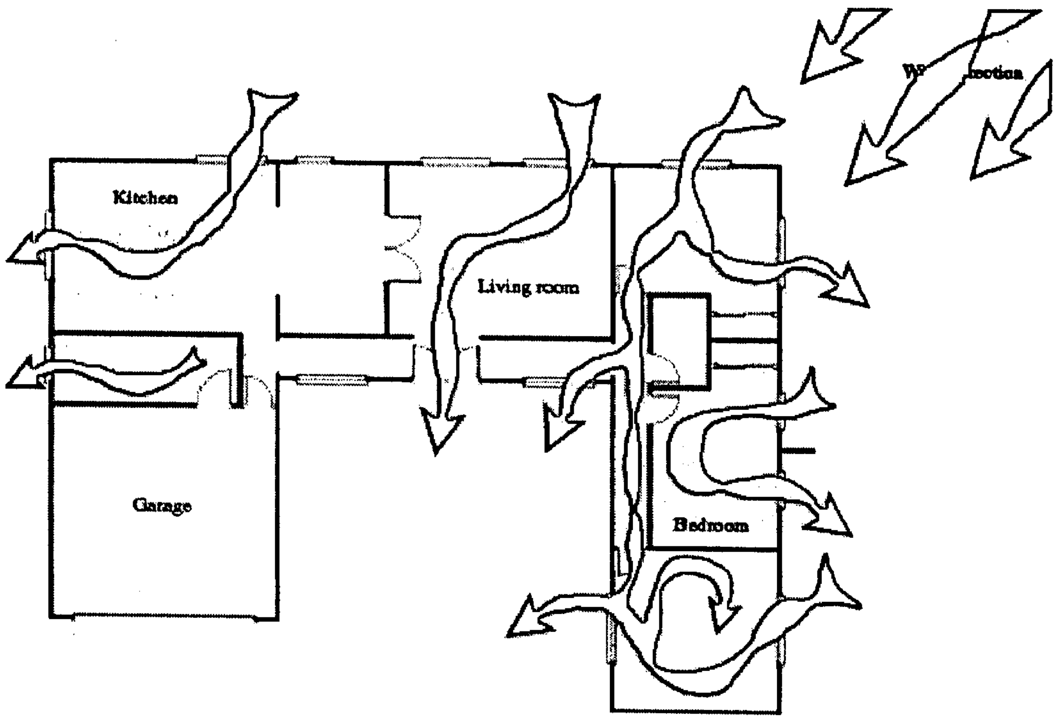


Fig (4.7): Designing for Good Cross Ventilation.

4.7.1Ventilation

For naturally ventilated buildings the most important issue is the location of nearby exterior pollution sources. Obvious sources include roads, parking lots, dusty fields, agricultural areas and some commercial or industrial activities.

Ventilation is traditionally employed as an indoor air quality solution for air-conditioned buildings. However, ventilation alone cannot guarantee a healthy building, and high ventilation rates raise energy costs.

4.7.2 Moisture control

Good moisture control in the roof, walls and floors is important to prevent mold growth. Careful design of the air conditioning system can also improve dehumidification to inhibit mold growth.

4.7.3 Indoor Pollution

To improve indoor air quality, reducing indoor pollution sources is critical. Choose furniture and finishings with low emission rates of toxic chemicals. Ensure that air from storage spaces for chemicals and cleaning materials is directly exhausted to the outside. It is also a good idea to exhaust air from areas with photocopiers or printers.

4.8 NATURAL VENTILATION

- Cross Ventilation
- Stack Ventilation

The indoor air quality and occupant comfort perspectives, natural ventilation is usually a better choice than air conditioning. Natural ventilation can save substantial energy by decreasing or eliminating the need for mechanical cooling.

It may also improve the building's indoor air quality, provided that dust and other pollutants in the air outside the building aren't a problem. And buildings with well-designed natural ventilation systems often provide very comfortable and pleasant environments for the occupants.

Window types and size have substantial impact on natural ventilation. Types of windows vary substantially in their net opening size, the degree of protection they offer from rain, and their ability to direct airflow. All window types should be provided with screens and protected from direct sunlight. To admit sufficient outside air, windows and other operable openings should have a net opening area equal to at least 12% of the room's floor area.

Single and double hung windows are the least effective window for controlling rain and air flow due to their small open area and vertical orientation. Single hung windows especially are a poor choice since the upper sash, although usually protected by eave overhangs, is not operable and does not allow for ventilation. Sliding windows are also vulnerable to rain. Casement windows have the largest open area but they do not provide as much protection against rain. Awning windows have relatively large open areas and provide good rain protection when open. Awning and jalousie windows have approximately the same open area. Both provide reasonable rain protection, but jalousie windows offer better airflow control.

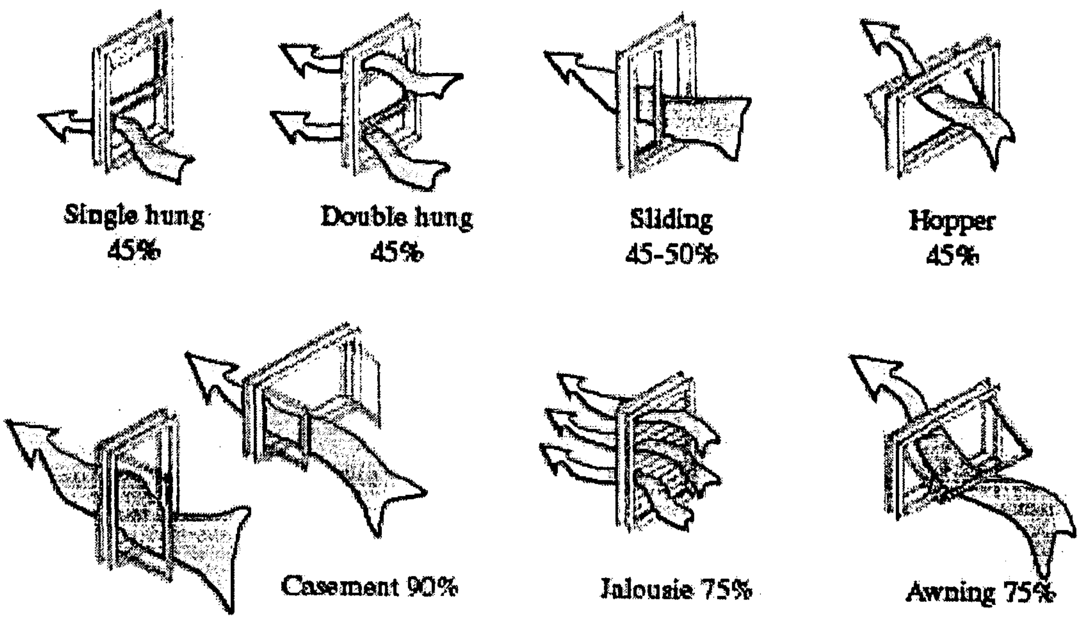
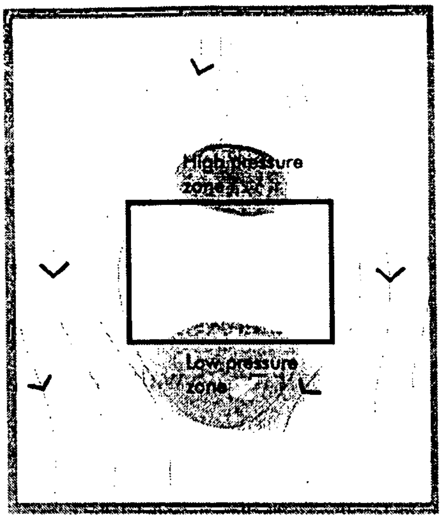


Fig (4.8): Effective Open Areas for Various Window Types.

4.8. 1 Cross Ventilation

Provide equal area of operable openings on the windward and leeward side. Ensure that the windward side is well shaded to provide cool air intake. Locate the openings on the windward side at the occupied level.

Cross ventilation is one of the methods of providing natural ventilation. All natural ventilation strategies rely on the movement of air through space to equalize pressure.



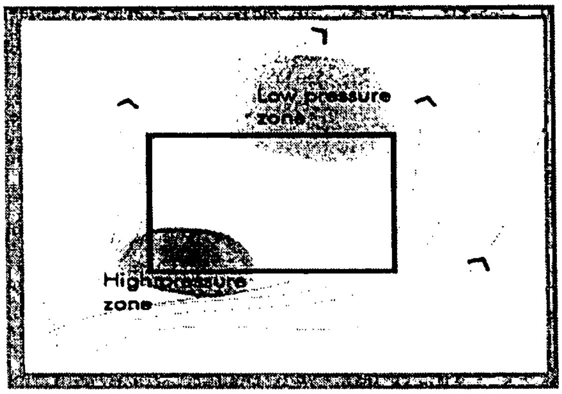


Fig (4.8.1a): Pressure Difference

Cross ventilation is optimum well when inlet openings are slightly smaller in total area than outlet openings (1:1.25 is a good ratio).

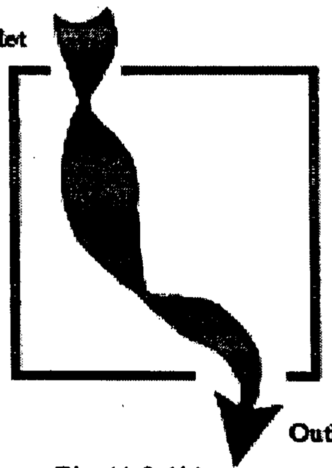


Fig (4.8.1b): Sizing Inlet and Outlet Openings

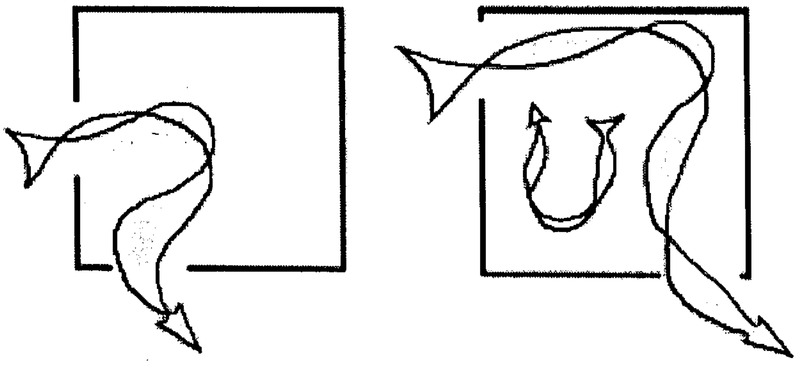


Fig (4.8.1c): Window Arrangement for Cross Ventilation
(Adjacent Walls).

Air flow is limited when windows are in placed close together. Improved airflow is achieved when windows are spaced further apart. Casement windows are a better choice in this situation because the window's glazing acts as a small wing wall and maximizes airflow.

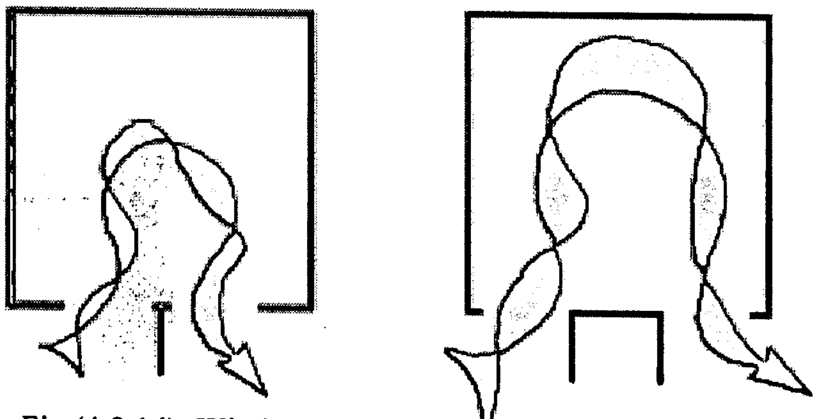


Fig.(4.8.1d): Window Arrangement for Cross Ventilation
(Same Wall).

Two wing walls spaced apart perform better than a single wing wall.
Casement windows are a good choice in this situation because the window's glazing acts as a wing wall to maximize airflow.

DESIGN DETAILS

An effective cross-ventilation design starts with limiting space sizes to facilitate inward flow of air from one face and outward flow from the other. Architectural elements can be used to harness prevailing winds.

- Orient the building to maximize surface exposure to prevailing winds.
- Provide the inlets on the windward side (pressure zone) and the outlets on the leeward side (suction zone).
- Use architectural features like wing walls and parapets to create positive and negative pressure areas to induce cross ventilation.
- Air speed inside a space varies significantly depending on the location of openings. The most effective strategy is to provide openings on opposite walls. Using single-loaded corridors makes it easier to provide openings on opposite walls. Limit room widths to 15 to 20 feet if openings cannot be provided on two walls.
- For small spaces where it's not possible to have openings on opposite walls, placing windows on adjacent walls may provide some cross ventilation. This should be limited to smaller spaces (less than 15 ft x 15 ft).
- Consider designing cross-ventilation openings that are secure enough to be left open at night, so that natural ventilation can provide additional nighttime cooling benefits.
- The openings must be easily accessible to and operable by the occupants.
- Equal inlet and outlet areas maximize airflow whereas outlets that are 25% larger than inlets produce higher air velocities.
- The inlet location affects airflow patterns far more significantly than outlet location. Inlet location should be a higher priority
- (if faced with a choice) as a high inlet will direct air toward the ceiling and may bypass the occupied level. Provide inlets for cross-ventilation openings at the occupied level.
- Stagger the outlet openings both vertically and horizontally by a few feet to achieve longer air paths. Concentrate ventilation openings in spaces most likely to require cooling.
- For natural ventilation to function properly, minimize solar gain. Direct sunlight penetration may make it difficult or impossible to achieve comfortable conditions

with natural ventilation alone. Use shading devices like overhangs, awnings and fins to control solar gain.

DESIGN TOOLS

The following algorithm shows the rate of wind-induced airflow through inlet openings:

Q = C4CvAV

where,

Q = airflow rate,

Cv = effectiveness of openings (Cv is assumed to be 0.5–0.6 for perpendicular winds and 0.25 to 0.35 for diagonal winds)

A = free area of inlet openings

V = wind speed, mph

C4 = unit conversion factor = 88.0

4.8.2 Stack Ventilation

Use inlets and outlets of equal area and maximize the vertical distance between these two sets of apertures. Place inlets close to or in the floor or at the occupied level. Locate the outlets closer to the ceiling on the opposite wall.

Description:

Stack ventilation utilizes air density differences to provide air movement across a space. At least two ventilation apertures need to be provided — one closer to the floor and the other high in the space.

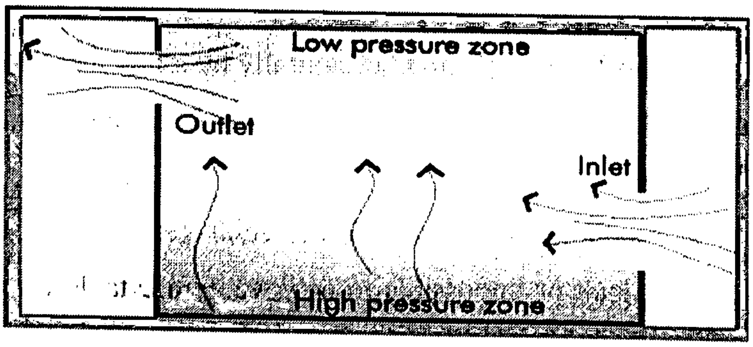


Fig.(4.8.2): Stack Ventilation

DESIGN TOOLS

The airflow required can be reasonably estimated using spreadsheet-based calculations. The following algorithm defines the airflow as it varies with the area of openings, indoor temperature, outdoor temperature, and location of the inlet and outlet:

$Q = 60CDA \quad 2g\Delta HNPL\ (Ti - To) / Ti$

Q = airflow rate

CD = discharge coefficient for opening

ΔHNPL = height from mid-point of lower opening to NPL, ft

Ti = indoor temperature, °R

To = outdoor temperature, °R

4.9 DAY LIGHTING

Daylighting is the use of transparent or translucent panels located in the building envelope to let natural light into interior spaces. To provide balanced, glare-free illumination, daylight can be diffused in a variety of ways, such as by using louvers or translucent glazing panels, designing apertures to bounce daylight into the space, and using shading devices to block direct sun penetration.

There are two forms of daylighting: toplighting and sidelighting. With toplighting, the daylighting openings — or *apertures* — are located in the ceiling plane to provide uniform, glare-free illumination. Daylight is diffused using translucent glazing, reflective fixed or operable baffles, or deep skylight wells. Several configurations — such as vertical and splayed skylight wells, clerestory windows, light boxes and sawtooth roof monitors — can be used successfully in toplighting designs. Daylight levels are highest directly under the aperture and drop off as you moven away from it. The spacing of the daylight aperture depends on the ceiling height.

Sidelighting allows daylight to enter through windows in vertical walls. With sidelighting, uniform illuminance is more difficult to provide, as there is always more light next to the window. Glare is also more difficult to control. But there is design techniques that can substantially reduce problems associated with sidelighting.

Daylighting is at the heart of sustainable design for most buildings. A well-designed daylighting system can significantly reduce or even eliminate the need for electric lighting during the day, which can save a substantial amount of lighting energy and air conditioning energy.

Daylight affects us in both obvious and subtle ways: it provides light to see our environment, go about our lives and do our work; it determines the cycles of our days and seasons; and on a biological level it stimulates hormones that regulate our body systems and moods. Daylight also affects certain physiological functions. For example, it stimulates the assimilation of Vitamin D, which is important for healthy bone formation, and it affects sleep cycles.

Daylighting Strategies:

Daylighting uses natural light to provide adequate interior illumination for doing various tasks. Illumination may be provided completely through daylighting or through a combination of daylight and electric light.

Daylighting can be provided through an opening in the wall, roof or ceiling via transparent or translucent panels such as windows, glazed doors, skylights and other sources. These glazed apertures are referred to as fenestration.

The availability of sunlight depends primarily on the daily and seasonal path of the sun, while the intensity of daylight depends on the presence of clouds and moisture in the air. To successfully daylight a building it's important to understand the basic principles of solar orientation, climatic conditions and shading systems.

These Daylighting Guidelines provide an overview of daylighting and fenestration design, including basic principles for good daylighting design and general and specific guidelines for toplighting and sidelighting strategies.

- Provide uniform illumination using **GOOD DAYLIGHT DESIGN**
- Provide access to exterior views through **VIEW WINDOWS**
- Use **CLERESTORIES** for deeper daylight penetration
- Add **LIGHTSHELVES TO CLERESTORIES** to improve daylight distribution
- Balance daylight from window walls with **WALL-WASH TOPLIGHTING**
- Provide even daylight with **CENTRAL TOPLIGHTING**
- Use **PATTERNED TOPLIGHTING** to provide even illumination across a large area
- Use **LINEAR TOPLIGHTING** to direct movement or provide visual orientation in a linear space
- Employ **TUBULAR SKYLIGHTS** for toplighting areas with deep roof cavities and for low-cost retrofits.

General Principles for Daylighting Design

Provide daylighting for uniform and low glare illumination wherever possible. In locations that have predominantly clear days, provide daylight using vertical glazing. In locations with predominantly cloudy days, use horizontal glazing to provide daylight.
Provide toplighting in single-story structures or in the top floor of multistory buildings. Use sidelighting to provide illumination in areas near the walls and to provide views. Use high sidelighting to deliver daylight deeper into the space.
Daylighting provides uniform interior illumination through transparent or translucent panels located in the building envelope that let in natural light. Daylight can be diffused by using louvers or translucent glazing panels or by articulating the aperture.

Energy Savings

Turning off or dimming electric lights in response to the amount of available daylight can result in electric light savings of 40% to 80% during daylight hours. However, if the total glazing area is not optimized, these savings can be offset by increased solar gain.

Design Details

The following principles, which are discussed in detail below, are fundamental elements of good daylighting design.

- Prevent direct beams of sunlight from penetrating the space
- Provide uniform illumination
- Avoid glare
- Provide methods of controlling daylight
- Integrate daylight with electric lighting
- Lay out the interior spaces so that they benefit from daylighting opportunities
- Optimize the aperture size
- Consider safety and security issues when designing daylighting apertures

Methods for daylighting

- View Windows
- High Sidelighting — Clerestory
- High Sidelighting — Clerestory with Lightshelves or Louvers
- Wall-wash Toplighting
- Central Toplighting
- Patterned Toplighting
- Linear Toplighting
- Tubular Skylights

4.9. 1 VIEW WINDOWS

North-facing view windows can provide enough daylight to reduce electric lighting loads, But view windows on the other orientations will often have to have their blinds or curtains drawn to reduce glare, and so should not be counted on to provide adequate

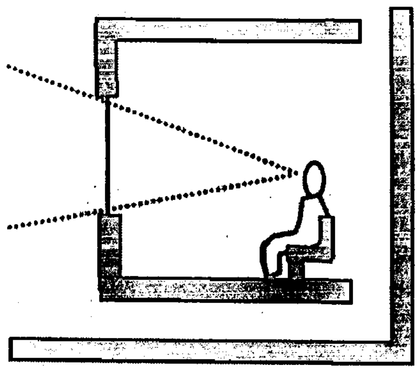
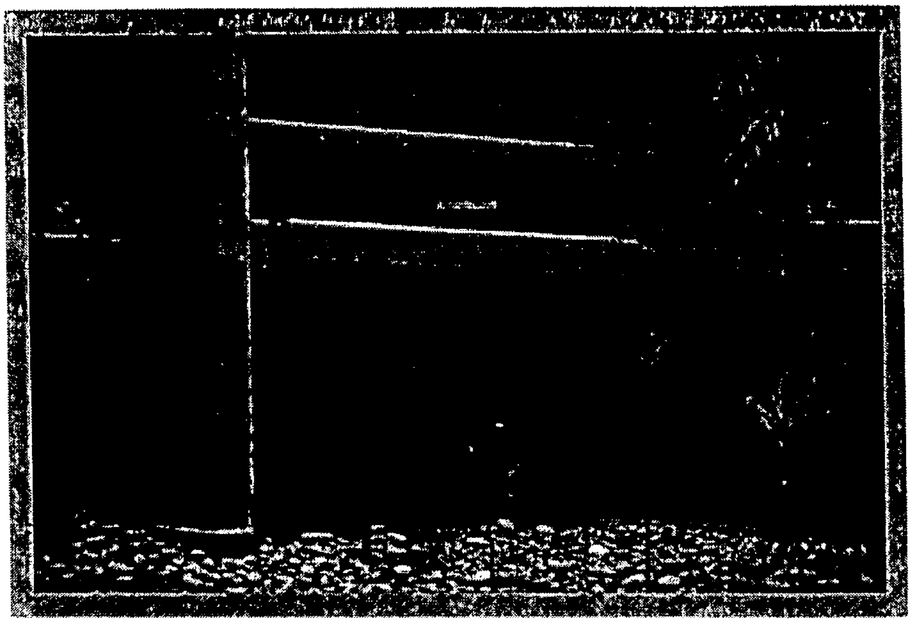


Fig.(4.9.1): View Windows

daylight or to predictably reduce a space's electric lighting use.

Orientation: Orient view windows toward the north or south to avoid the low-angle east and west sun. On south, east and west orientations, an interior shade such as a shade screen, blinds or drapes, will provide control over brightness and sun penetration.



4.9.2 HIGH SIDELIGHTING — CLERESTORY

Use high sidelighting clerestories in perimeter walls to deliver daylight deeper in spaces such as offices, classrooms, warehouses, industrial spaces, gymnasiums, and many other building types. High sidelighting is characterized by vertical glazing in an exterior wall above eye level, typically above 7 ft.

Orientation : Clerestories are most effective on south and north orientations. For east and west

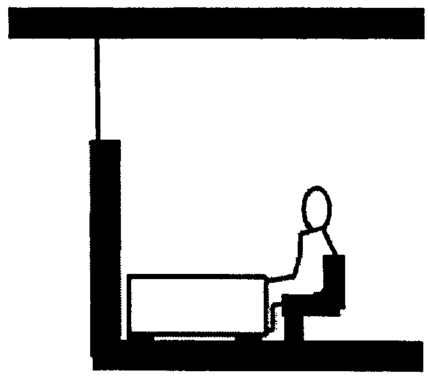


Fig.(4.9.2a): High Sidelighting -Clerestory orientations, evaluate the design to reduce low sun angle penetration. With east, west and south orientations, reduce solar gain by shading the glazing with an overhang or use a selective low-e coating

Sloped ceiling at perimeter increases window head height by reducing the plenum height.

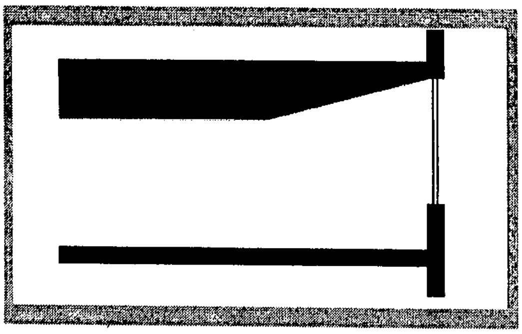


Fig.(4.9.2b): High Sidelighting -Clerestory

Clerestories in multistory buildings can redirect daylight onto the perimeter wall to brighten it.

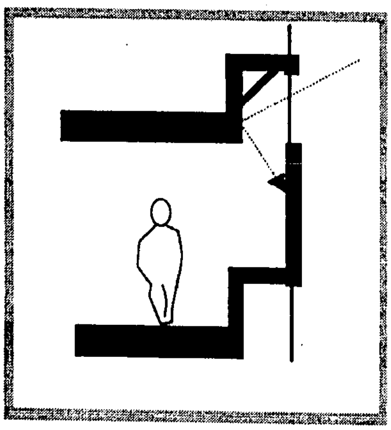


Fig.(4.9.2c): High Sidelighting -Clerestory

High Sidelighting — Clerestory with Lightshelves or Louvers

Exterior lightshelves improve light distribution and help stop heat gain before it enters the building.

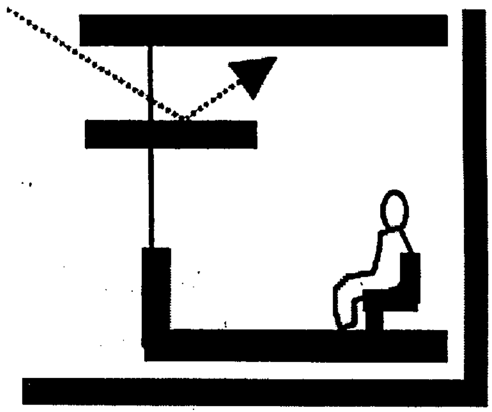
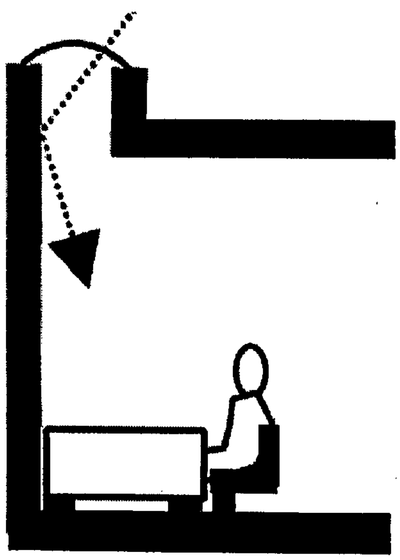


Fig.(4.9.2d): High Sidelighting — Clerestory with Lightshelves or Louvers

4.9.3 WALL-WASH TOPLIGHTING

Skylights: Skylights perform better in a predominantly overcast sky condition and non-north/south orientations.

A pyramid or arch-shaped diffusing skylight is more effective at collecting daylight during the low sun angles of early morning or late afternoon. Horizontal glazing is more effective when the sun is high in the sky and associated higher solar gains.



very

with

Fig.(4.9.3): Wall-Wash Toplighting

4.9.4 PATTERNED TOPLIGHTING

Skylights: As a rule of thumb, skylights used in a patterned toplighting scheme should be spaced roughly 1.5 times the floor to- ceiling height. Their glazing should be about 3% to 12% of the floor area to be lighted.

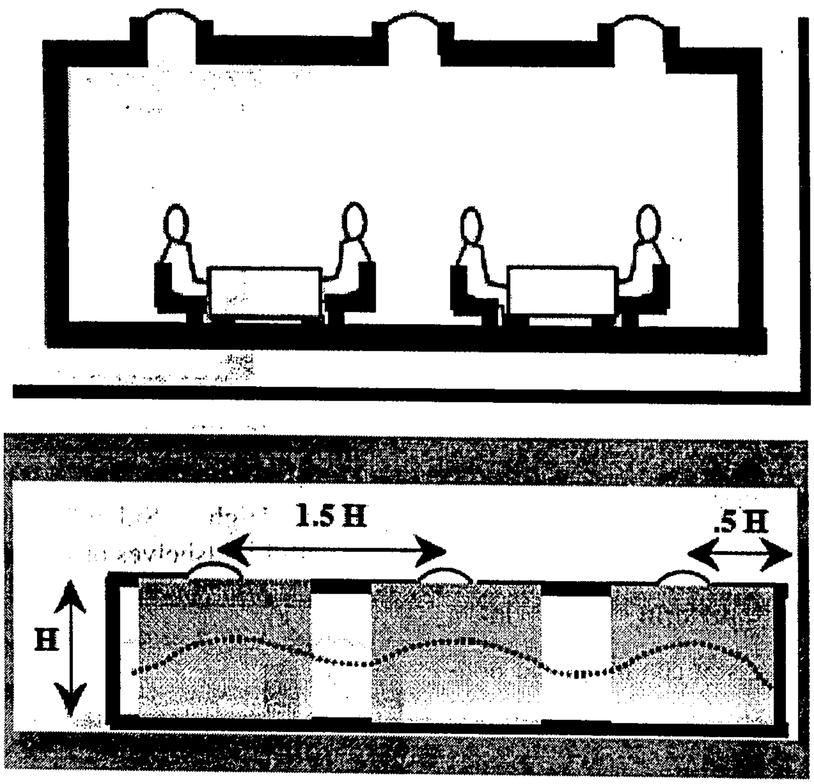


Fig.(4.9.4):Patterned Toplighting

4.9.5 TUBULAR SKYLIGHTS

Use tubular skylights to bring daylight into spaces with deep roof cavities and for low-cost retrofits to existing spaces. Tubular skylights are small, domed skylights with clear glazing. They are connected to the space's ceiling with mirrored reflective ducts. An interior diffuser at the ceiling plane distributes daylight in the space. Some tubular skylights have electric lighting in the duct or a diffuser that is controlled in response to daylight levels.

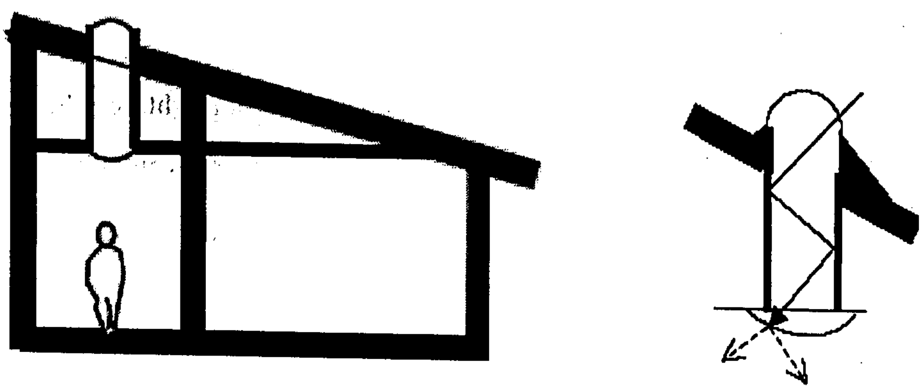


Fig.(4.9.5): Tubular Skylights

ENERGY-EFFICIENT WINDOWS

WINDOW TERMINOLOGY

SOLAR CONTROL GLAZING

EXTERIOR OVERHANGS AND SIDE FINS

CHAPTER 5

0 ENERGY-EFFICIENT WINDOWS

window is vertical glazing located in a building to provide views, natural ventilation, ıylight, or some combination of these three. Energy-efficient window design takes into ;count the window area, glass type, building orientation, and shading devices to aximize daylighting while minimizing solar heat gain.

'indows serve many important functions. They can provide views, fresh air and cooling ·eezes, and daylight. Views of the outdoors give people a sense of connection to nature ıd the surrounding community, and also provide a sense of passing time and changing 'eather conditions. Natural ventilation and daylight can help provide more comfortable ɔnditions for occupants, and may result in significant energy savings for the building wner or tenant. Access to views, daylight and natural ventilation has been associated with ıcreased employee productivity. Views through windows, for example, may improve eye ealth by encouraging people to occasionally shift their eyes' focus from close-up tasks to ıore distant sights. Windows also provide people on the outside with views of the ctivities inside a building, which is quite important for many types of commercial uildings

Vhile there are many powerful arguments for including windows in commercial buildings, ʲindows also admit direct solar gain into a space. This heat gain can be a source of passive eating in colder climates, but it is not desirable in cooling-dominated climates.

n addition to affecting HVAC energy use, a window's surface temperature can make ıccupants in the building's peripheral zones feel uncomfortably hot or cold. Glazing types that tend to have high surface temperatures when exposed to direct sun are not desirable. Also, if windows are not properly located or shaded, direct sun penetration may cause uncomfortable glare for the occupants.

But by optimizing aperture size, glazing type and solar shading, it's possible to take advantage of the benefits of windows without significantly increasing the cooling load or causing thermal or visual discomfort.

Solar control — whether achieved with shading devices, window orientation or glass selection — reduces heat gain by cutting off direct solar penetration into the building. In existing buildings that are retrofitted with solar control devices such as interior or exterior shading, this results in significant savings in peak load energy and lower energy bills. In new construction, good solar shading design may also mean that the size of the air conditioning equipment can be reduced. In some cases, the savings in equipment costs will offset the cost of the shading devices.

5.0.1 Window Terminology

Windows have four principle performance characteristics: solar heat gain coefficient (SHGC), visible light transmittance (VLT), Ufactor and efficacy. Other important window terminology includes window-wall ratio (WWR) and projection factor (PF).

Solar heat gain coefficient (SHGC) is the ratio of solar heat gain entering a space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which then enters the space through reradiation, conduction or convection. A window that allows no solar gain would have an SHGC of zero, while perfectly transmissive glazing would have an SHGC of 1.0 (these extremes are both theoretical and are not possible in the real world)..

Visible light transmittance (VLT) is the ratio of visible light transmitted through the glazing to the total amount of light that strikes the glass. Single-pane clear glass has a VLT of about 0.9, while highly reflective glass can have a VLT as low as 0.05. In general, VLT should be as high as possible to allow more daylight inside, as long as it does not create glare or other visibility problems.

U-factor measures the heat flow through a window assembly due to the temperature difference between the inside and outside (U-factor = 1/R-value). The lower the U-factor, the lower the rate of heat loss and of heating energy consumption. However, U-factor is more critical in areas that have very hot summers or cold winters.

Efficacy is the ratio of VLT to SHGC. The higher the efficacy, the better the fenestration product is at allowing daylight in and reducing solar gain.

Glazing materials with a high efficacy are known as **"spectrally selective"** because they selectively transmit radiation in the visible portion of the spectrum while blocking solar radiation in the ultraviolet and infrared spectra. Spectrally selective products typically have a VLT to SHGC ratio greater than 1.3.

Window-wall ratio (WWR) is the ratio of window area to the exterior wall area.

Projection factor (PF) is the ratio of an overhang's horizontal projection to the vertical distance from the windowsill to the bottom of the overhang. The overhang projection is measured as the perpendicular distance from the window surface to the overhang's outside edge.

5.0.2 Solar Control Glazing

In composite climate the most important glazing characteristic for windows is low solar heat gain coefficient. A low SHGC can be provided through several different technologies:

Heat-absorbing tints. These tints are available in a range of colors. Some tints, typically blue or green, offer better visible light transmittance while providing equal or better solar control than gray or bronze tints. Consider using these blue or green tints in daylighting designs. All heat-absorbing tints get hot in direct sunlight, which is an important concern in buildings where occupants work close to windows.

Heat-reflecting coatings (including low-e). Several types of coatings are available. Some appear mirror like, while others are designed to reflect as much heat as possible while also appearing as clear as possible. The latter type of coating is called "spectrally selective" and is a better choice for simultaneously providing daylight and solar control. Some — but not all — of these heat-reflecting coatings will have low-emissivity (low-e) properties. Low-e coatings reduce the radiant heat transfer between two surfaces, for example from one pane to the other in a double-pane glazing. Low-e coatings improve a window's insulation value (lower U-factor), but in composite climate, SHGC is a much more important concern.

Therefore, when specifying a heat-reflecting window, it's not adequate to specify a low-e window; **it's critical to specify the desired SHGC and VLT.**
Be aware that not all low-e windows have a low SHGC. There are several types of low-e coatings

Often these heat-reflecting coatings are applied to one of the surfaces facing the air gap in a double-pane window. This is necessary to protect the coating from scratches that might occur if it were exposed. double-pane windows are necessary if you want the performance benefits of higher performance coatings. .

Laminates. Either heat-absorbing or heat-reflecting plastic film can be sandwiched between two sheets of glass to create a single pane. To provide further solar control, heat-absorbing glass can be used.

Retrofit films. Plastic films similar to those used to create laminated glass can be applied to the surface of the glass. This should be considered only as a retrofit measure because the exposed film is not as durable as glass.

Glass Type(a)	**SHGC**	**VLT**	**U factor**	**Efficacy**
Single Clear	0.82	0.88	1.09	1.08
Single High-Performance Tinted (green or blue tint)	0.50	0.66	1.09	1.32
Single Reflective (medium reflectance)	0.55	0.39	1.09	0.71

Single Reflective (high reflectance)	0.25	0.13	0.91	0.52
High-Performance Laminated Clear	0.45	0.71	1.06	1.58
High-Performance Laminated Clear Low-e	0.38	0.63	0.71	1.66
Glass Type(a)	**SHGC**	**VLT**	**U factor**	**Efficacy**
Double Clear	0.70	0.78	0.48	1.12
Double Tinted	0.47	0.38	0.48	0.81
Double High-Performance Tinted	0.38	0.58	0.48	1.55
Standard Double Clear Low-e(c) (lowest SHGC)	0.36	0.47	0.31	1.32
Standard Double High-Performance Tinted Low-e(c) (lowest SHGC)	0.22	0.35	0.31	1.63
Premium Double Clear Low-e(c) (highest efficacy)	0.38	0.70	0.31	1.87
Premium Double High-Performance Tinted Low-e(c) (highest efficacy)	0.27	0.53	0.31	2.00

Notes:

(a) All values are COG, based on 1/4-in. thick glass. Double-pane alternatives have 1/2-in. air gap.

(b) Relative cost column shows approximate incremental increase in cost compared to single-pane clear glass.

(c) Some manufacturers offer many different types of low-e coatings, with a range of SHGC and VLT values. The four low-e glazings listed here represent two generic categories: "standard" refers to a low-e coating with very low solar heat transmission, while "premium" refers to a low-e coating with relatively low heat transmission but much higher light transmission (better efficacy).

Glass Type	Description	Advantages	Disadvantages
Single Clear	Single layer of glass. Recommended only for well-shaded windows.	Lack of tinting allows good color rendition.	Allows a lot of direct solar radiation into the space. Poor thermal performance (high SHGC).
Single Tinted.	Single layer of tinted glass (blue, green, gray, bronze, etc.). Green and blue are preferable to gray and bronze. Not recommended for unshaded windows	Relatively inexpensive. Can improve visual comfort by reducing glare. Green and blue tints have relatively high efficacy	Gray and bronze tints have relatively low efficacy, so they reduce visible light more than they reduce overall heat gain. Tinted glazing is less desirable if it's important that views are not altered by tinting. Tinted glazing gets hot when the sun strikes it so may be uncomfortable for people next to it.
Single High-Performance Tinted	Some manufacturers offer higher performance blue or green tinted glazing. These are similar to standard single-pane tinted but the tint transmits more visible light and less visible heat. These highperformance tints usually range from light green to	Relatively high efficacy. Lower cooling load impact and Relatively affordable price. More expensive than standard single tinted but much less expensive than double-pane low-e glass.	Views are not rendered in true color, although the tinting is lighter than with standard singlepane tinted. SHGC still somewhat higher than the best performing glazings.

	light blue.		
Single Reflective (medium reflect-ance)	Special coating reflects much direct solar energy.	Relatively low SHGC	Mirrorlike appearance causes excessive glare outside. Low efficacy. Low VLT makes it a poor choice for view windows or daylighting
Single Reflective (high reflectance)	Similar to single reflective–medium but reflects a higher percent of incident	Lower SHGC than single reflective–medium solar radiation.	Mirrorlike appearance causes excessive glare outside. Very low efficacy and VLT. The light-to heat-gain ratio makes it one of the worst choices for daylighting.
High-Performance Laminated Clear	Special heatreflecting plastic film sandwiched between two sheets of clear glass to create a single pane.	High efficacy. Good daylighting performance. Can provide similar performance to high performance Tinted glass without the green or blue color cast. Provides the Typical penetration resistance of standard laminated glass, with better energy performance.	Relatively expensive. Laminated glass may require more careful handling during installation to prevent cracking.
High performance Laminated Clear Low-e	Similar to highperformance laminated clear glazing but one of the panes of glass has a spectrally selective low-e coating.	Even higher efficacy and lower SHGC than the non-low-e laminated alternative (above). Very good daylighting performance.	Relatively expensive. Laminated glass may require more careful handling during installation to prevent cracking
Double	Two sheets of clear	Has lower U-	The performance

Clear	glass separated by a gap filled with air or gas (such as argon). Depth of gap typically varies from 1/8 in. to 1/2 in.	factor and somewhat lower SHGC than singlepane clear	improvements over single-pane clear glazing are not worth the cost of adding an extra pane of glass.
Double Tinted	Similar to double clear glazing, with one pane (typically the exterior) tinted.	Lower SHGC than double clear glazing.	Worse efficacy than double clear glazing
Double High-Performance Tinted	High-performance tint on outer layer of glass.	High efficacy. Typically cheaper than double low-e glazing.	The extra expense of adding a second pane isn't worth the improvement in performance.
Standard Double Clear Low-e(a) (lowest SHGC)	Double-pane glazing with a low-e coating typically on the inner surface of the outer pane. Premium low-e (see below) is typically a better choice because of its enhanced daylighting performance. But for larger glass areas, standard low-e would be a better choice than the highest efficacy low-e coating because higher VLT wouldn't be as important.	Low SHGC and high VLT	Similar SHGC but lower efficacy than premium low-e glazing. Expensive. Sacrifices some efficacy
Standard Double High Performance Tinted Low-e(a) (lowest	Outer pane has highperformance tint and low-e coating on inner surface; separated from inner	Very low SHGC. Relatively good efficacy	May not be very cost Effective

SHGC)	clear glass pane with 1/2-in. air gap. Different thicknesses of glass and air gap are available.		
Premium Double Clear Low-e(a) (highest efficacy)	Same type of glass as standard double clear low-e (lowest SHGC), but with better thermal and daylighting performance.	Excellent efficacy. In general, best Daylighting performance	For large glass areas, the standard double-clear low-e might be a better choice because it has lower SHGC and high enough VLT.
Premium Double High Performance Tinted Low-e(a) (highest efficacy)	Same type of glass as standard double high performance	Tinted low-e, but with better thermal and daylighting performance	Excellent efficacy. In general, best daylighting performance. For large glass areas, the standard double highperformance tinted low-e might be a better choice because it has lower SHGC and high enough VLT

Notes:

(a) Some manufacturers offer many different types of low-e coatings, with a range of SHGC and VLT values. The four low-e glazings listed here represent two generic categories: "standard" refers to a low-e coating with very low solar heat transmission; while "premium" refers to a low-e coating with relatively low heat transmission but much higher light transmission (better efficacy).

General Principles of Window Design

To achieve high-performance window design, choose a combination of building orientation, shading, window area and glass type that maximizes daylighting while minimizing heat gain.

Orientation: Proper orientation is the most important strategy.
Whenever possible, limit the amount of window area on the east and west facades. Sunlight is easier to control on the north and south sides of a building.

Exterior Shading: A designer's first choice should be to minimize the amount of direct solar radiation that reaches the windows. If direct sunlight can be kept off the windows, then inexpensive clear or lightly tinted glass can be used. Overhangs are typically the best choice for keeping sunlight off the windows, and are especially effective on the north and south facades. The combination of overhangs and vertical fins can nearly eliminate direct solar gain for most of the year. See the Exterior Overhangs and Side Fins Guideline for details. Operable exterior shades are another option. They are particularly useful where it's difficult to provide complete shading with overhangs or fins. The operable shades could be automatically controlled in response to the sun's position or manually adjusted to shade the window at different times of the year.

Interior shading: Interior shades such as blinds and drapes provide some reduction in heat gain, but are not nearly as effective as exterior shades. Consider using interior shades on east- and west-facing windows where it's difficult to provide exterior shading throughout the day. See the Design Details section later in this General Principles section for more information about interior shading.

Combination of size and glazing type: There's no single best combination of window size and glazing type. The optimum design will allow enough light transmission to provide good daylighting and adequate views while admitting no more solar heat than necessary. The energy, peak cooling load and lifecycle cost graphs in this chapter can be used to evaluate designs employing various window sizes and glass types.

Glazing performance: If it is not possible to completely shade the windows from direct sunlight, then solar-control glazing should be specified. In Composite climate, select glazing materials with a low solar heat gain coefficient and a high visible light transmittance. Consider "spectrally selective" low-emissivity (low-e) products and blue or green tints that combine low SHGC with high VLT. Remember that in Composite climate, high SHGC is much more important than low U-factor.

Well-designed, energy-efficient windows can reduce the overall building cooling loads. They can also deliver enough dependable daylight to reduce electric lighting loads, if manual or automatic controls are used to turn off the electric lights when not needed.

Windows are essential in most commercial buildings (except in spaces requiring visual privacy) to provide relaxing views and information about exterior natural conditions, to allow people outside of a space to view and connect wi[illegible] daylight. They should be planned for in the schematic design phase.

Exterior Overhangs and Side Fins

Use exterior shading devices such as overhangs and side fins to block the direct penetration of sun into a space and to reduce heat gain.

- Exterior shading is most effective on the south side of a building.

- For south facades, horizontal overhangs work better than fins, while east and west facades can use horizontal overhangs, vertical fins or a combination of the two. On the north side, a small overhang combined with sidefins is very effective.

- Exterior shading makes more of a difference when used with clear glass; it has much less of an impact when used with solar-control glazing.

- Consider the daylighting impacts of exterior shading. Elements such as lightshelves can provide shading while also improving daylighting performance. See the Daylighting Guidelines for details on lightshelf design.

Horizontal overhangs, vertical side fins or a combination of these two devices are recommended on the outside of buildings to shade windows and block the direct penetration of sun into a space.

Other exterior shading options such as louvers may also be used.
While both exterior and interior shading devices help reduce glare and improve visual comfort for the people inside a building, exterior shading devices offer the additional advantage of stopping heat gain before it enters the building.

Exterior shading devices enhance visual comfort by reducing glare inside a space. If properly designed, they can significantly reduce the cooling load by blocking the sun's heat from entering the building, while still allowing adequate daylight penetration.

Design details

Exterior window shades are almost always desirable. However, it is difficult to shade east and west orientations from the early morning and late afternoon sun. In some cases, it may be preferable to use a combination of exterior and interior shades. If exterior shading devices are used with high-performance glazing, interior shades are usually not needed. Interior shades are more effective with glazing types that have a relatively high SHGC.

Cut-off angle: The cut-off angle should be designed to minimize or completely eliminate direct solar penetration. The cut-off angle is the angle formed by a straight line from the edge of the overhang to the bottom of the window (or the inner edge of the next lower overhang in the case of multiple overhangs) and the horizontal plane. In the case of side fins, it is the angle formed by the straight line connecting the outer edge of the fin to the opposite edge of the window (or the inner edge of the next fin in the case of multiple fins) and the normal to the window.

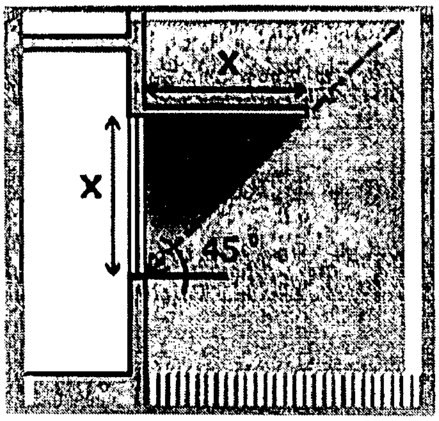


Fig: (5.0.2a) Cut Off Angle

Sizing Overhangs and Fins for Ample Shading:

To reduce solar gain and eliminate glare, windows should ideally be shaded during all daylight hours. However, trying to accomplish this can lead to some impractical overhang and fin designs when the sun is low in the sky, particularly for east and west orientations during the early morning and late afternoon.

Fig: (5.0.2b)
The following figures provide information on the recommended size of overhangs and fins to completely shade windows during the periods indicated in the solar path diagram. Different sizes for overhangs and fins, or a combination of exterior and interior shades, may be appropriate if the design criteria are different from the assumptions used here.

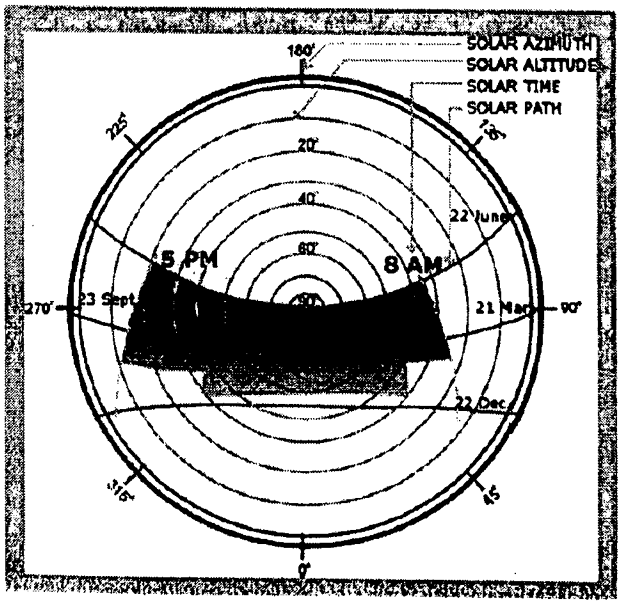


Fig: (5.0.2b)

5.1.1 SOUTHWEST WINDOWS

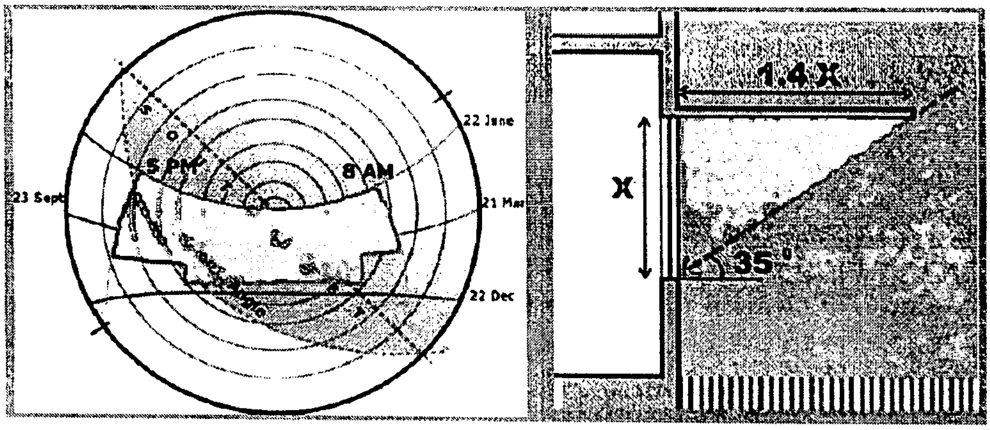


Fig: (5.1.1a) **Left:** An overhang with a 35-degree cut-off angle will shade a southwest window from 8 AM to 4 PM in summer, but only until about 2 PM in winter.

Right: Section through overhang with 35-degree cutoff angle.

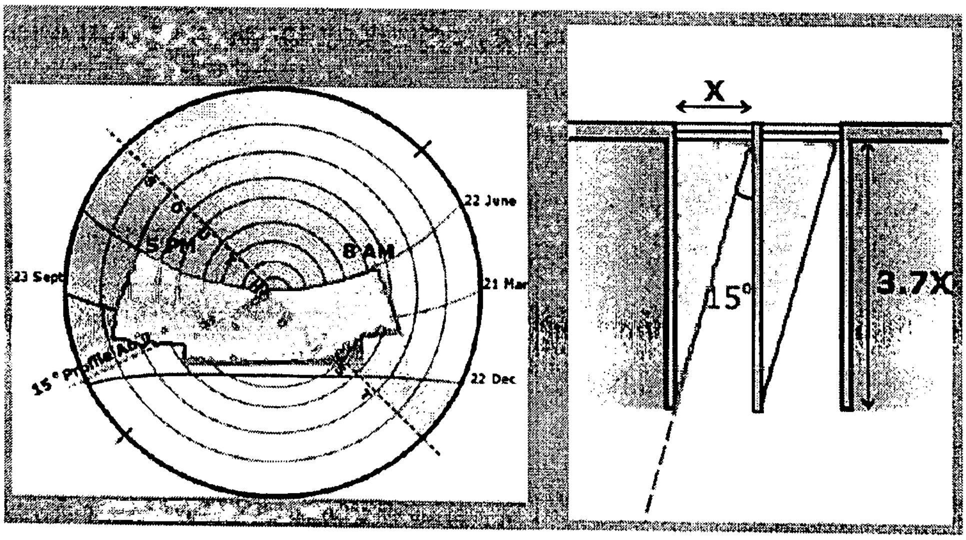


Fig: (5.1.1b)
Left: Vertical fins with a 15-degree cut-off angle will shade southwest window from 8 AM to 4 PM in summer except for a few hours around midday, and not provide any shade through much of the winter.

Right: Plan view showing vertical fin with 15-degree cut-off angle

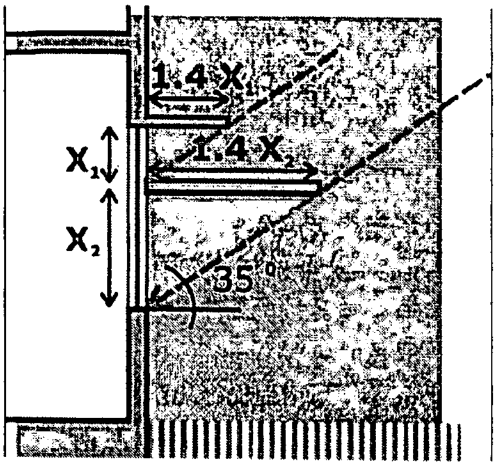


Fig: (5.1.1c) **Section through southwest window with multiple overhangs (35- degree cut-off angle).**

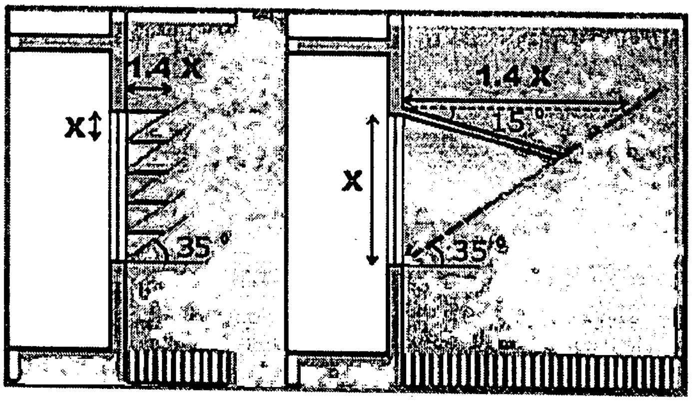


Fig: (5.1.1d) **Alternative overhang sections showing multiple louvers (left) and sloped overhang (right). Note that the cut-off angle remains unchanged.**

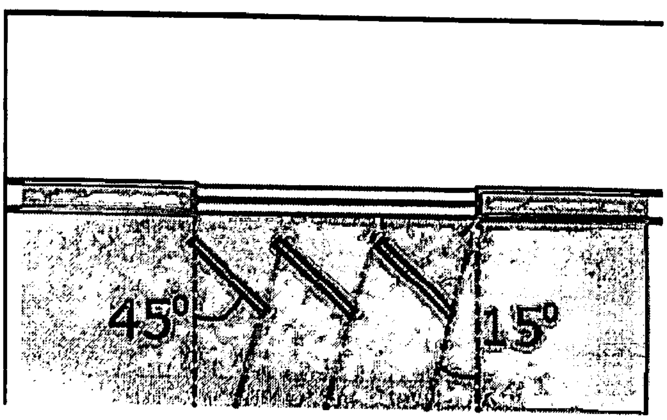


Fig: (5.1.1e) **Plan view showing alternative design for vertical fins.**

5.1.2NORTH WINDOWS

Side fins can provide shading most of the time, except for the middle of the day in the summer. To provide shading during normal business hours, the depth of the fin should be at least 0.25 times the width of the window it is shading, or have a cutoff angle of 75 degrees.

A small overhang (with a cut-off angle of 85 degrees or with depth equivalent to 10% of the window height) in addition to side fins with a cut-off angle of 75 degrees will provide complete shading during normal business hours.

If the window does not face true north, then larger shading devices are necessary. North windows are very easy to shade, so it's possible to have relatively large expanses of north-facing glass without significantly increasing solar heat gain.

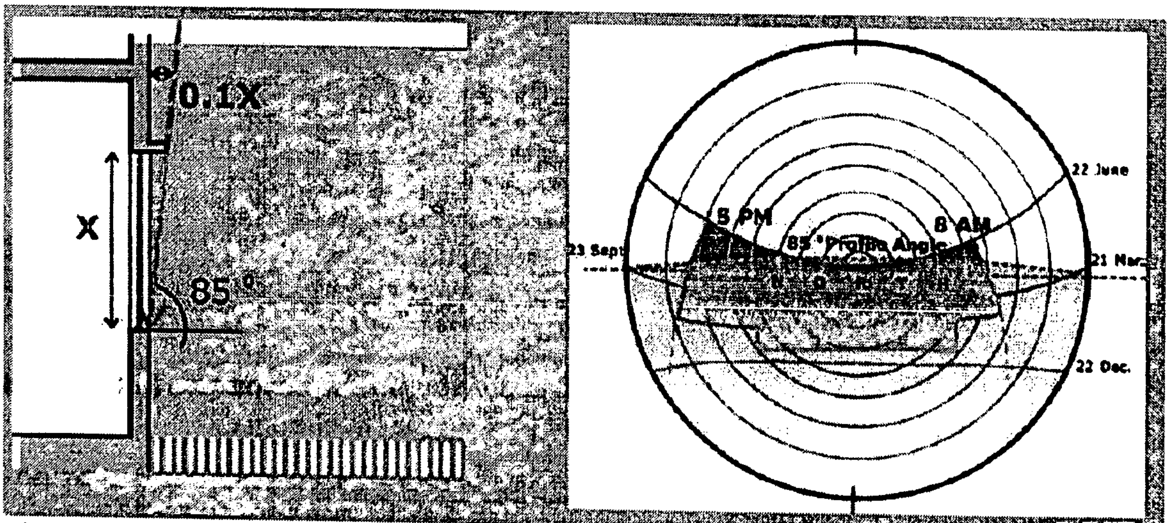


Fig: (5.1.2a) **Overhang with 85-degree cut-off angle will shade north window from8 AM to 5 PM at all desired times except during early morning and late afternoon in the peak summer months.**

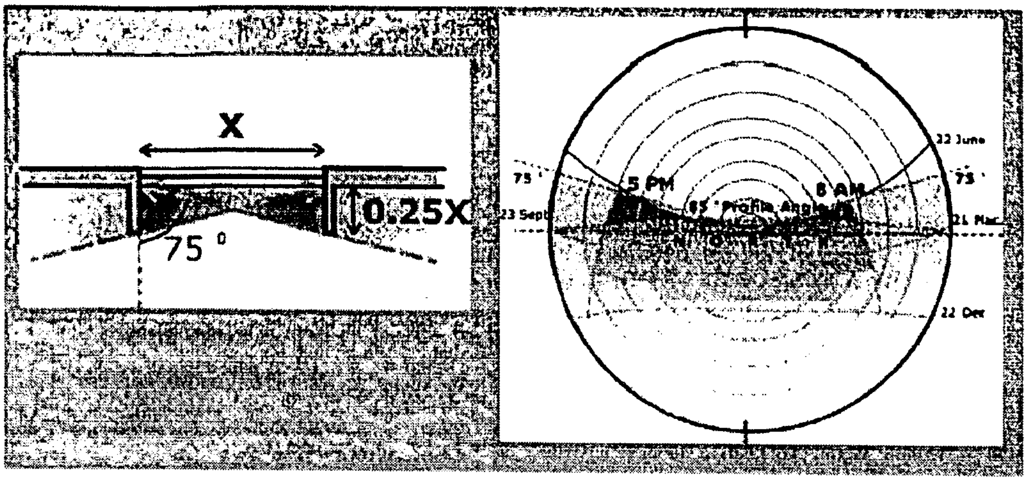


Fig: (5.1.2b) **Combination of overhangs (85-degree cut-off) and side fins (75- degree cut-off) will provide complete shading from 8 AM to 5 PM during all months.**

5.1.3 NORTHEAST WINDOWS

Either side fins or overhangs can provide nearly complete shading from 8 AM to 5 PM on northeast-facing windows.

If overhangs are used, the overhang should have a cut-off angle of 35 degrees. The overhang depth recommended to completely shade the window in winter should be at least 1.4 times the window height.

Alternatively, overhangs can be sloped away from the wall or a series of short louvers can be used.

If fins are desired, the fin should have a cut-off angle of 30 degrees. A more practical approach would be to tilt the fins away from the normal to the window

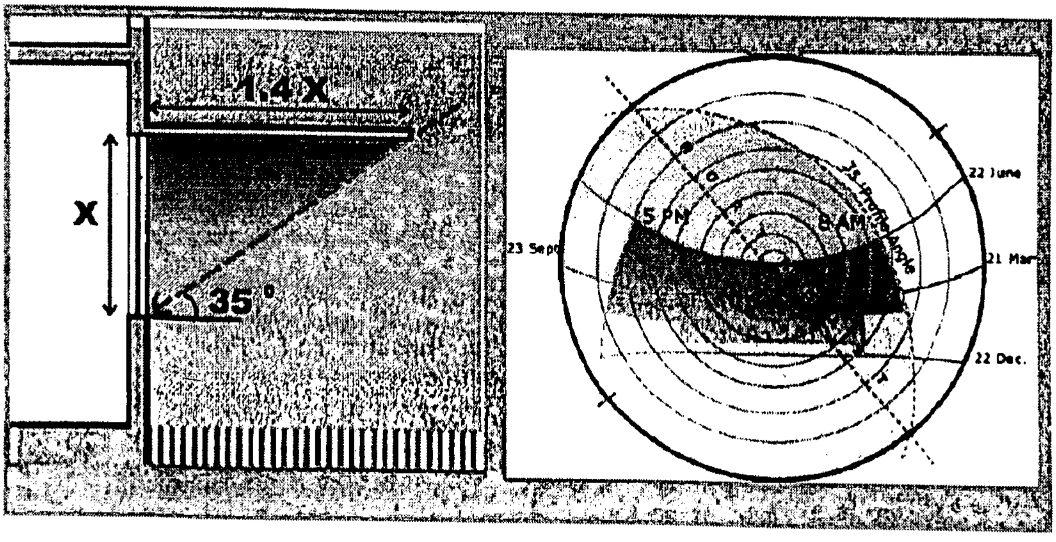


Fig: (5.1.3) **An overhang with a 35-degree cut-off angle will shade a northeast window from 8 AM to 5 PM during all months**

5.1.4 EAST WINDOWS

Overhangs are the best option for east-facing windows, but the overhang must be very deep to block the sun from 8 AM to 5 PM in winter. The overhang should have a cut-off angle of 30 degrees. The overhang depth recommended to completely shade the window in winter should be at least 1.7 times the window height.

Side fins will not be very effective.

Consider interior shades in addition to an overhang if the overhang cannot be as deep as the ideal recommended size.

Alternatively, overhangs can be sloped away from the wall or a series of short louvers can be use,

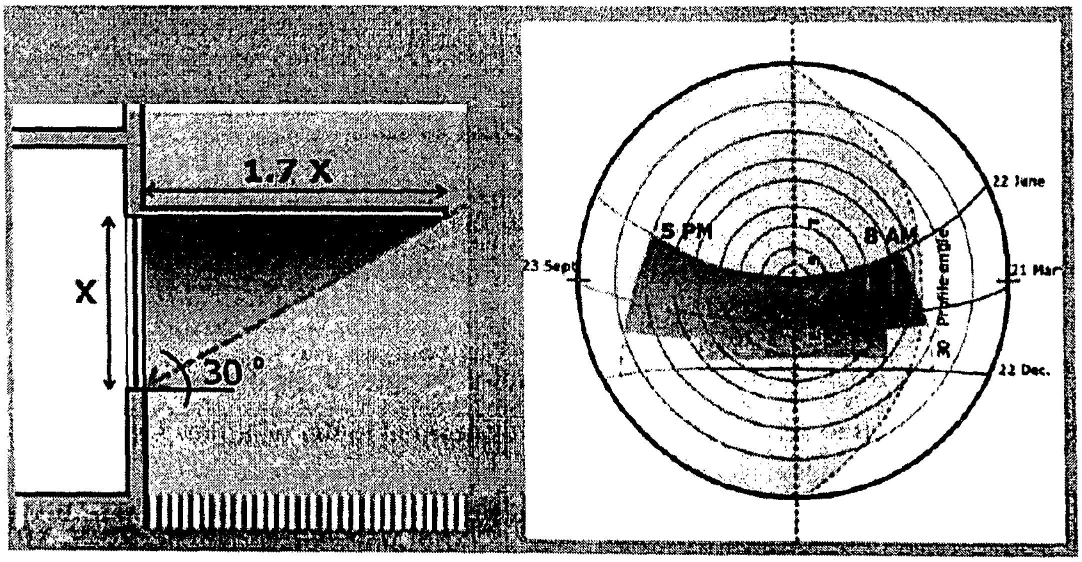


Fig: (5.1.4) **Overhang with 30- degree cut-off angle will shade an east window from 8 AM to 5 PM.**

5.1.5 SOUTHEAST WINDOWS

An overhang will provide nearly complete shading, but it must be fairly deep (1.7 times the window height).

If such a large shading device isn't feasible, consider also using interior shades or rotate the window orientation to face true south.

Alternatively, overhangs can be sloped away from the wall, or a series of short louvers can be used

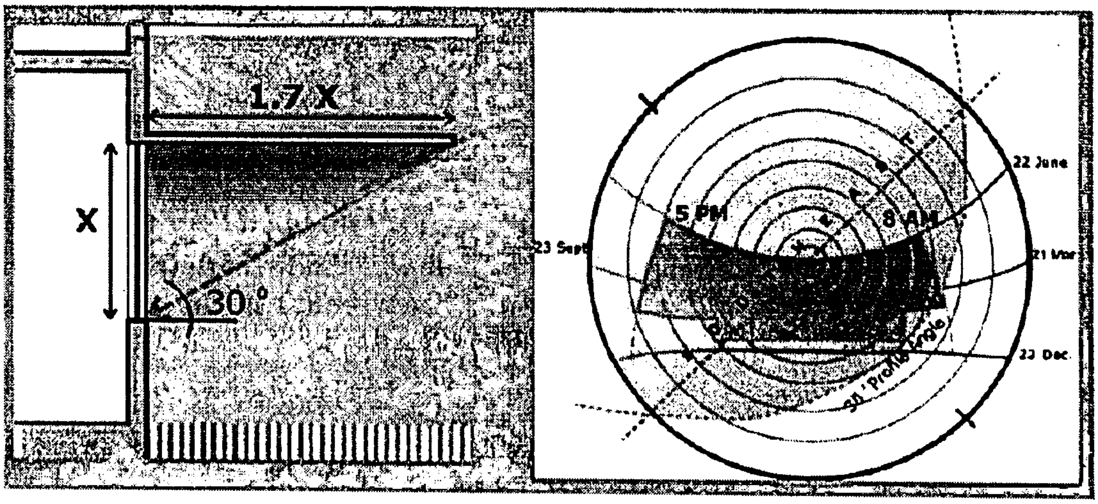


Fig: (5.1.5) **Overhang with 30-degree cut-off angle will shade southeast window from 8AM to 5 PM from March to September. It will not provide shade for a couple of hours in the morning during winter.**

5.1.6 SOUTH WINDOWS

Overhangs are the best shading option for south-facing windows, and they don't need to be excessively large. An overhang with a depth equal to the window height (or cut-off angle of 45 degrees) is sufficient to provide complete shading for the periods shown in the shading mask diagram.

Side fins are not very useful on south-facing windows because they will provide shading only in the early morning and late afternoon.

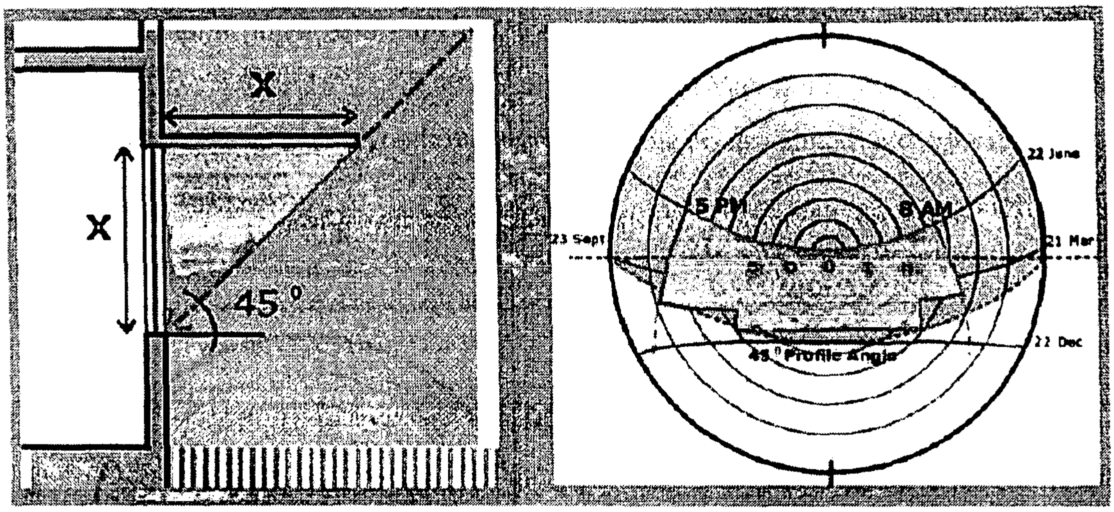


Fig: (5.1.6) **Overhang with 45-degree cut-offangle will shade south window from 8AM to 5 PM during all desired times except for a few hours in the morning and late afternoon in winter.**

5.1.7 West Windows

West windows are the most difficult to shade. The overhangs need to be very deep (4 times the window height) to be effective. This may not be desirable for both aesthetic and practical reasons. Where views are not a priority, it's best to avoid west-facing windows.

If west windows are unavoidable, then choose solar-control glazing and/or interior shades in addition to smaller sloped overhangs (or multiple louvers)

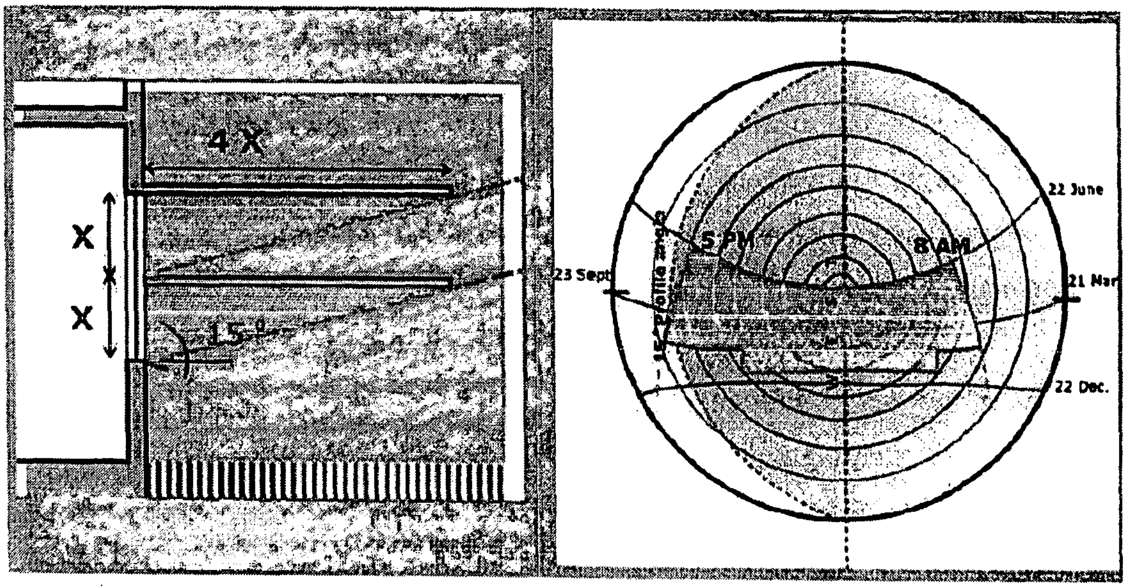


Fig: (5.1.7) **Large overhangs with a 15-degree cut-off angle will shade west windows**

CASE STUDIES

THE CONDE NAST BUILDING AT FOUR TIMES SQUARE

THE PLAZA AT PPL CENTER

BUILDING RESEARCH ESTABLISHMENT

GSW HEADQUARTERS

INLAND REVENUE CENTRE

PEDA OFFICE COMPLEX, CHANDIGARH

TRANSPORT CORPORATION OF INDIA

CHAPTER 6

Two 200 kW fuel cells are located in the 4th floor outside air plenum with a separate exhaust. The building is using the electricity generated from these two fuel cells to cover almost 100% of its base load late at night and approximately 5% of the building's electrical needs during the day.

ENERGY

Green Strategies

- **Daylighting for Energy Efficiency**
  - Use large exterior windows and high ceilings to increase daylighting
- **Cooling Systems**
  - Use accurate simulation tools to design cooling system
  - Use a gas-fired absorption chiller/heater
  - Commission the HVAC system

- **Light Levels**
  - Design for no more than 1.0 watts/square foot

- **Photovoltaics**
  - Use building-integrated photovoltaics (PV) to generate electricity on-site

- **Light Sources**
  - Use LED or other super-efficient exit signs

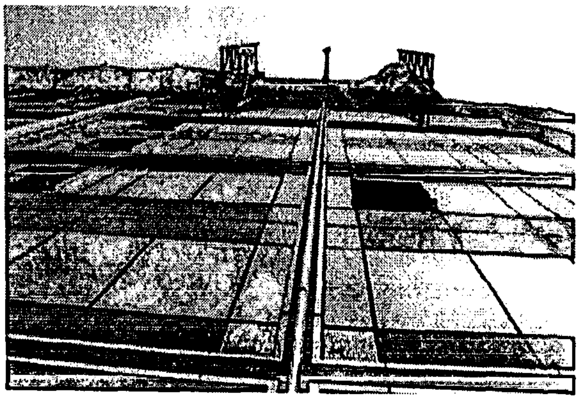


Fig (6.1c): facade

- **High-performance Windows and Doors**
  - Use windows with a whole-unit U-factor less than 0.32 (greater than R-3.0)
- **Ventilation Systems**
  - Draw supply air from favorable microclimates around the building

    - Use demand-controlled ventilation
- **Lighting Controls**
    - Use occupancy sensors
- **HVAC Controls and Zoning**
    - Use direct digital control (DDC) systems
    - Use variable-volume air distribution systems

Indoor Environment

Tenants are provided with better-than-code air delivery: outside air is delivered at 0.20 cfm/ft2 with an additional 0.50 cfm available if desired. The system has the capacity to purge any 3 floors simultaneously with 100% outside air ducted into the building at high elevations, avoiding street exhaust.

Central monitoring of air quality is accomplished through a network of tubes in the plenum. Periodic IAQ monitoring and analysis of tenant spaces will establish baseline information and test IAQ over time. Carbon dioxide and, in some cases, carbon monoxide monitoring is provided on an ongoing basis.

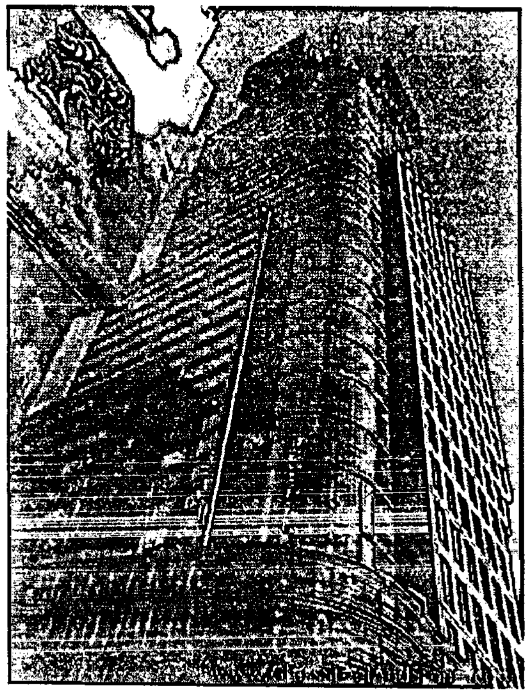


Fig (6.1d): facade

The project's exterior skin is designed for up to 30% relative humidity in the winter without risk of problematic condensation formation.

Tenants are required by NYC code to connect smoking rooms to the general exhaust shaft in the building's core. Tenants are encouraged to connect all private offices in which smoking is allowed to this shaft. These dedicated exhaust shafts may also be used for copy rooms or high-VOC-content rooms.

A selection of materials with low to no VOCs was specified for the base building. The Durst Organization is committed to using the most environmentally sound cleaning materials and procedures. All cleaning solutions and materials will be nontoxic.

Tenants were given the option to link their air distribution system to the main controls to take advantage of the balancing of air supply, IAQ purge capability, humidity control, etc.

Green Strategies

Entry of Pollutants

Locate outdoor air intakes away from pollution sources

Keep positive pressure in the building

Visual Comfort and The Building Envelope

Choose interior and exterior glazing to maximize daylight transmission

Visual Comfort and Interior Design

Design open floor plans to allow exterior daylight to penetrate to the interior

Place primarily unoccupied spaces away from daylight sources

Direct Exhaust from High-source Locations

Provide local exhaust ventilation for rooms with high-emitting sources

Reduction of Indoor Pollutants

Use only very low or no-VOC paints

Materials & Resources

Recycled and recyclable materials were used in the construction of Four Times Square. Tenants are encouraged to use materials with high recycled content as well as easily recyclable materials. Two recycling chutes are located on each floor in the service area of the core: one for paper and one for wet trash. Each chute is connected to an appropriate container in the loading area.

Existing footings at the corner of 42nd Street and Broadway were reused. The amount of needed steel was reduced by the introduction of concrete as a structural element, the rooftop HVAC units, and the use of "hat trusses."

Tenants are encouraged to use light-gauge metal framing and gypsum board with as much recycled content as possible; to use modular wiring assemblies to facilitate easy relocation of power and communication cabling; to provide for effective and efficient waste handling of fluorescent lamps and ballasts; to consider open office furniture systems for flexibility; and to specify ceiling tiles with 100% post-industrial recycled material, with exposed spline to minimize damage during alterations, and that can be easily recycled.

Green Products Used

- Access Flooring Systems
- Carpet Recycling
- Cork Flooring
- Fabric Wall Covering
- Lighting Control Systems
- Low-VOC, Materials-Efficient Office Furniture
- Recycled-Aluminum Ceiling
- Recycling System for Multistory Buildings
- Zero-VOC Acrylic Latex Interior Paint

CASE STUDY II

6.2 The Plaza at PPL Center

- Location: Allentown, PA
- Building type(s): Commercial office, Retail
- New construction
- 280,000 sq. feet (26,000 sq. meters)
- Project scope: 8-story building

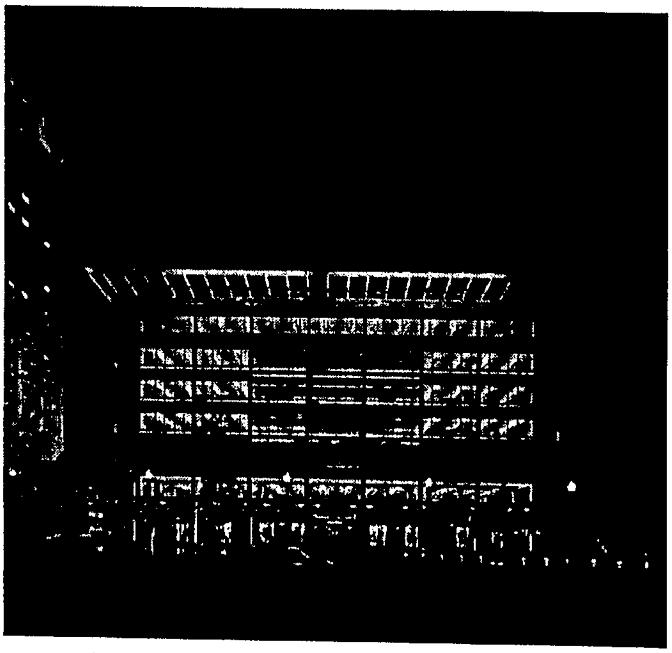


Fig (6.2a): Night View

- Urban setting
- Completed July 2003
- Rating: U.S. Green Building Council LEED-NC, v2--Level: Gold (40 points)

The Plaza at PPL Center, an urban office building, was designed and built in 18 months on a suburban real-estate budget. Located in the center of Allentown, Pennsylvania, this eight-story building is the first new downtown office development in more than 25 years and represents a major commitment to the City by the building's tenant, the PPL Corporation, a regional energy company. While the PPL Corporation occupies most of the building, the owner, Liberty Property Trust, developed one floor as speculative office space, and the plaza level of the building includes retail storefronts.

Environmental Aspects

The highly transparent south façade animates the street scene and metaphorically opens to public view the activity inside.

A dramatic eight-story central glass atrium brings natural light deep into the core of the building, while extensive perimeter glazing provides abundant daylight to, and views from, all building spaces.

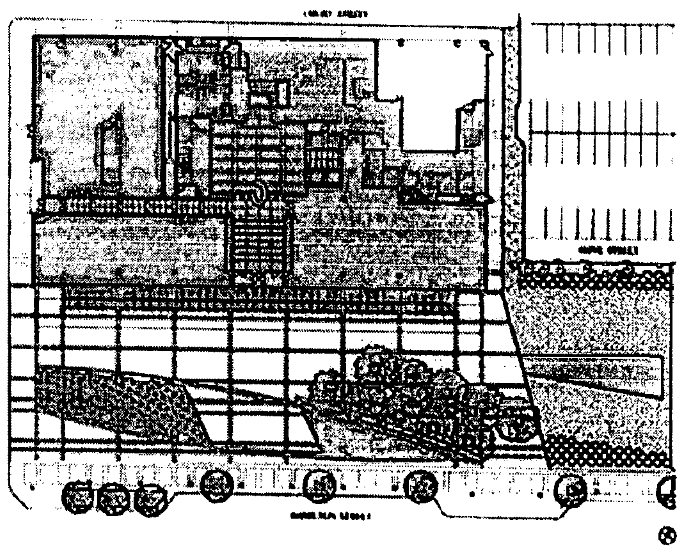


Fig (6.2b): Site Plan

Carbon dioxide sensors insure that fresh air is supplied to each building area as needed,

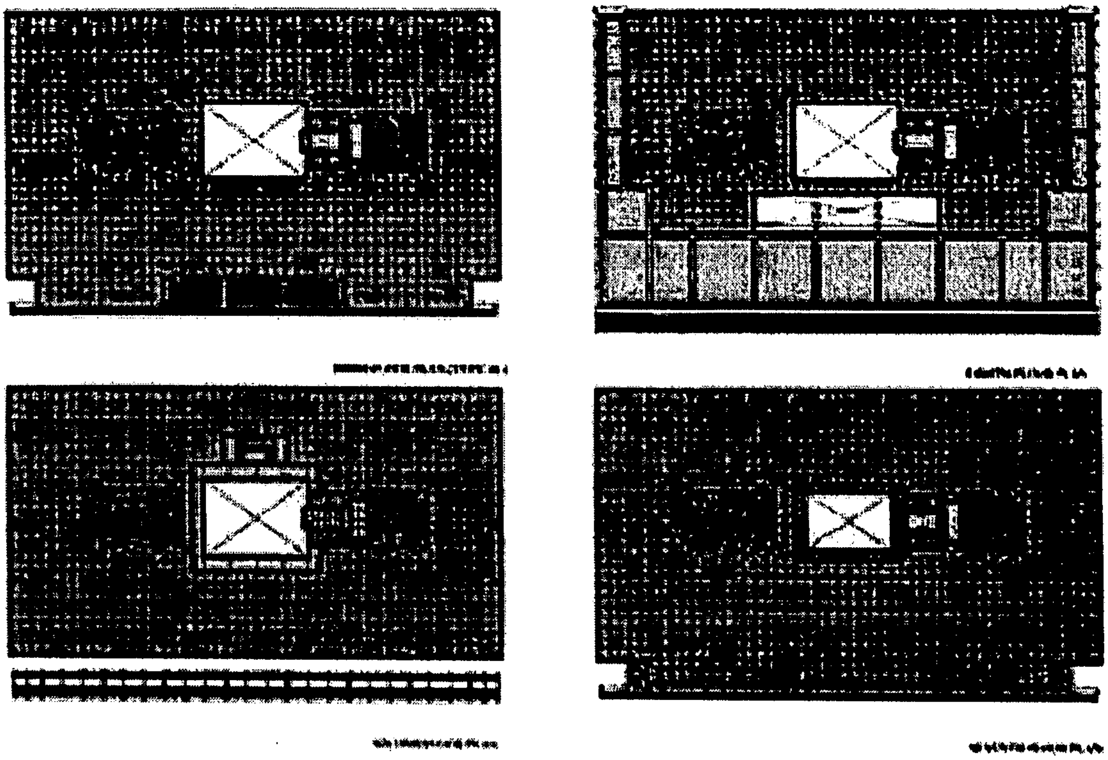


Fig (6.2c): Floor Plans

and zero-emitting or low-VOC paints, adhesives, sealants, carpet, and composite wood were used throughout.

Two two-story, plant-filled winter gardens along the south façade of the building provide unique workspaces, bring daylight deeper into the floor plates, control glare, and improve indoor air quality.

The design integrates environmental moderation and control into the fabric of the building with high-performance glazing, and a vegetated roof.

The building's energy demand is more than 30% lower than code requirements, its water use is 45% below code requirements, and its construction materials contain over 20% recycled content.

Indoor Environment

Sensors monitor carbon dioxide levels within the Plaza, ensuring that fresh air is supplied directly to each building area as needed. Interior finish materials including paints, carpets, adhesives, sealants, and composite wood paneling were selected for low emission of VOCs, urea-formaldehyde, and other contaminants, and all building spaces were flushed with 100% outdoor air for at least two weeks before occupancy

Fig (6.2d): Double Facade

Abundant natural light enters all areas of the building through extensive glazing on all facades and through the central atrium. The interior of the building is organized such that all office areas maintain direct line-of-sight views out of the building. Two-story plant-filled winter gardens along the south façade of the building provide unique workspaces for the occupants, bring daylight deeper into the building plan, control glare, and improve indoor air quality. Open-plan building areas have zone temperature, light, and daylight controls, all accessible to occupants, while personal offices have individual temperature and light controls.

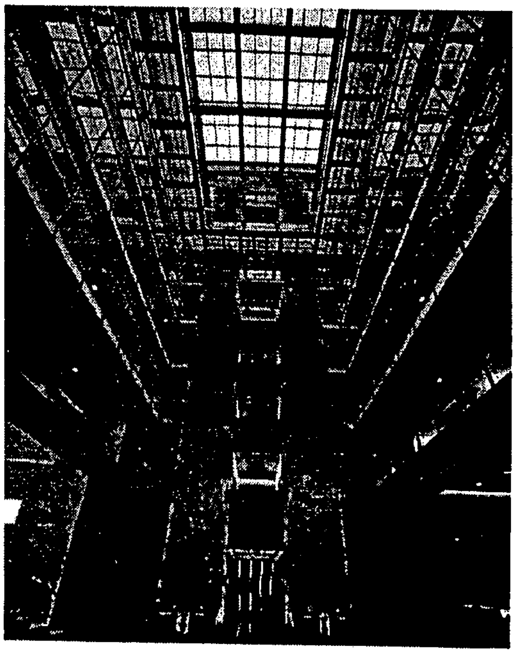


Fig (6.2e): Atrium

Green Strategies

- **Thermal Comfort**

Use glazing with a low Solar Heat Gain Coefficient Provide occupants with the means to control temperature in their area

- **Visual Comfort and The Building Envelope**

Choose interior and exterior glazing to maximize daylight transmission

- **Visual Comfort and Interior Design**

Design open floor plans to allow exterior daylight to penetrate to the interior

- **Ventilation and Filtration Systems**

Design ventilation system to exchange both heat and humidity between incoming and outgoing air

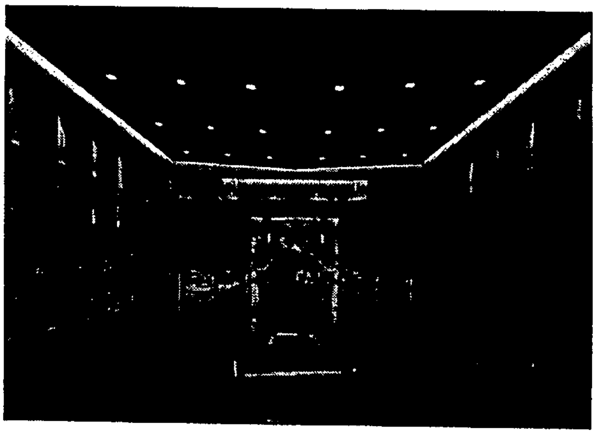


Fig (6.2f): Main lobby

- **Elimination of Indoor Pollutants**

Use finishes that are easy to clean using mild surfactants and water

- **Reduction of Indoor Pollutants**

Use only very low or no-VOC paints

Avoid wood products made with urea-formaldehyde binder

Energy

The Plaza at PPL Center is an energy efficient building, designed to exceed the ASHRAE 90.1-1999 energy requirements by more than 30%. During the first nine months of operation, energy data show that the building (at 85% occupancy) used only 70% of the energy predicted, which is roughly equivalent to exceeding ASHRAE requirements overall by 50%.

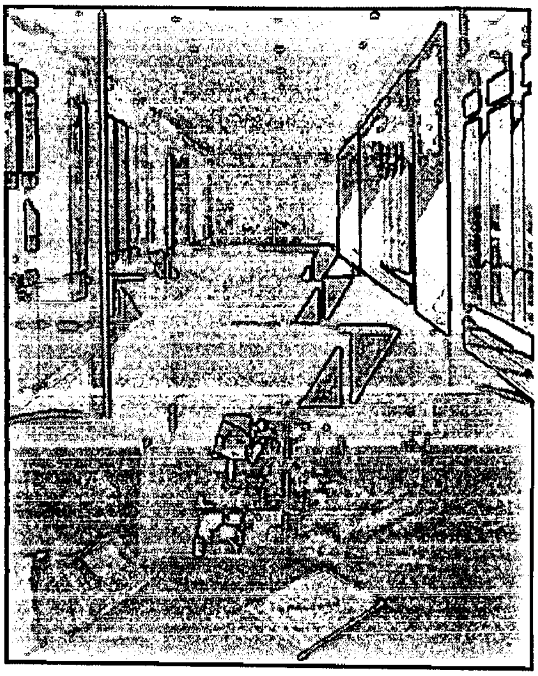


Fig (6.2g): Day lighting

Energy efficiency begins with the building envelope, where brises-soleils and canopies shade the south façade of the building, and high-performance glazing, walls, and roofs reduce conductive gains and losses. Abundant natural light allows lighting controls to reduce lighting energy more than 30% during the day, while occupancy sensors further reduce lighting energy in support rooms without daylight. HVAC systems further contribute to energy efficiency: an enthalpy wheel recovers heat and humidity from exhaust air to precondition incoming ventilation air;

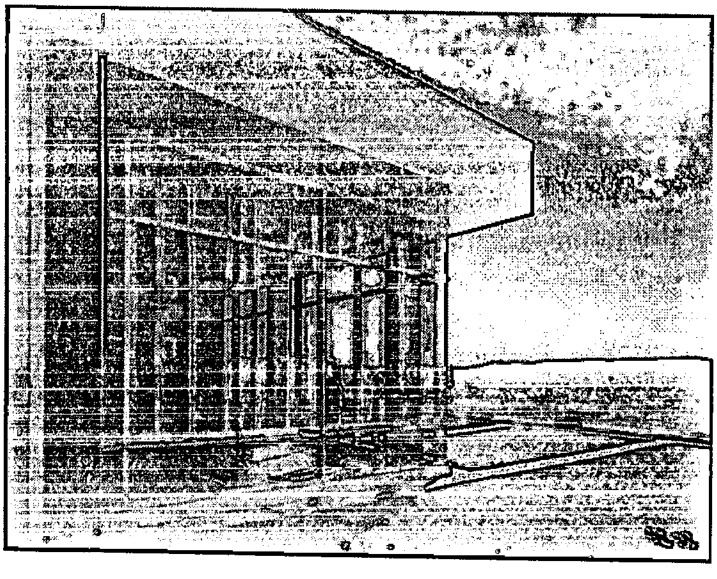


Fig (6.2h): Terrace Garden

carbon dioxide sensors control the flow of outdoor air directly to spaces where it is needed; an ice-storage system allows small chillers to run only at peak efficiency, and smart controls carefully regulate building system operation.

Energy Security

Peak energy loads are reduced in this building by two means. The overall demand is reduced through architectural design measures, such as external solar shading, that reduce peak conditioning energy loads, and through advanced building controls, which reduce electrical demand through means like daylight dimming and occupant sensing to turn off lights and HVAC when they are not needed.

Secondly, peak cooling demands are reduced significantly through the use of an ice-storage system that allows the building cooling system to make ice at night which is used during the day for cooling. In addition to reducing the peak energy demand, this also shifts the building's cooling-system use to nighttime, when systems operate more efficiently. This ice-storage system also allows the building cooling system to continue operation, in conjunction with an emergency power generator, when there is no grid-supplied power. The building is supplied with 100% Green-e certified power, which insures that at least 50% of the building's electricity has been generated sustainably.

Green Strategies

- **Solar Cooling Loads**
  - Shade south windows with exterior louvers, awnings, or trellises
  - Use south windows with a low SHGC

- **Daylighting for Energy Efficiency**
  - Use south-facing windows for daylighting
  - Use atrium for daylighting

- **Cooling Systems**
  - Use waterside economizers in chiller-based cooling systems

- **High-performance Windows and Doors**
  - Optimize energy performance of glazing systems

- **Ventilation Systems**
  - Use enthalpic heat-recovery ventilation

- **Lighting Controls**
  - Use occupancy sensors
  - Use dimming switches
  - Use small-scale switching zones

- **HVAC Controls and Zoning**
  - Provide sufficient sensors and control logic
  - Use thermostats with night setback
  - Use occupancy-based conditioning controls

Materials & Resources

The Plaza at PPL Center was designed to minimize its environmental footprint. More than 20% of the building materials (by cost) is composed of recycled materials such as structural steel and rebar, metal framing and panels, gypsum wallboard, carpet, and medium density fiberboard (MDF) wood. In addition, more than 85% of the wood-based materials are from sustainably managed forests certified in accordance with FSC guidelines. Approximately 25% of building materials (by cost) were manufactured within 500 miles of the building.

Interior finish materials were selected for low emissions of VOCs and other contaminants. High-traffic materials were selected for durability, environmentally friendly maintenance requirements, easy cleaning, and the ability to be completely recycled. Office operations emphasize recycling, and all floors have a recycling center located adjacent to the kitchen area.

Green Strategies

Reusable Components

Specify carpet tiles that can be resurfaced for reuse

Recyclable Materials

Facilitate recycling by avoiding materials with toxic components

Job Site Recycling

Investigate local infrastructure for recycling

Design for Adaptablity

Use an access floor to facilitate reconfiguring of spaces and cabling systems

Post-Consumer Recycled Materials

Specify heavy steel framing with highest recycled content

Transportation of Materials

Prefer materials that are sourced and manufactured within the local area

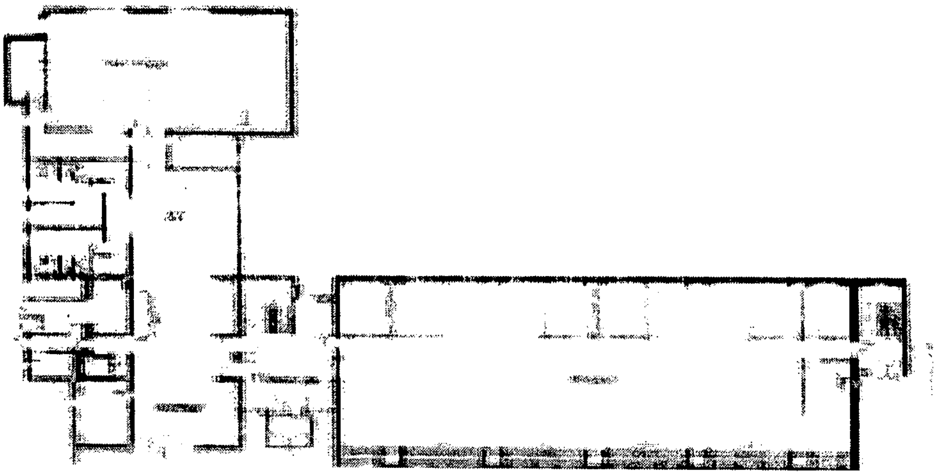
CASE STUDY III

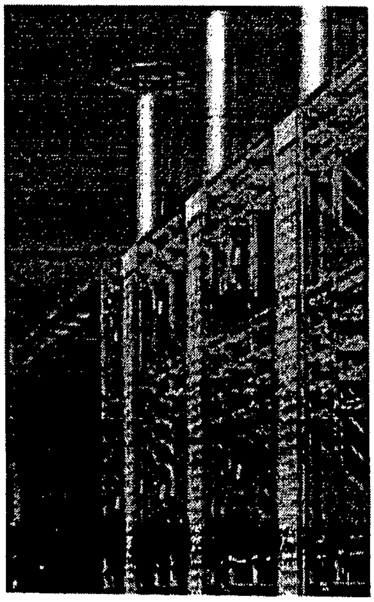
6.3 Building Research Establishment

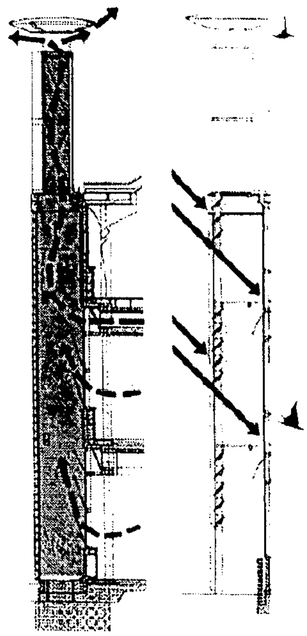
- Building: Environmental Building, Building Research Establishment
- Location: Garston, UK
- System: Operable solar shading and stack ventilation
- Architect: Fielden Clegg
- Completion: 1991/1997
- Project Description: Low-rise, low-energy office building for 100 people with stack ventilation, cross ventilation, and operable shading systems on the south building facade.

A key feature of this building is the integration between natural ventilation and daylighting strategies. The floor plan (shaded in yellow in the picture to the left) is divided into open-plan and cellular offices allowing cross ventilation in the open plan arrangement while the 4.5-meter-deep cellular offices are located on the north side with single-sided natural ventilation. A shallow open-office plan is coupled to a highly glazed façade.

A wave-form ceiling structure is used. At the high point of the wave, a clerestory window allows daylight to effectively penetrate the space. A duct providing space conditioning and ventilation was placed within a hollow core at the low point of the wave-form structure







Cross section through the ventilati
stack (left) and the glazed façade

Fig (6.3a): Active Facade

A stack ventilation system was designed as an alternative ventilation strategy for the open plan offices during extreme cooling conditions. Vertical chimneys were designed to draw hot air through the duct in the wave-form structure as well as through bottom-hung, hopper, etched windows. The exterior of the stacks are glazed with etched glass blocks, allowing daylight admission. Low-resistance propeller fans were mounted at the top-floor level, to provide minimum ventilation and to flush internal heat gains during the night

CASE STUDY IV

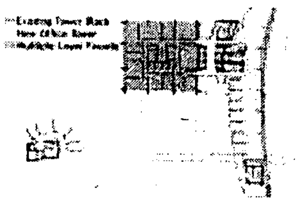
6.4 GSW Headquarters

- **Building**: Gemeinnützige Siedlungs-und Wohnbaugenossenschaft mBH
- (GSW) Headquarters
- **Location:** Berlin, Germany
- **System:** Double-skin façade
- **Architect:** Sauerbruch Hutton Architekten
- **Completion:** 1995-1999
- **Project Description:** 22-storey, 11-m wide office building with cross ventilation and a double-skin thermal flue on the west-facing façade.

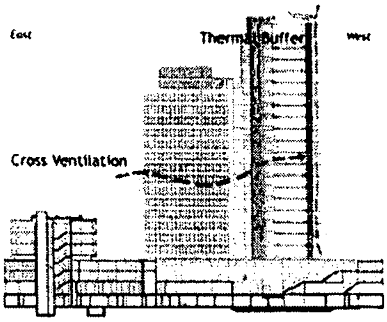
This 11-m wide office building allows for cross ventilation. The east façade consists of automatically and manually-operated triple-glazed windows with between-pane blinds. Louvered metal panels also occur on the east façade to admit fresh air independently from the windows. The west façade consists of a double-skin façade with interior double pane windows that are operated both manually and automatically and a sealed 10-mm exterior glazing layer. The interstitial space is 0.9 m wide. Wide, vertical, perforated aluminum louvers located in this interstitial space are also automatically deployed and manually adjustable. The louvers can be fully extended to shade the entire west façade.

Outside air admitted from the east façade provides cross ventilation to the opposing west façade. The prevailing window direction is from the east. The west façade acts as a 20-storey high shaft inducing vertical airflow through stack effect and thermal buoyancy. Where partitioned offices occur, soundbaffled vents permit airflow across the building. During the heating season, the air cavity betweenmulti-layer facade acts as a thermal buffer when all operable windows are closed. Warm air is returned to the central plant via risers for heat recovery. Fresh air is supplied from the raised floor system. Radiant heating and cooling are provided. Thermal storage in the ceiling and floor was created using exposed concrete soffits and a cementitious voided screed system. Various building systems such as lighting and diffusers are either integrated into the soffit or into the voided

screed



Typical floor plan of the office building, showing the existing tower on the left (gray) and the new 22-storey tower on the right (yellow).



Sectional diagram showing wind- and stack-induced cross ventilation.

CASE STUDY V

6.5 Inland Revenue Centre

Building: Inland Revenue Centre

Location: Nottingham, UK

System: Solar chimney stack-induced cross-ventilation

Architect: Michael Hopkins & Partners

Engineer: Ove Arup & Partners

Completion: 1994

Project Description: Low-rise L-shape buildings with corner staircase towers.The main strategies are the maximization of daylight and engineered natural ventilation.

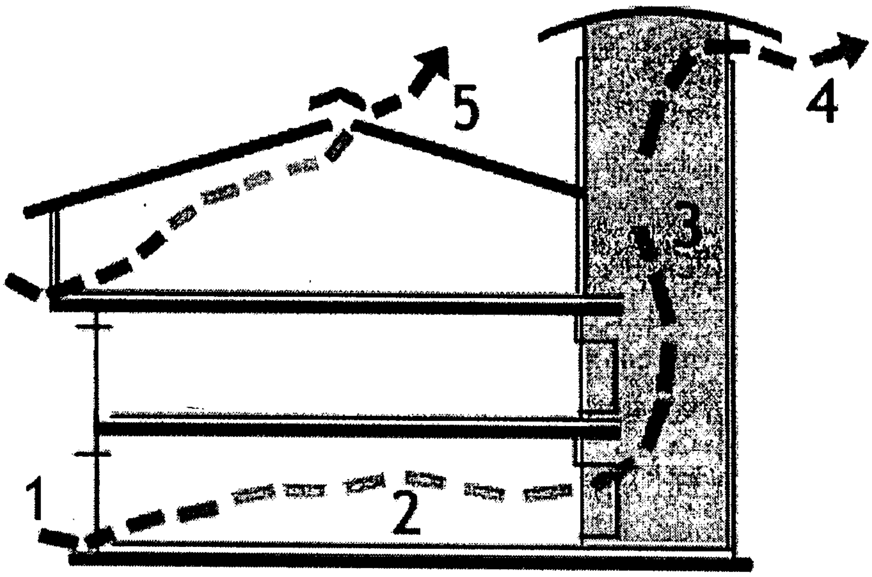


Fig (6.5a):**Cross Section Diagram Showing Ventilation Strategies**

1. Fresh air is drawn through underfloor duct and grill which can be mechanically-induced.
2. Cross ventilation in office area (from open windows).
3. Warm air exhaust through the door, connected to the stair tower. Solar gain in the tower increases thermal buoyancy, warm air is drawn up through the tower by stack effect.
4. Operable tower roof moves up and down to control the rate of air flow.

5. On the top floor, warm air is exhausted at the roof ridge.

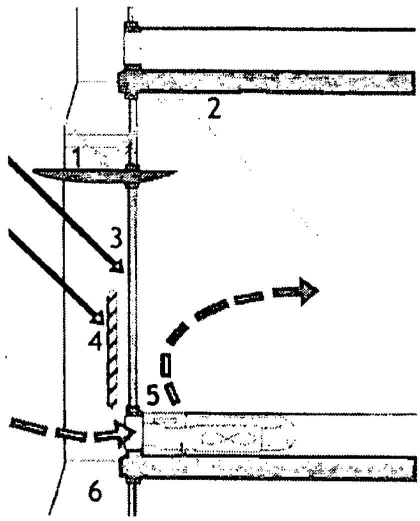


Fig (6.5b): **Section Diagram Showing Facade Strategies**

1. Integrated lightshelf shades space in the perimeter zone and reflects light into the space.
2. Light-colored ceiling improves reflectance of daylight High ceiling (3.2 m) helps with thermal stratification. Exposed concrete soffit acts as thermal mass, absorbing daytime heat gain.
3. Triple glazing with between-pane adjustable blinds

4. Balcony and shading devices.

5. Fresh-air inlet with occupant-controlled fans allows windows to be closed in winter or to protect outside noise from entering the space.

6. External brick piers provide lateral solar shading.

CASE STUDY VI

6.6 PEDA office complex, Chandigarh

Fig (6.6a): External view

- **Architects** : Arvind Krishan and Kunal Jain
- **Site:** Practically square site that lies on flat land with no major topographical variations.
- **Built-up area:** 7000 m2
- **The climate:** Chandigarh experiences Composite

Design response

The demand on building design, therefore, is to respond to the extremes: eliminate (minimize) heat gain in the hot-dry period, maximize ventilation in hot humid period from zones / areas designed as heat sinks and maximize heat gain in the cold period. Within the context of the radical experiment that is Chandigarh, the PEDA building has been designed with an ethos: design with nature. The physical context although unique in itself, i.e. the urbanity of Chandigarh, offers yet another challenge for design

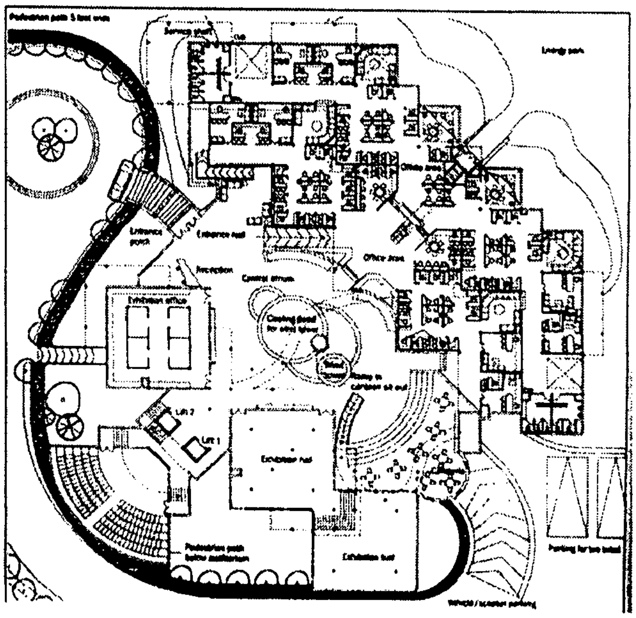


Fig (6.6b): Site Plan

The site

The site is located on a major road intersection and lies on the edge of a residential area with other proposed office buildings on the other edge

Scale form

While the three-dimensional form of the building has been developed in response to solar geometry, i.e. minimizing solar heat gain in the hot-dry period and maximizing solar heat gain in the cold period, the scale and form of the building responds to its urban context as well. Whereas, expression of the building on the two main roads of the intersection bears the character and scale of an office building, the building responds to the residential context on the south/south-east edges by gradually scaling down in mass and volume.

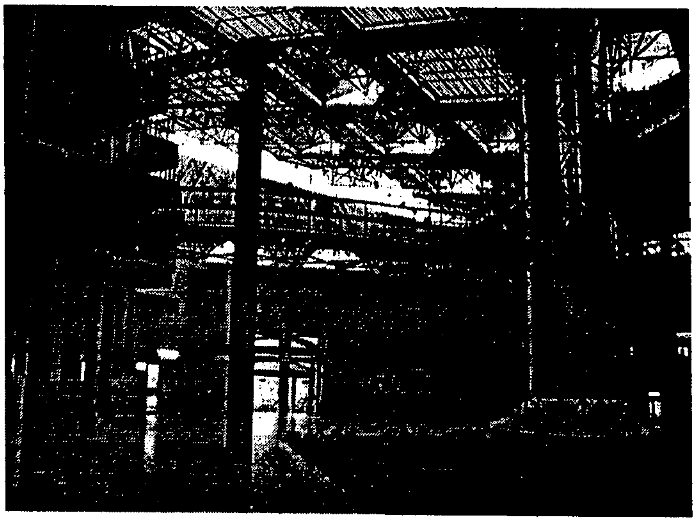


Fig (6.6c): Central courtyard

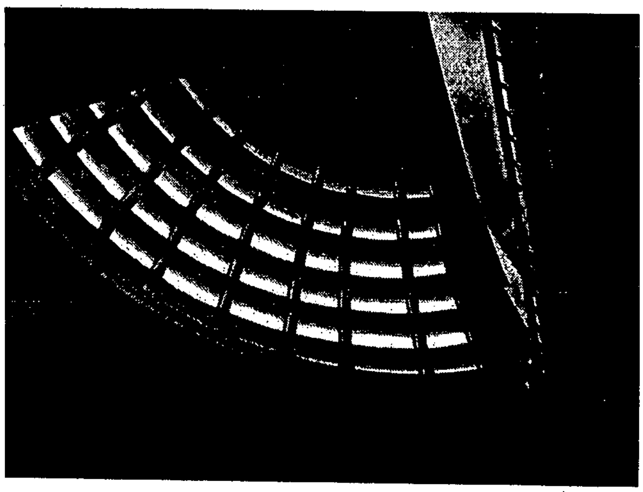


Fig (6.6d): Light Well

Climate responsive building form Light wells, solar chimneys, and wind towers to achieve a climate-responsive building, an innovative concept in architectural design has been developed. In place of the 'central loaded corridor' plan stacked on top of

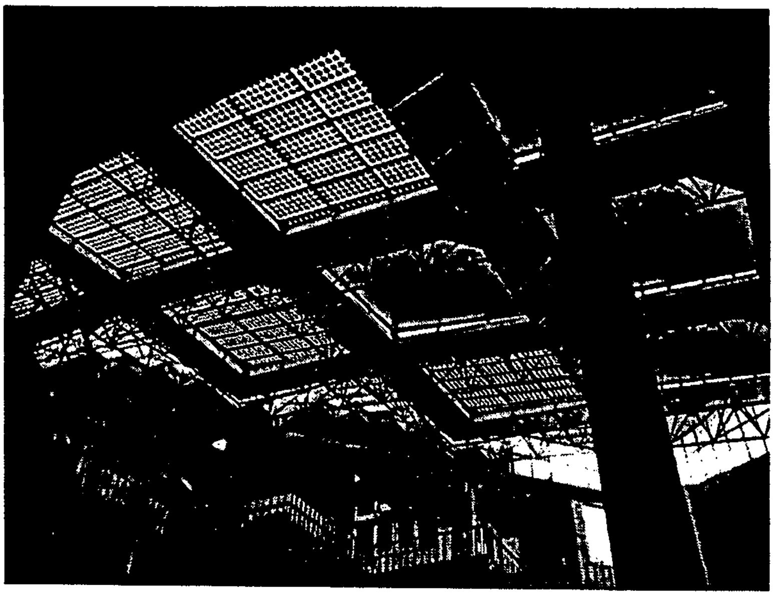


Fig (6.6e): Roofing for day lightt

each other to make various floors, which has become virtually the generic form for an office, the PEDA building is a series of overlapping floors at different levels in space floating in a large volume of air, with interpenetrating large vertical cut-outs. These vertical cut-outs are integrated with light wells and solar-activated naturally ventilating, domical structures.

This system of floating slabs and the interpenetrating vertical cutouts is then enclosed within the envelope of the building. The envelope attenuates the outside ambient conditions and the large volume of air is naturally conditioned by controlling solar access in response to the climatic swings, i.e. eliminating it during hot-dry period and maximizing its penetration in cold period. The large volume of air is cooled during the hot period by a wind tower,

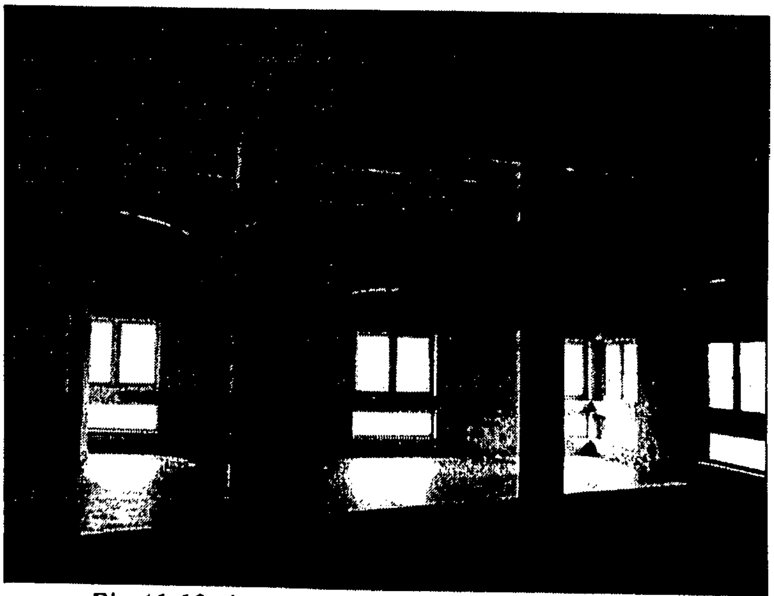


Fig (6.6f): low Height windows for Daylighting

Light wells , solar chimneys, and wind towers building form

Consequently the design is thermally responsive to its climatic context and very good day-light distribution is achieved, thereby minimizing consumption of electrical energy.

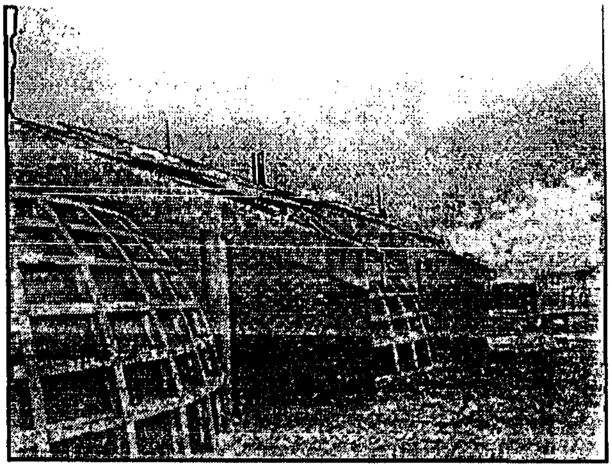


Fig (6.6j): External View of Light Wells

Energy Profile

- The connected load of the Building is 80 kw, whereas a conventional building of this size would have a connected load of 250 kw.
- Out of 80 kw, 27kw is generated by building integrated Photo voltaic systems.

CASE STUDY VII

Transport Corporation of India

PROJECT DETAILS

- Site Location - 69, Sector 32, Institutional Sector , Gurgaon, Haryana, India.
- Architects - A B Lall Architects
- Climate - Composite
- Year of Start / Completion - 1998 / 99
- Client /Owner - Transport Corporation of India Ltd
- Total built up area - 2750 Sq.m
- Cost - Rs 55 million

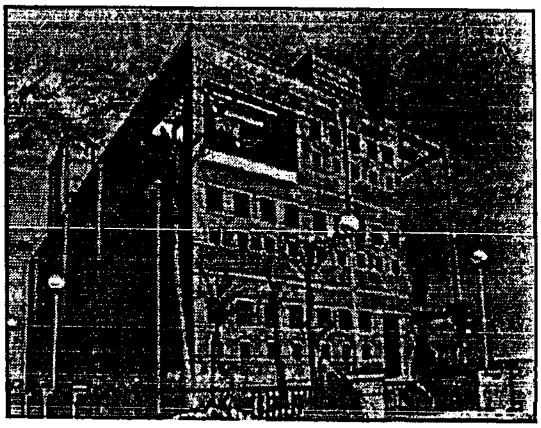


Fig (6.7a): View

The corporate office building of the Transport Corporation of India has beer designed to meet the demands of a modern office, with high level of environmental comfort, integration of systems to support information technology, with flexibility and adaptability for growth and change.

The building sits on a rectangular plot in an institutional area close to Delhi. Three stories of offices and a basement surround the central court. The basement houses building services and some work spaces.The building opens towards its entrance through a planted and shaded forecourt with water pool. The orientation of all the interior spaces is towards the central court with the exception of the managing director's suite, which enjoys its own garden terrace on the top floor.

Fig (6.7b): Central courtyard

Architectural concept

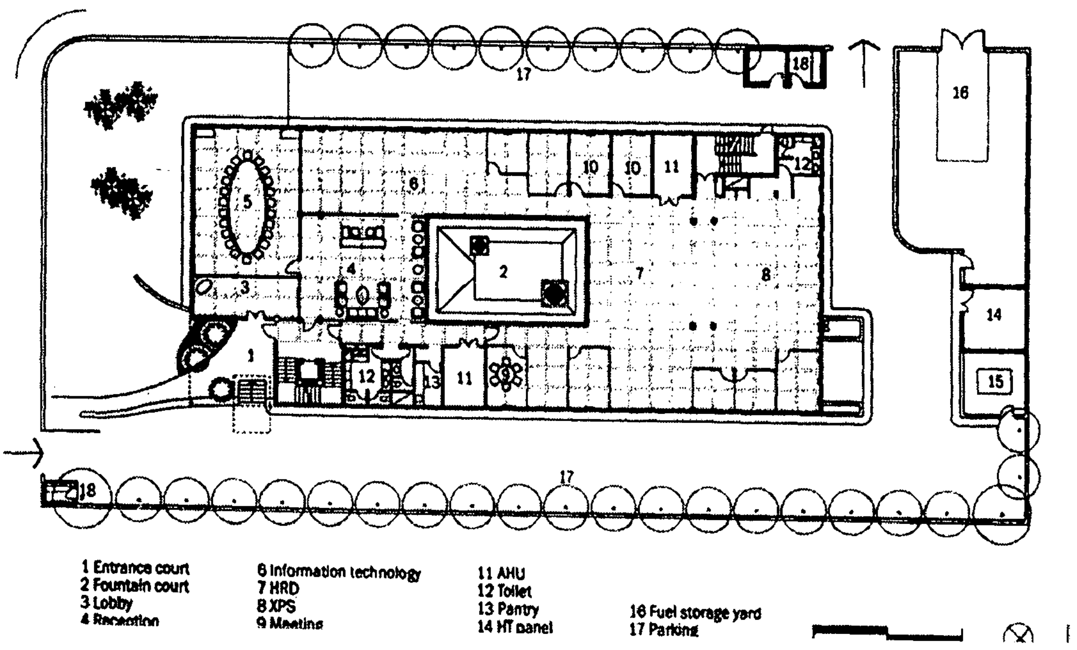


Fig (6.7b): Site Plan

The

The basic design strategy is inspired by the traditional inward-looking haveli plan. The central fountain courtyard acts as an environment generator for the office spaces opening towards it. The external skin is treated as a solid insulated wall with peep windows for possible cross-ventilation and higher windows for daylight. Selection of materials and systems of environmental control is prioritized in favour of sustainability and efficiency in energy consumption.

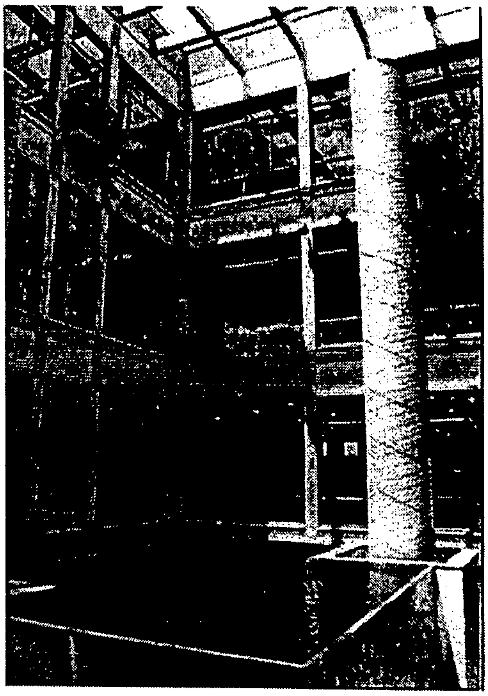


Fig (6.7c): Central courtyard

Energy-saving features

Being situated in a composite climate with climatic extremes, the building adopts a compact rectangular form and minimum height above ground to limit exposure to the

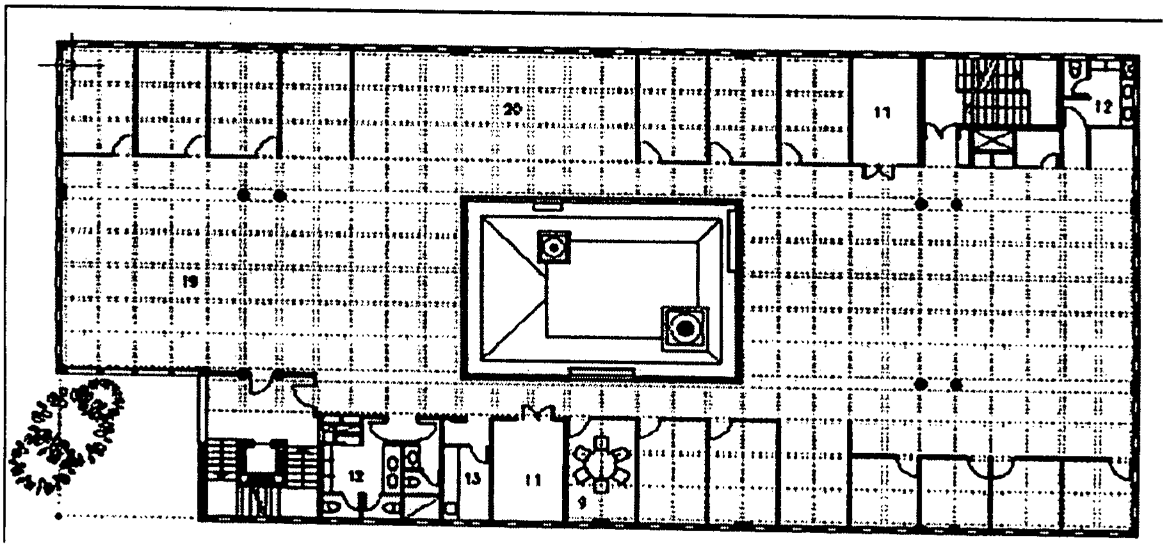


Fig (6.7d): First Floor Plan

external conditions. Openings on the external walls are designed for two separate functions: small peep windows at seating height provide for possible cross-ventilation and views out; larger windows at ceiling level are designed to distribute glare-free daylight across the office floor. Taking the daylighting function into account, the window area is minimized to 18% of the external wall area.

Both the entrance forecourt and central fountain court, towards which the building envelope opens out with greater transparency, have a structural framework which would provide support for shading screens to be stretched according to seasonal demands. The planting scheme along the edges of the site with tall evergreen (Silver Oak) trees provides another protective layer for the building

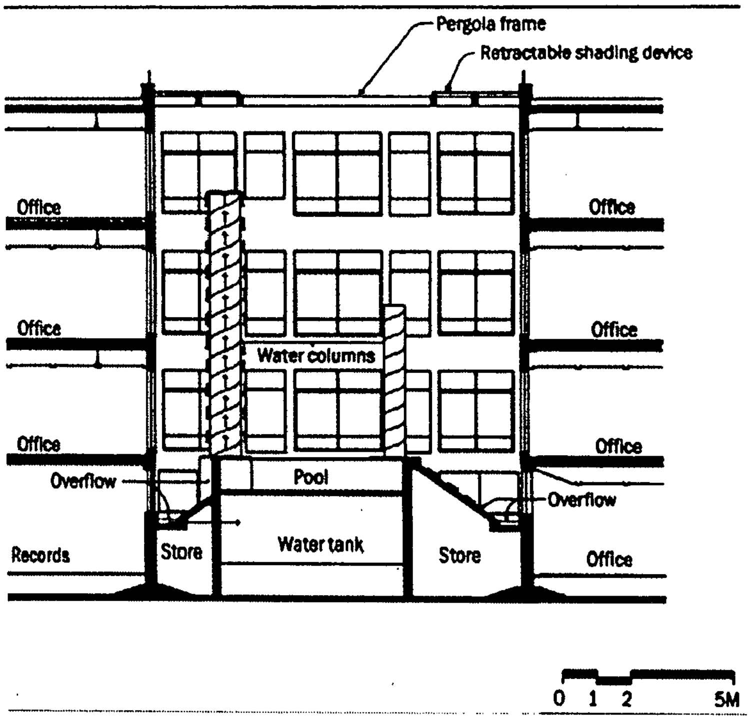


Fig (6.7e): Section through Central courtyard

Insolation

The orientation of the building is determined by the site. The small peep-windows, due to the deep reveal in which they are set, allow insolation in winter, cutting out the mid-summer sun by the shade of the reveal on to I glass. The large daylight windows house adjustable Venetian blinds in a double-window sandwich. The blinds are to be adjusted seasonally (thrice j year) by the building maintenance staff to control direct isolation and to reflect light towards the ceiling

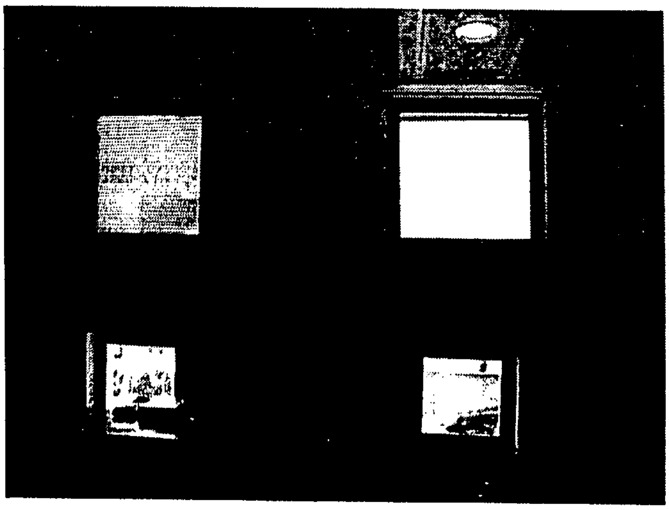


Fig (6.7f): Double windows

for distribution into the office spaces. The large glazed areas towards the central court and the entrance court rely on screens that will be stretched and gathered seasonally. The structural frameworks enclosing the courts provide the necessary support systems for the screens. It is planned that the screens would be works of art in themselves, which play upon opacity, translucency, reflection, and colour as ways of accentuating the experience of seasonal change.

Heat transfer

In principle, the building is a heavy mass construction insulated from the outside. Wall insulation is a 25-mm thick polyurethane foam protected by a dry red-stone slab cladding system. The roof

Fig (6.7g): Daylighting

insulation is 35-mm thick and has a reflective glazed tile paving cover to minimize sol-air temperature on the roof surface. The daylight windows provide insulation by way of tight-sealed two layers of glass with a Venetian blind installed between the two layers.

The glazing panels around the inner courtyard, however, are single glazed; it is anticipated that with the tall water fountain working, the courtyard temperatures would shift substantially towards wet-bulb temperature. This would considerably reduce heat load from the courtyard side during summers, and during spring and

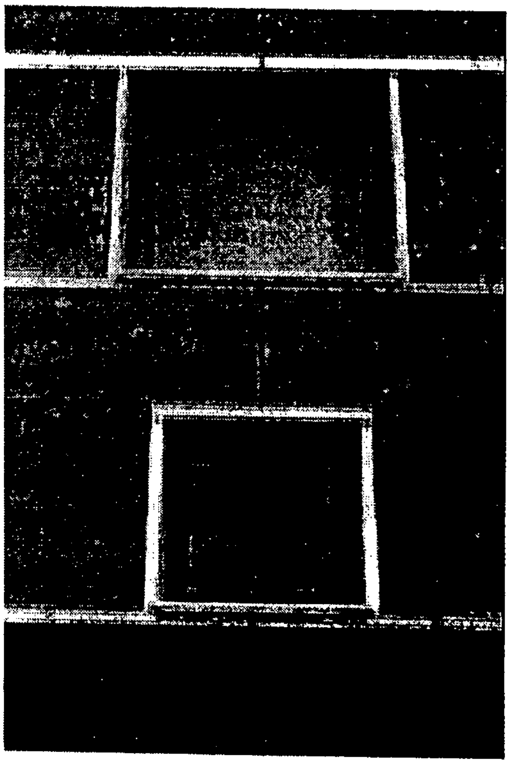
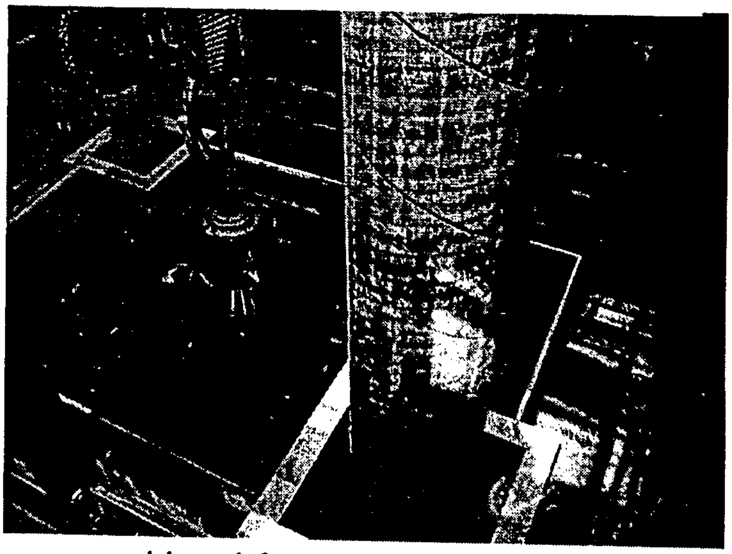


Fig (6.7h): External Insulation

autumn would act as a heat sink. The choice of single glazing here evidently means savings in capital expenditure, considering the year-round operation of the fountain court.

Fountain court

Fig (6.7i): Central courtyard
Water Tower



The fountain court is an environmental device that seeks to combine the principles of physics, perception, and cultural psychology to produce an aesthetic language in which nature is reinstated as a beneficent force in architecture. The fountain is designed as a visible object in which water can be seen and heard from all levels of the building, catching the light from above and in a variety of forms of movement. The gentle play of water and the pool conveys a sense of peace and tranquility. The use of white-textured concrete of the columns and white marble of the pool establishes its status, by association with tradition, as a work of art.

The fountain is a recirculating system in which a large body of water flows over extensive surfaces to maximize evaporation. The tall solid concrete columns of broad diameters over which the water trickles down the height of the courtyard, and the thin sheet

Fig (6.7j): Water Body

that overflows the sides of the pool at ground level create a large heat sink and a body of air close to wet-bulb temperature. The white marble sides of the tank reflect the courtyard light into the basement work areas.

Interactive strategy for an air-conditioned building

Recognizing that climatic conditions range on both the cold and the hot sides of the comfort zone, building systems are designed to draw upon the external environment to supplement the air-conditioning system.

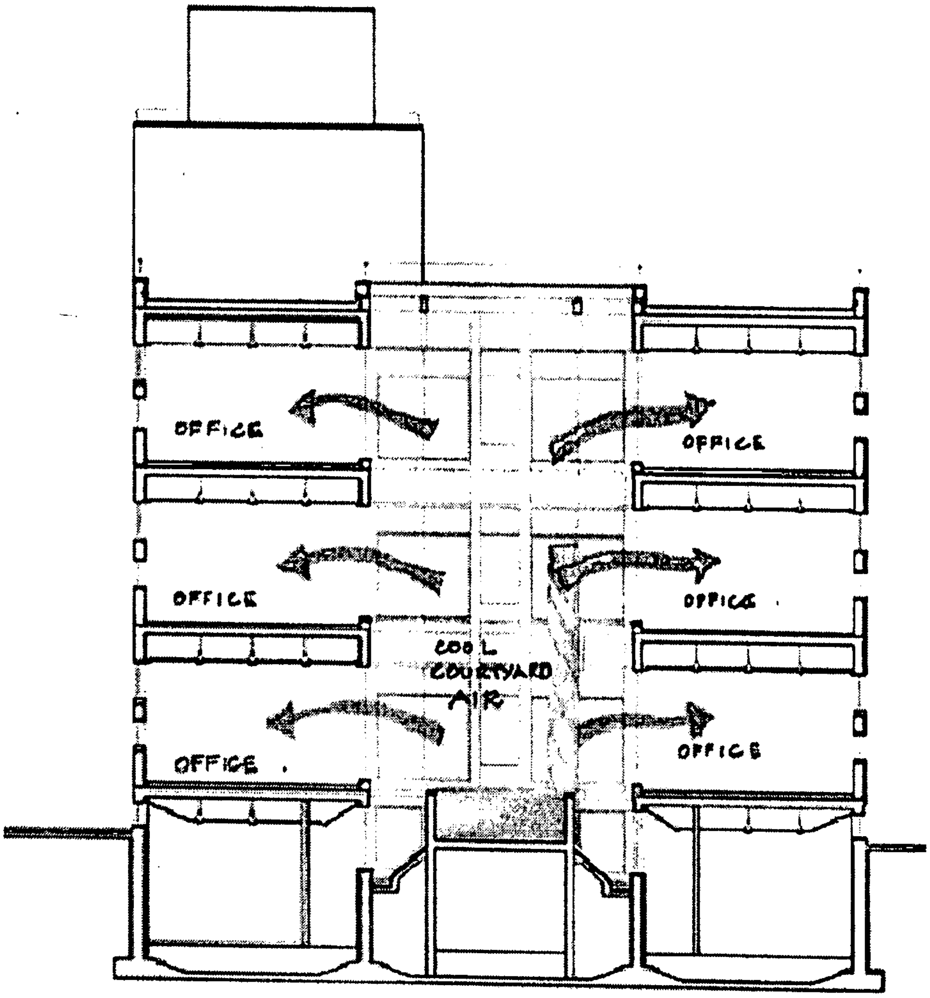


Fig (6.7k): Section Showing the movement of Cool Air from the Central Court

Insulation is clothed on the outer surface of the building envelope giving a high thermal mass interacting with the interior spaces. The air-handling system has provision for.100% filtered fresh air intake. Coolth can be stored in the building mass by night flushing during spring and autumn. Similarly, during early and late winter, when internal heat is tol be rejected, fresh air would be drawn in, replacing the function of the chilling plant.

Absorption technology for air-conditioning

After a careful cost-benefit study, an absorption system chilling plant ha* been installed. Apart from not contributing to ozone depletion, the plant results in reduction of the capital expense of the electrical system, panic larly its electricity generation back-up. This is of critical value in a state] Haryana, where due to acute electricity shortage the electricity generation] back-up must cater to 100% of peak load. The absorption chillers run on a diesel-fired furnace. Electricity generation provides for illumination, office machines, and mechanical equipment.

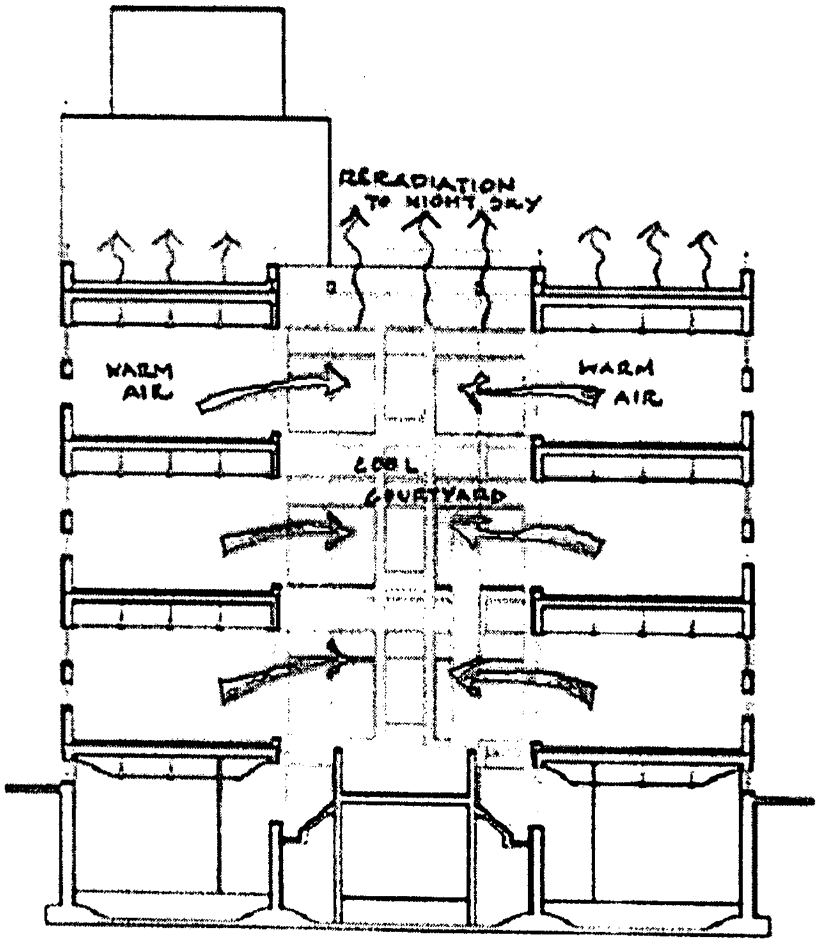


Fig (6.71): Air Movement for Ventilation

Air distribution

Each of the office floors is served with two air-handling units. The allocation of areas handled by each unit is designed to balance out peak demands on each unit. This is done by responding to the orientation exposure of the building sides to the sun so that peak morning and afternoon loads are shared by the air-handling units even as the loads shift from the easterly faces of the building in the morning towards the westerly faces in the afternoon.

Control on air-conditioning loads

The primary-level control on external gains has been described under exposure and heat transfer; and internal gain is controlled by minimizing internal lighting loads. Air-conditioning standards are set according to the acceptance level of the office staff, rather than by any international norms, thereby resulting in significant energy saving. The system is designed based on the following parameters.

Outdoor	Summer 43.5 °C dry bulb temperature, 24 °C wet-bulb temperature (ignoring peak temperatures)
Indoor	Summer 24 °C dry bulb temperature (± 1 °C)

Also, circulation passages and ancillary function rooms have no air-conditioning. Toilets and pantries expel air to the outside at a minimal rate drawing relief air from neighbouring conditioned spaces.

Illumination

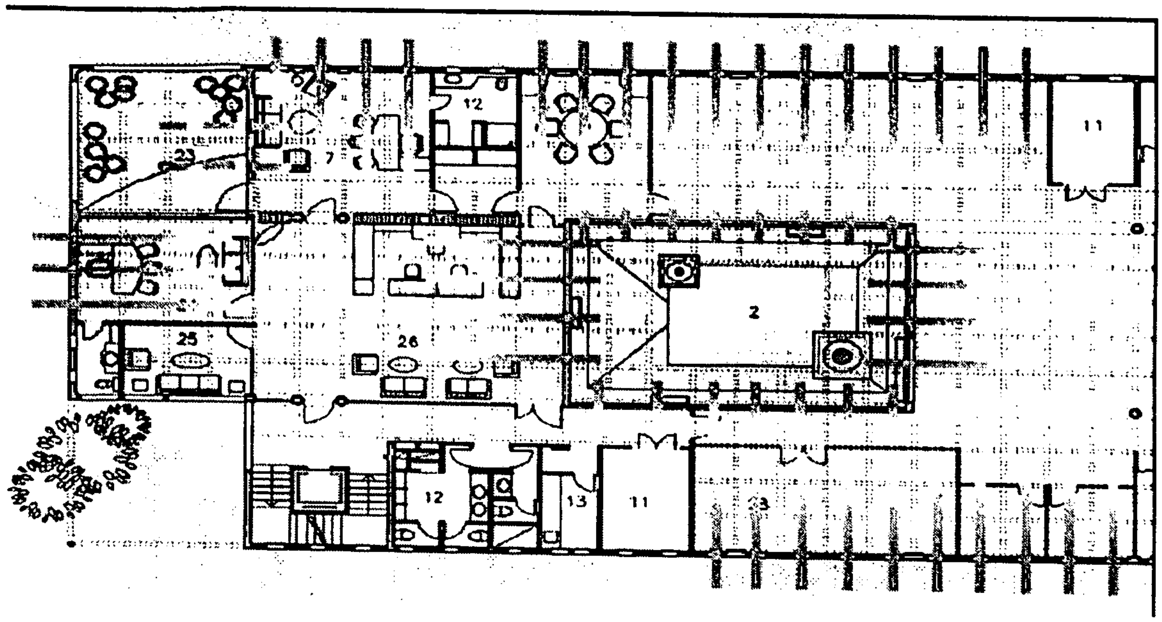


Fig (6.7m): Penetration of Light in the Building

Daylight is the primary source of illumination. All work spaces receive adequate daylight, the maximum distance of a workstation from the daylight source being 5 m. The high windows on the external walls are designed to throw daylight deep into the office space. This is varied seasonally by adjusting Venetian blinds installed in the window sandwich to control glare and to modulate distribution. On the courtyard side, fabric screens would be stretched over the structural frame to respond to each season.

Artificial illumination is on the ceiling grid with compact fluorescent luminaries at 5 W/m^2 of floor area. Most of the office work is done on computers and working hours are generally limited to daylight hours. The illumination level offered by this system supplements daylight when necessary, and is comfortable for short working hours. It has been agreed that task light desk lamps will be provided on desks for elderly people and those who have late working hours.

To provide visual interest and a feeling of brightness, occasional spot lights are provided to light up wall surfaces with paintings and other artwork.

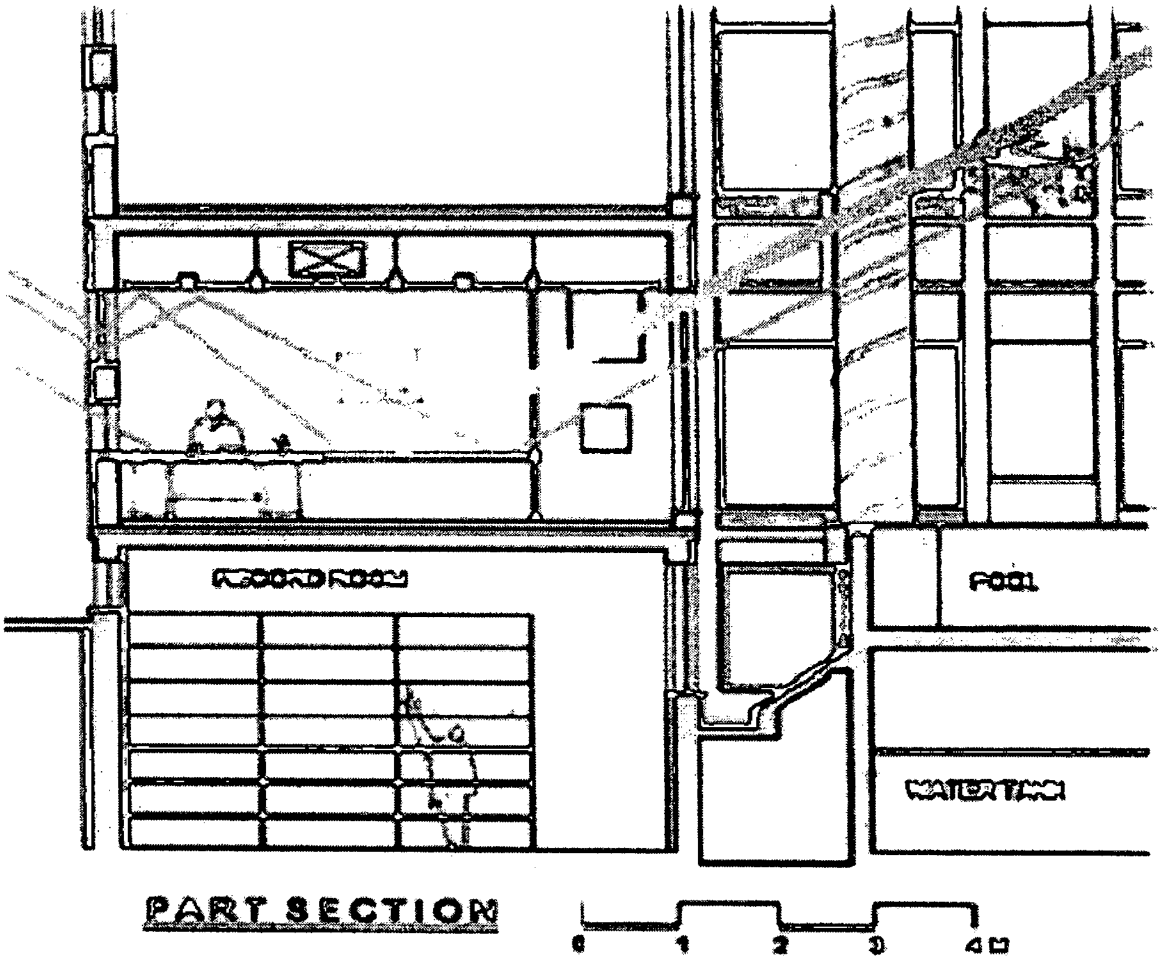


Fig (6.7n): Lighting Pattern

Control of ceiling 'lights is in the hands of the building management staff. The control circuits for ceiling lights are arranged in zones running parallel to the daylight source so that they can be switched on progressively to compensate for variation in and/or falling daylight levels. It is proposed . that these will be controlled by automatic timer switches with timing set for each season (with manual override for unusually cloudy weather). A significant feature of energy saving is the economy of the building envelope.

Structural system and floor-to- floor height

A flat-slab system is adopted for floors and roofs. This minimizes the height required for accommodating air-conditioning and other services. With a clear ceiling height for office spaces at 2.65 m, the floor-to-floor height of the building is 3.5 m. This compactness of height means minimizing heat transfer through vertical surfaces of the external skin.

Restricting the building height to three stories was a deliberate choice. With maximum ground coverage, this pattern of planning consumes the total permissible floor area ratio with the least possible building height. The major advantage is that the energy consumed in transport of materials to heights during const uction is minimized. Similarly the energy consumed in conveying water and diesel for the air-conditioning plant on the, roof is minimized. A major gain is being able to eliminate the necessity of lifts. Only one 6-passenger elevator is provided for disabled or ill persons and for special guests.

Embodied energy

It is in the deployment of finishing materials of the building that some gains are affected by conscious choice. The criterion for choice of materials was that within the constraints of performance specifications demanded of the surface, the material should be chosen from the nearest possible source and should call for minimum processing towards converting or installing it. The external cladding is undressed split red Agra sandstone with precast concrete and terrazzo cills and jambs. For office areas, floors are pre-pol-ished granite from Jhansi (the nearest source to Delhi). For service areas, it is Kota stone. The use of glass and aluminium is kept to the minimum possible.

Monitoring and automation

For the present, automation in the air-conditioning system is limited to the solenoid control valves and thermostats to regulate the flow of chilled water to the air-handing units and the switching on and off of the absorption chiller units; and for artificial illumination, the use of switches on timers. More sophisticated computerized automation systems were found to be beyond budgetary provisions and of doubtful cost-benefit. However, it is proposed to install a simple monitoring system for illumination and air-conditioning to help in rationalizing the systems management routines for the daily as well as the annual cycles of building use.

Performance survey and user feedback

The building is the corporate headquarters of the Transport Corporation of India. The air-conditioning requirement of the building is met by two 62.5 tonnes of refrigeration chillers. The space-conditioning requirements of the building are met by operating a single chiller for major part of the year. Two chillers are operated from mid-April through September only. The average electricity consumption is about 330 kWh per day. The office areas including the basement areas are very well daylit and artificial lights are not required to be switched on during the daytime. Water conservation is practised by using fountain and cooling tower discharge for gardening.

INFERENCES AND OBSERVATIONS

INFERENCES FROM CASE STUDIES

OBSERVATIONS

TREND IN COMMERCIAL BUILDINGS

CHAPTER 7

7.1 INFERENCES FROM CASE STUDIES

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

- **Cooling requirements for summer months**
- **Heating requirements for winter months**
- **Humid conditions prevalent during hot summer months. (monsoon)**

2). The design concept should be to developed keeping the **new technologies** in the field of **energy efficiency.**

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

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

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

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

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

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

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

9). As most of the **commercial buildings** are occupied during the **day time**, there should **ample provision of daylighting.**

10). **Enhanced sun protection** and **cooling load control** while improving **thermal comfort** and providing most of the **light needed** with **daylighting.**

11). Balance should be **maintained** between the **aesthetics** and the **energy efficiency.** **Use Recycled Material or Material which can be Recycled.**

7.2 OBSERVATIONS

7.2.1 Reduce Heat Buildup

- **Limit exposure** to heat build-up by **orienting longer** sides of the building **North and South.**
- Use **existing or new landscape elements** to shade the **site and the roof, walls, and openings.**

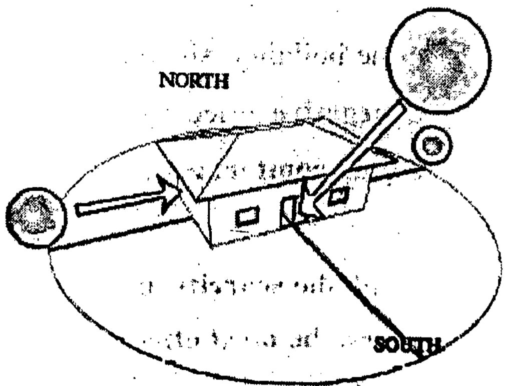


Fig :(7.2.1a) Orientation

- Limit the area of **unplanted** and **paved exterior surfaces.**
- Use **porous paving materials** to reduce **thermal mass, heat gain, and glare**
- Use **light colored materials** that will **reflect sun's heat** rather than **absorb** and **transfer** it to the building's **interior.**
- **Insulate the building shell (roof, ceilings, walls).**
- Install **radiant barriers** in the roof and walls.
- Ventilate the **roof or attic properly.**
- Use **high performance glazing** on **windows exposed to the sun.**

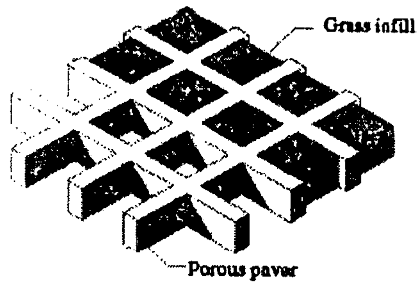


Fig :(7.2.1b) Porous Paver

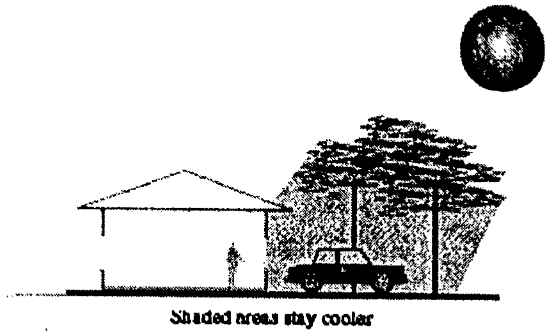


Fig :(7.2.1c) Shading Hardscape

- **Limit** the area of **openings** (windows, skylights, glass doors) to prevent **solar heat gain.**

7.2.2 Provide natural ventilation to remove heat and humidity from building Interiors:

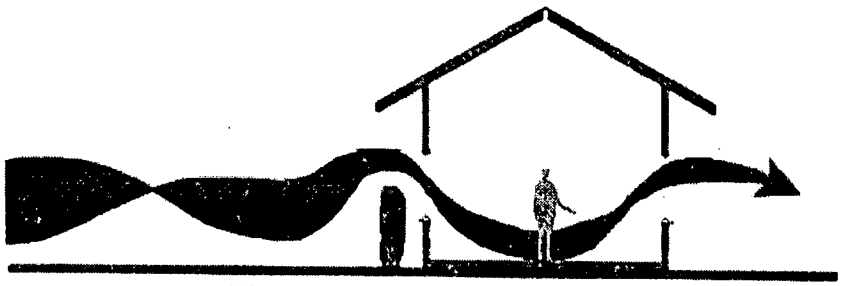


Fig :(7.2.2a) Air movement

- **Orient** buildings to **maximize** the **cooling potential of prevailing winds.**
- Provide **ample spacing** between buildings in the direction of **wind flow** so that all **structure have good airflow.**
- **Arrange** buildings to provide for **good airflow** around all structures.

- Use **landscaping elements** such as **trees, fences and hedges** to improve airflow around structures.
- **Design floor plans** that provide **effective cross ventilation** and **good air circulation** at body level.
- For spaces with openings on opposite walls, **orient the room 45 degrees** from the wind direction.
- Keep **inlet openings** slightly **smaller than outlet** openings.
- For spaces with **openings on adjacent walls,** place windows far apart and at **a diagonal.**
- For spaces with openings on the **same wall,** use **casement windows** or wing walls spaced as far apart as possible.
- Locate **windows at body level.**

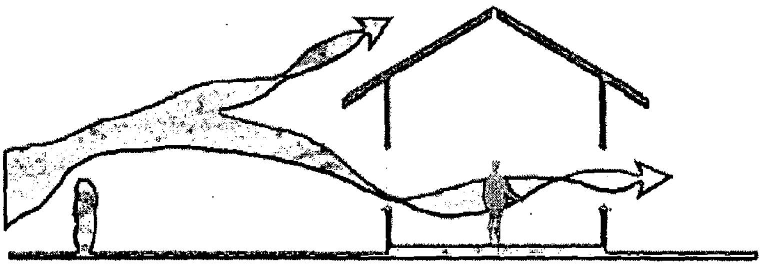


Fig :(7.2.2b) Good Air Movement

7.2.3 Landscape & Site Design

- **Limit heat build-up** by **orienting longer** sides to the **North and South direction.**
- Use **existing or new landscape elements** (trees) to shade the building.
- **Shade hardscapes,** such as walls and paved areas.
- Limit area of **unplanted** and **paved exterior surfaces**; provide generous areas of **planting** and **ground cover** to help **reduce site temperatures.**
- Use **porous paving materials** to reduce thermal mass, heat gain, and glare.

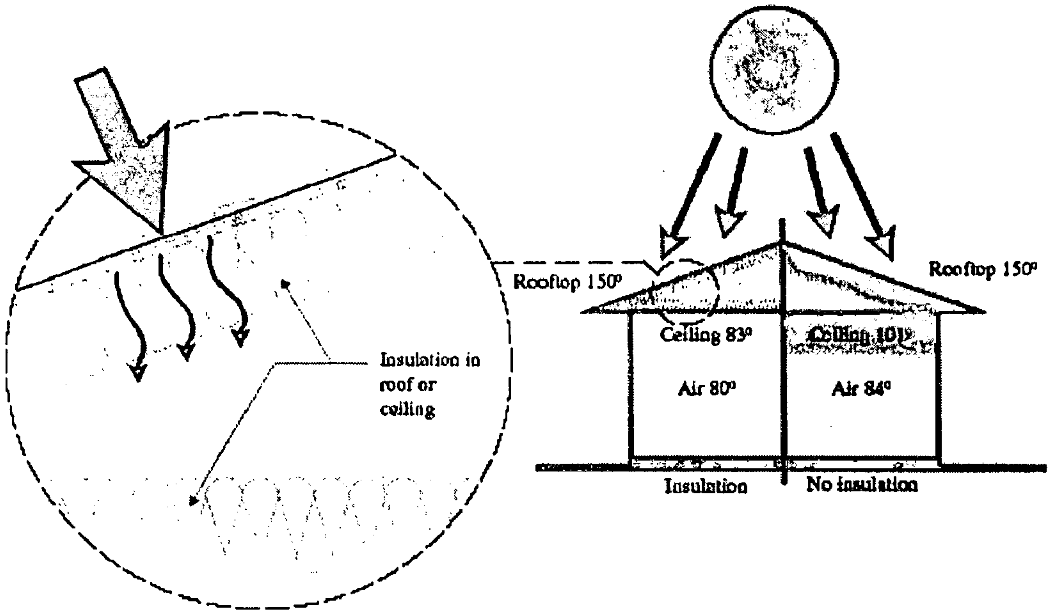


Fig :(7.2.4a) Roof Insulation

.4 Roofs

- **Shade** roof to prevent **heat build-up.**
- Use **roofing materials** that **reflect** the sun's heat rather than **absorb** and transfer it to the interior.
- **Insulate ceilings** and attic spaces.
- **Install radiant barriers** in ceilings and attic spaces.
- **Ventilate** roof properly.
- Integrate roof strategies.

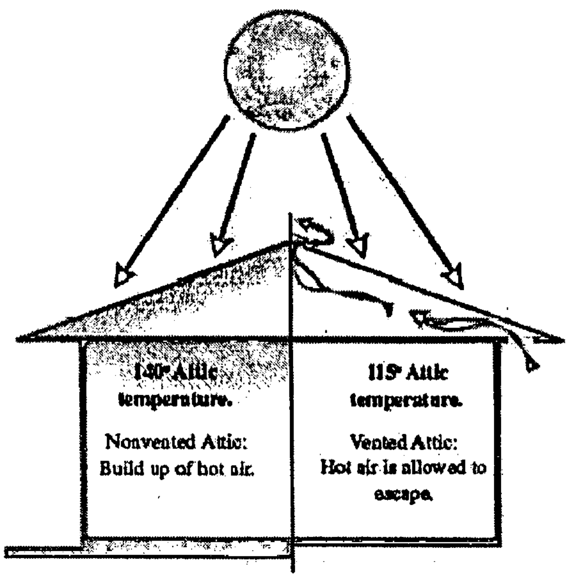


Fig :(7.2.4b) Roof Ventilation

7.2.5 Walls

- Use **design elements** to shade walls.
- **Use light-colored** wall finishes.
- **Insulate walls** exposed to the sun.
- **Install radiant barriers** in walls exposed to the sun.

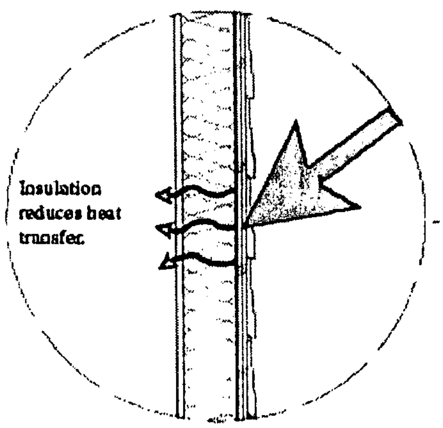


Fig :(7.2.4b) Wall Insulation

7.2.6 Windows and Other Openings

- **Shade windows** and other openings.
- **Use high performance glazing** on windows exposed to the sun.
- **Limit area** of openings.
- **Use skylights** with great care.

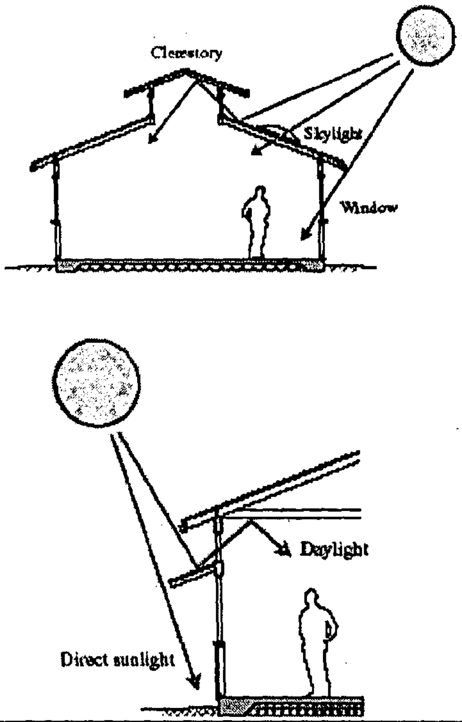


Fig :(7.2.6a) Daylighting

Composite Climate						
Window Type	Orientation Percentage	Window Area	Lighting Energy	Cooling Energy	Heating Energy	Total Energy
Double Glazed	South	12.5	60.87	76.12	14.25	143.54
Double Glazed Low- E	South	15	60.71	62.249	11.25	134.209
Triple Glazed	South	15	61.34	52.267	10.51	124.117

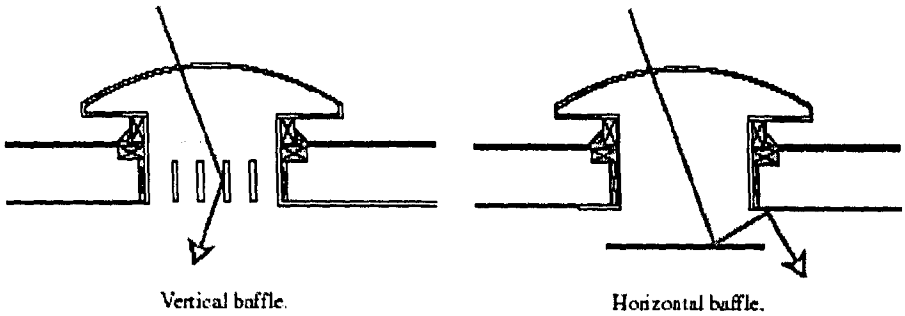


Fig :(7.2.6b) Daylighting

7.2.7 Airflow around Buildings

- **Orient** buildings to maximize the **cooling potential of prevailing winds.**
- Provide **ample spacing** between buildings in the direction of **wind flow** so that all structures have good air flow.

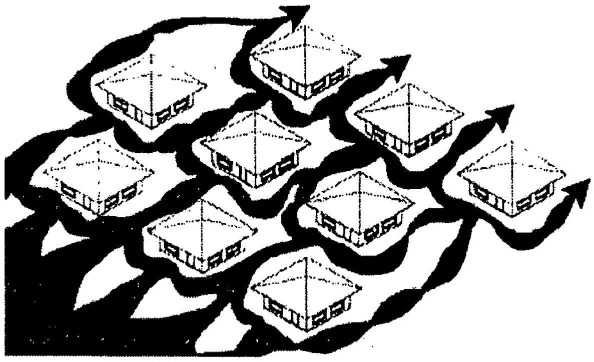


Fig :(7.2.7) Arranging Multiple Buildings for Good Air Flow.

- **Arrange buildings** to provide for good air flow around all structures.
- Use **landscaping elements** such as trees, fences, and hedges to improve air flow around structures.

7.2.8 Airflow in Buildings

- Design floor plans that provide **effective cross ventilation** and good circulation at body level.
- Keep inlet openings slightly smaller than outlet openings.
- For spaces with openings on adjacent walls place windows far apart and at a diagonal.

7.2.9 Air Conditioning

- Use air conditioning only when **absolutely necessary.**
- Employ **passive cooling strategies** to reduce cooling load.
- Seal the **building envelope** against energy leaks.
- Zone and **control** the AC system.
- Ensure AC system provides a **generous supply** of fresh air.
- When installing central AC, **seal ducts to avoid leaks.**
- When installing window units, **optimize performance.**

7.2.10 Daylighting

- Minimize **difficult-to-shade east- and west-facing windows.**

- Design interior layouts to match **lighting needs to daylight availability.**
- Use **light-colored interior finishes** effectively.
- Design floor plans to allow **deep daylight penetration.**
- Uses **light shelves** when **sidelighting.**
- Rely on **clerestories for toplighting.**
- Prevent **heat gain** and **glare** when **installing skylights.**

7.3 TREND IN COMMERCIAL BUILDINGS

(Offices)

Significant and growing interest in the use of highly-glazed facades in commercial buildings. Large portions of the façade or even the entire facade are glazed with relatively high transmittance glazing systems.

Different building types present different opportunities for energy efficiency. This highlights important issues for a number of commercial and institutional building types.

Solar Control

Windows are the critical element in office solar control. Proper orientation and exterior shading are the preferred approach. Otherwise, glazing with low solar transmission is appropriate (but also remember light transmission for daylighting).

What is a high-performance commercial building façade?

Glass is a remarkable material but its functionality is significantly enhanced when it is processed or altered to provide added intrinsic capabilities. The overall performance of glass elements in a building can be further enhanced when they are designed to be part of a complete façade system. Finally, the façade system delivers the greatest performance to the building owner and occupants when it becomes an essential element of a fully integrated building design. This work examines the growing interest in incorporating advanced glazing elements into more comprehensive façade and building systems in a manner that increases comfort, productivity and amenity for occupants, reduces operating costs for building owners, and contributes to improving the health of the planet by reducing overall energy use and environmental impacts. The role of glazing systems in dynamic and responsive facades that provides the following functionality:

- **Enhanced sun protection** and **cooling load control** while improving **thermal comfort** and providing most of the **light needed with daylighting.**

- **Enhanced air quality** and **reduced cooling loads** using **natural ventilation** schemes employing the façade as an **active air control element.**
- **Reduced operating costs** by **minimizing lighting, cooling and heating energy** use by optimizing the **daylighting-thermal tradeoffs.**

- **Improved indoor environments** leading to **enhanced occupant health, comfort** and **performance.**

n addressing these issues, façade system solutions must of course respect the onstraints of latitude, location, solar orientation, acoustics, earthquake and fire safety, etc. Since climate and occupant needs are dynamic variables, in a high performance building the façade solution must have the capacity to respond and adapt to these variable exterior conditions and to changing occupant needs. This responsive performance capability can also offer solutions to building owners where reliable access to the electric grid is a challenge, in both less-developed countries and in industrialized countries where electric generating capacity has not kept pace with growth. We find that when properly designed and executed as part of a complete building solution, advanced facades can provide solutions to many of these challenges in building design today.

7.3.1 TECHNOLOGICAL SOLUTIONS

The variety of technological solutions used to produce "high-performance" commercial building façades are based on fundamental building physics concepts for daylighting, solar heat gain control, ventilation, and space conditioning. The following descriptions of the various advanced building energy-efficiency strategies are therefore related to these fundamental concepts.

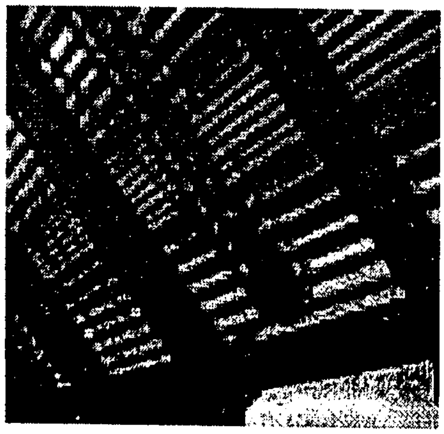


Fig: (7.3.1a) Automated tubular grid skylight controls daylight

7.3.2 SOLAR CONTROL FACADE

Spectrally selective solar control

Spectrally selective glazing is window glass that permits some portions of the solar spectrum to enter a building while blocking others. This high-performance glazing admits as much daylight as possible while preventing transmission of as much solar heat as possible. By controlling solar heat gains in summer, preventing loss of interior heat in winter, and allowing occupants to reduce electric lighting use by making maximum use of daylight, spectrally selective glazing significantly reduces building energy consumption and peak demand. Because new spectrally selective glazings can have a virtually clear appearance, they admit more daylight and permit much brighter, more open views to the outside while still providing much of the solar control of the dark, reflective energy-efficient glass of the past. They can also be combined with other absorbing and reflecting glazings to provide a whole range of sun control performance. Because of its solar heat transmission properties, spectrally selective glazing benefits both buildings in warm climates where solar heat gain can be a problem and buildings in colder climates where solar heat gains in summer and interior heat loss in winter are both of concern.

The energy efficiency of spectrally selective glazing means that architects who use it can incorporate more glazing area than was possible in the past within the limitations of codes and standards specifying minimum energy performance. When spectrally selective glazing is appropriately used, the capacity of the building's cooling system might also be downsized because of reduced peak loads.

Spectrally selective glazings screen out or reflect heat-generating ultraviolet and infrared radiation arriving at a building's exterior surface while permitting most visible light to enter. Spectral selectivity is achieved by a microscopically thin, low-emissivity (low-E) coating on the glass or on a film applied to the glass or suspended within the insulating glass unit. There are also carefully engineered types of blue- and green-tinted glass that can perform as well in a double-pane unit as some glass with a spectrally selective low-E coating. Conventional blue- and green-tinted glass can offer some of the same spectral properties as these special absorbers because impurities in tinted glass absorb portions of the solar spectrum. Absorption is less efficient than reflection, however, because some of the heat absorbed by tinted glass continues to be transferred to the building's interior.

Type of glazing

- Tinted glazings
- Reflective glazings
- Spectrally selective glazings
- Applied films
- Low-E glazings
- Switchable glazings

Tinted Glazings

Tinted glass, sometimes called absorbing glass, has energy-absorbing materials dispersed through it, lowering the shading coefficient and giving a tint— generally bronze, gray, blue, or green. Blue and green more naturally allow more visible light through than the bronze and gray. A tint by itself achieves only a modest shading coefficient—typically 0.5 to 0.8—because some of the heat it absorbs eventually transfers into the space as radiant heat, as the window heats up. Shading coefficients vary by tint composition and glass thickness.

Reflective Glazings

Reflective glazing has better shading coefficients because it reflects rather than absorbs most of the infrared heat. The reflective coating is made of thin layers of metals or metallic oxides on the surface of the glass. Unfortunately, light transmittance is very low and the reduced cooling load due to barring infrared heat may be offset by the increased lighting requirements and indirect cooling load attributable to the lighting. Reflective coatings should be applied on the outside surface of the glass or the outer pane of double-pane glass for best performance. This minimizes the amount of heat that is reradiated to the space by heated glass.

Spectrally Selective Glazings

Tinted and reflective glazings achieve a low shading coefficient at the price of making the window appear dark. Spectrally selective glazings bring in light without the heat. They are highly transmissive in the visible spectrum while blocking the infrared. They select to transmit or reflect specific wavelengths and the result is both an excellent shading coefficient and good visible transmittance. Glazing is generally considered selective if it has relatively high visible transmittance and a relatively low shading coefficient. Luminous efficacy constants greater than 1.0 indicate that a glazing is selective.

Low-Emissivity (Low-E) Glazings

Where heat loss is more of a concern, such as smaller buildings in cooler climates, low-E glazings may be economic. Glass is highly conductive, which means single-pane windows let heat pour out of a room. By trapping air between two panes of glass, the thermal resistance is doubled—a simple enough solution that the majority of windows in the U.S. are now manufactured

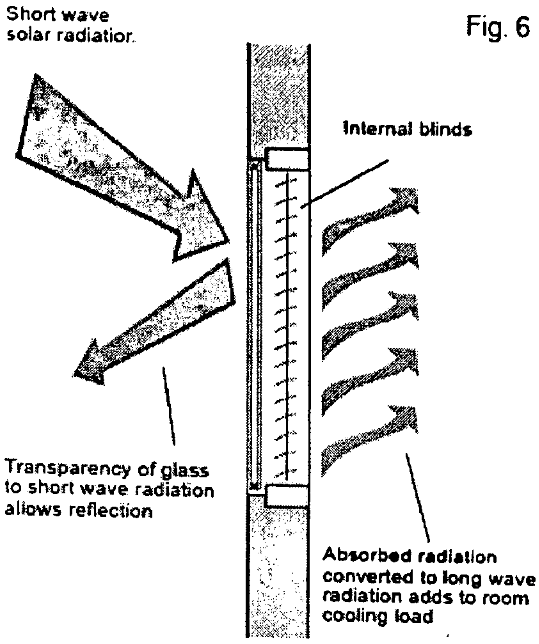


Fig: (7.3.2a) Low -E Glazing

with ***insulating glass*** (IG). Low-E coatings further improve a window's thermal resistance. These ultra- thin, transparent, metallic coatings reflect heat back to its source. Applied to at least one of the inside glass surfaces in an IG unit or on a plastic layer suspended in the air gap, low-E coatings increase the window's ability to reflect long wave infrared radiation, reducing energy loss from a warm room. Using gases such as argon and krypton between the glass surfaces can also improve thermal resistance. Low-E gas-filled windows are so effective that attention is now focused on the edge of the IG unit and the window frame as thermal weak points; improvements include thermal breaks in metal frames, greater use of wood and clad wood sash and frames, or the use of lower conductance frame materials like vinyl. On a winter day in a northern exposure ***superwindows*** actually achieve a net heat gain, contributing more useful solar heat gain than conductive losses.

Mechanism of Solar Radiation On Glass

The effect of solar radiation on any transparent medium such as glass can be defined as follows:

t - Transmitted solar energ

a - Absorbed solar energy

r - Reflected solar energy

where t + a + r = 1

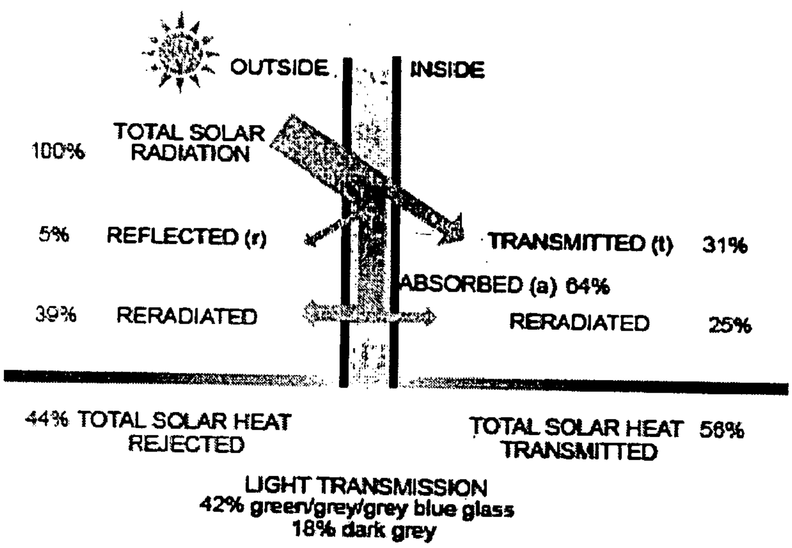


Fig: (7.3.2b) Mechanism of solar radiation on glass

Heat Absorbing Glass

Due to the varying degrees of tint, absorbs a majority of direct solar radiation and re-radiates the absorbed heat in the ration of one third inwards and two thirds outwards.

Angular Selective Solar Control

Angular selective facades provide solar control based on the sun's angle of incidence on the façade. The main technical objective is to block or reflect direct sun and solar heat gains during the summer, or during the majority of the cooling season for a given building type, but admit diffuse sky-light for daylighting.

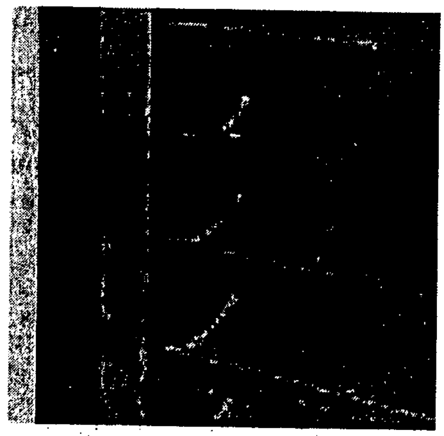


Fig: (7.3.2b) Angular Fins

Solar Filters

Solar filters indiscriminately absorb or reflect a portion of both direct and diffuse solar radiation. Overhangs, fins, "lightshelves", or a secondary exterior skin made of filter material are applied to south, east, or west-facing facades to cut down on incident solar radiation levels and diffuse daylight. Filters may be made with an opaque base material (woven or perforated, metal screens or fabric) or transparent base material (etched, translucent, or fritted glass or plastic).

The effectiveness of solar control is normally in proportion to the percentage of opaque material and will vary with the thickness, opacity, reflectance/absorptance of the material, and position within the façade. Interior fabric roller shades can provide modest solar heat gain control if its exterior-facing surface reflectance is high (white or semi-reflective). Translucent composite fiberglass panels used as part of the window wall also provides modest solar control.

7.3.3 DAYLIGHTING FACADES

Conventional side-lighting concepts distribute flux principally 0-15 feet from the window wall causing glare, high contrast, and excessive brightness, leaving the remainder of the perimeter zone and the core "in the dark." Lightredirecting systems rely on principles of reflection, refraction, diffraction or non-imaging optics to alter or enhance the distribution of incoming daylight within the building's room cavity. The benefit of improved distribution is not only increased potential to offset electric lighting requirements with daylight across a greater depth within the perimeter zone but also to improve lighting quality and visual comfort. Similar technologes can improve skylight performance when ceiling height and/or spacing are not adequate

Sunlight redirection

In summer, when the sun is high in the sky, lightshelves block direct sun at both the upper and lower windows. In winter, low sun can penetrate to the back to the space through the clerestory, preheating occupied space in the morning, and providing light when needed. Tinted glazing can be used at the lower view window, while clear glazing can be used at the clerestory to increase daylight admission.

7.3.4 DOUBLE-SKIN FACADES AND NATURAL VENTILATION

The double-skin façade is a architectural phenomenon driven by the aesthetic desire for an all-glass façade and the practical desire to have natural ventilation for improved indoor air quality without the acoustic and security constraints of naturally-ventilated single-skin facades. The foremost benefit of double-skin facades is acoustics.

"Dual-layered glass façades ... allow natural ventilation in high wind environments such as at the upper stories of high-rise buildings, enables users to control their working environment while helping to eliminate "sick building syndrome," which can result from an over-reliance on air conditioning.

Heat extraction double-skin facades

1. Exterior upper air outlet

2. Controllable solar control device

3. Interior upper operable window (air inlet)

4. Interior operable or fixed view window

5. Exterior glazing layer

6. Air cavity

7. Interior lower operable window (air inlet)

8. Exterior lower air inlet

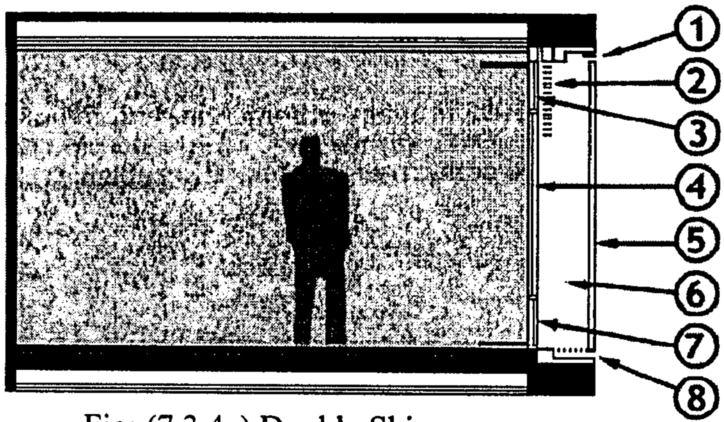


Fig: (7.3.4a) Double Skin Facade

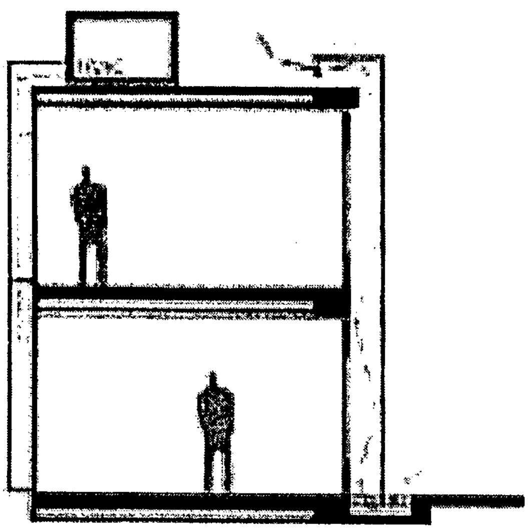


Fig: (7.3.4b) **Heat extraction**

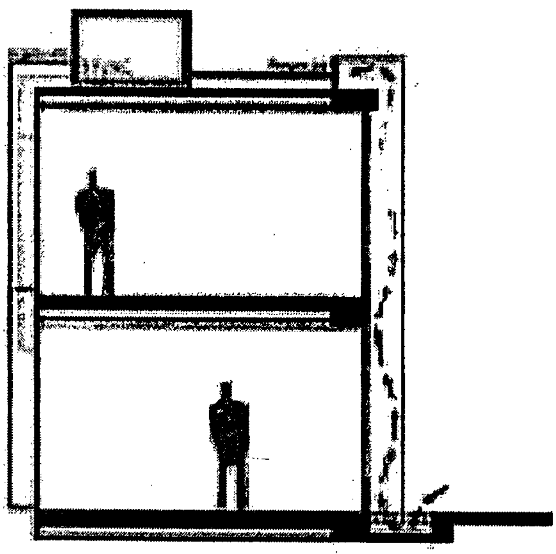
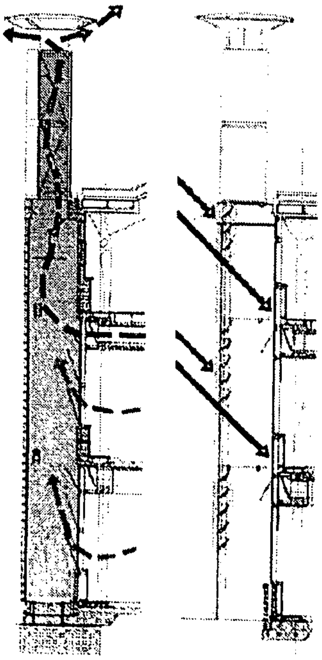


Fig: (7.3.4c) **Heat recovery**

7.3.5 ACTIVE FACADES

Smart windows and shading systems have optical and thermal properties that can be dynamically changed in response to climate, These include motorized shades, switchable electrochromic or gasochromic window coatings, and double-envelope macroscopic window wall systems. "Smart windows" could reduce peak electric loads by 20-30% in many commercial buildings and increase daylighting benefits, as well as improve comfort and potentially enhance productivity in our offices.



Cross section through the ventilation stack (left) and the glazed façade (right).

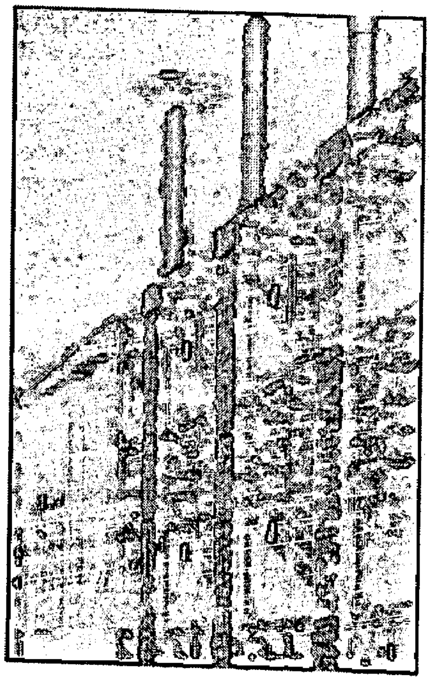
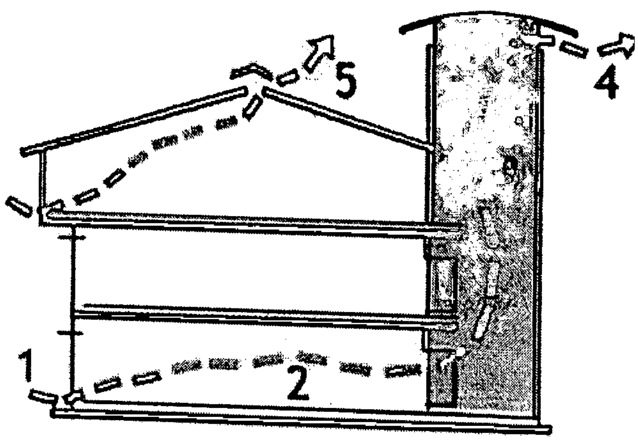


Fig: (7.3.5a) Active Facade

Cross Section Diagram Showing Ventilation Strategies



1. Fresh air is drawn through underfloor duct and grill which can be mechanically-induced.

2. Cross ventilation in office area (from open windows).

3. Warm air exhaust through the door, connected to the stair tower. Solar gain in the tower increases thermal buoyancy, warm air is drawn up through the tower by stack effect.

4. Operable tower roof moves up and down to control the rate of air flow.

5. On the top floor, warm air is exhausted at the roof ridge.

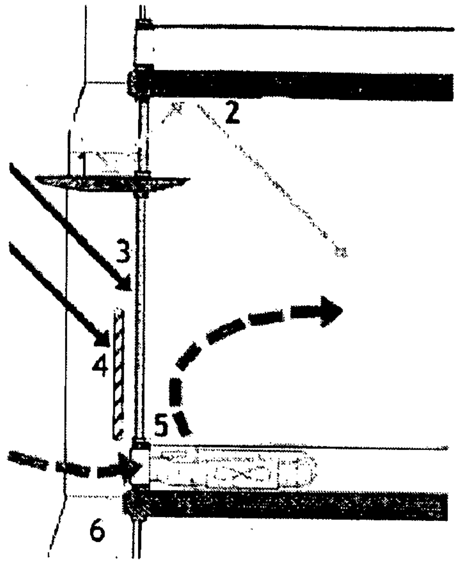


Fig: (7.3.5b) Section

Section Diagram Showing Facade Strategies

1. Integrated lightshelf shades space in the perimeter zone and reflects light into the space.

2. Light-colored ceiling improves reflectance of daylight High ceiling (3.2 m) helps with thermal stratification. Exposed concrete soffit acts as thermal mass, absorbing daytime heat gain.

3. Triple glazing with between-pane adjustable blinds

4. Balcony and shading devices.

5. Fresh-air inlet with occupant-controlled fans allow windows to be closed in winter or to protect outside noise from entering the space.

6. External brick piers provide lateral solar shading.

DESIGN GUIDELINES FOR ENERGY EFFICIENT COMMERCIAL BUILDINGS IN COMPOSITE CLIMATE

DESIGN FOR COMFORT AND VALUE

NATURAL VENTILATION

REDUCE ENERGY BILLS.

LIGHTING:

SELECT AND DESIGN ENERGY EFFICIENT AIR CONDITIONING SYSTEM

CHAPTER 8

8.0 DESIGN GUIDELINES FOR ENERGY EFFICIENT COMMERCIAL BUILDINGS IN COMPOSITE CLIMATE

8.1 Designs for Comfort and Value

Control Heat Gain: Use strategies to reduce solar heat gain through roofs, walls and windows.

1. **Orient** and **arrange building** to **control heat gain.**

2. **Landscape** and **design outdoor surfaces** to reduce **air temperatures** and **glare;** minimize **paving area** and use **grassed** and **planted areas** to provide **lowered site temperatures, shade and evaporative cooling.**

3. **Shade roofs, walls** and **windows** with:
a. **Architectural elements** such as **eaves, awnings and carports**, and
b. **Window treatments** such as **blinds and shutters.**

4. Use **insulation and/or radiant heat barriers** in roofs and **walls exposed to the sun.**

5. Use **high performance windows (Low-e, spectrally selective, or tinted glazing)** to keep solar heat out of interior spaces while **admitting daylight.**

6. Use **light colored roofing and wall finishes.**

7. **Shade** or **insulate materials** with **high thermal mass, such as concrete floors,** to avoid heat build up and **uncomfortably hot surface temperatures.**

8.1.1 Use Natural Ventilation: Provide ample fresh air ventilation for living spaces and areas where hot air and humidity accumulate, such as attics, high ceiling spaces.

1. **Orient buildings** to maximize the **cooling potential of prevailing winds** and minimize morning and afternoon heat gain.
2. Design **floor plans** and **opening placement** and type to provide **effective cross ventilation** with **good air circulation** throughout room areas and at body level.

3. Provide **generous screened openings** well protected from the rain.

4. Use **architectural design elements** such as **vents and casement windows** to improve **interior air circulation.**

5. Enhance **natural ventilation** with fans as needed:
a. Use **ceiling fans** to **provide comfort** on **warm, humid or still days.**
b. Use **solar powered attic vent fans** when appropriate and **economically feasible.**

8.2 III. Reduce Energy Bills.

Water Heating: Minimize the energy required for water heating.
1. Use **solar water heating systems.**

2. When solar water heating is not an option, use **energy efficient alternatives** such as **heat pumps, high efficiency electric or gas water heaters.**

3. Use **high efficiency water tanks, insulate older tanks.**

4. **Insulate** hot water supply lines.

5. Provide **water heater thermostats** .

8.4 Lighting: Minimize electric lighting energy demand and heat gain.

1. Use **controlled filtered and indirect daylighting** to light interior spaces and reduce **electric lighting loads.** Increase the **effectiveness of daylighting** with **generous wall** openings, open floor plans and **light colored interior finishes.**

2. Use **energy efficient electric lighting** to **reduce** heat gain and energy demand.

3. Don't **over light interior** and **exterior spaces**. Use **focused or task lighting** in preference to whole room or large area lighting.

4. Provide **controls such as timers, dimmers, sensors and separate fan/light controls** to limit power use to the times and levels needed.

5. Use **solar powered landscape lighting** when **economically feasible.**

8.5 Select and design energy efficient air conditioning system:

1) Select **minimum unit size** and **energy efficient system** type to reduce operating and maintenance costs and facilitate repair.

2) Design in **zoning and controls** to turn systems off **when not needed;** cool only spaces that need air conditioning, not the whole house.

3) Provide **operable windows,** screened doors and **ceiling fans** so that natural **ventilation** and fans can be used instead of the air conditioning system whenever possible.
4) **Insulate** and **ventilate attic** spaces housing air conditioning equipment and ducts.
5) **Seal and insulate chilled water lines** and cold air ducts in unconditioned spaces.

9.0 CONCLUSION

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

1) The microclimate of the area is an important parameter of dwelling design for energy effectiveness.
2) Architectural aspects such as orientation, form, site topography should be handled carefully while preparing a layout for either dwelling or colony.
3) Solar energy can be exploited fully with the proper design of active and passive systems.
4) It needs further study in the development of solar cooking and water heating processes.
5) Orientation directly affects the internal conditions like temperature, humidity, and ventilation etc., of the dwelling.
6) South orientation is optimum for the dwelling to allow for solar radiation to be maximum in winter and minimum in summer.
7) Orientation of the fenestration should be planned in such a manner so as to fulfill the comfortable conditions, for effective daylight use and proper ventilation as well as for psychological satisfaction.
8) Landscaping and topography of the site help in energy conservation by modifying the microclimate.
9) By using the active/passive solar systems, approximately 55 to 65% of the energy demand can be curtailed.
10) The initial expenditure on the construction may be higher due to the solar system incorporated in the dwelling, but it will directly reduce the life-time cost.

9.1 ENERGY EFFICIENCY PAYS

Why "Green" Building?

- Purpose: To enhance a building's overall performance while improving comfort; indoor air; energy, water and materials efficiency; and the bottom line.
- Buildings use or produce:
    - 30% of total energy use
    - 60% of electricity
    - Billions of gallons of water daily
    - 30% of solid waste generated

Economic Factors

- First Costs/Savings = costs and savings from incorporating green features into a building
- Life-Cycle Costs/Savings = costs/savings over a building's or feature's useful life
- Relative costs components of a commercial building over 30 years
    - Design & building = 2%
    - Operations, maintenance, finance & employees = 98%
    - Key point: more should be spent on better design

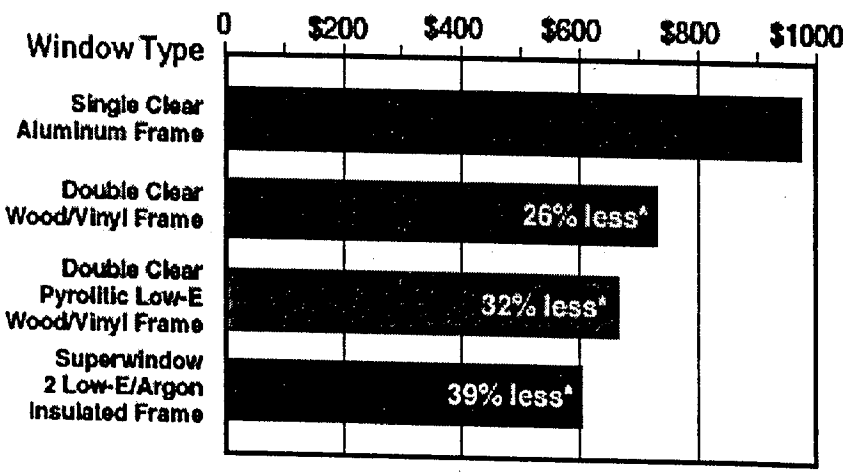
- First Costs of green buildings: will vary significantly depending on the specific project goals.
- While there are many significant benefits that are 'no additional cost' (e.g, South facing windows), some features will cost more in both design and materials costs.
- Estimates for additional first cost are as low as 0-3%, for LEEDTM Certified, to 10% or more for higher LEEDTM ratings.
- Existing incentives aimed at offsetting additional first costs range from 3% (Federal Office of General Services and California DGS) to 6% (NY State tax credit).
- Life-Cycle Savings from:
- Energy & Lighting Efficiency

- Water Efficiency
- Materials Efficiency
- Employee Productivity
- Employee Health
- Construction & Debris Recycling

Energy Efficiency & Lighting

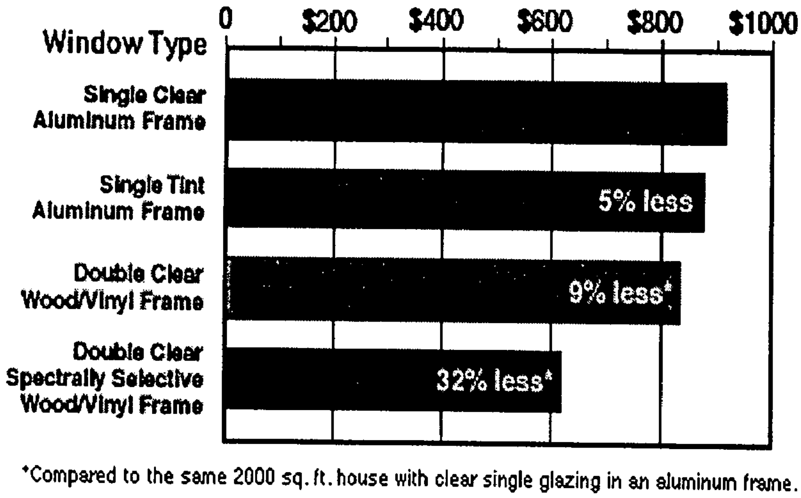
- **Energy savings up to 80%**
- **Sources of Savings:**
    - Lighting
    - Windows
    - HVAC Systems
- **Efficient lighting & better windows can lead to smaller and less costly HVAC system**
- **Energy savings from efficient lighting:**
    - Payback period can be < 2 years
    - Average investment return 50-80%
- **Energy efficient buildings**
    - Investment return usually 20-40%
    - Higher property asset value

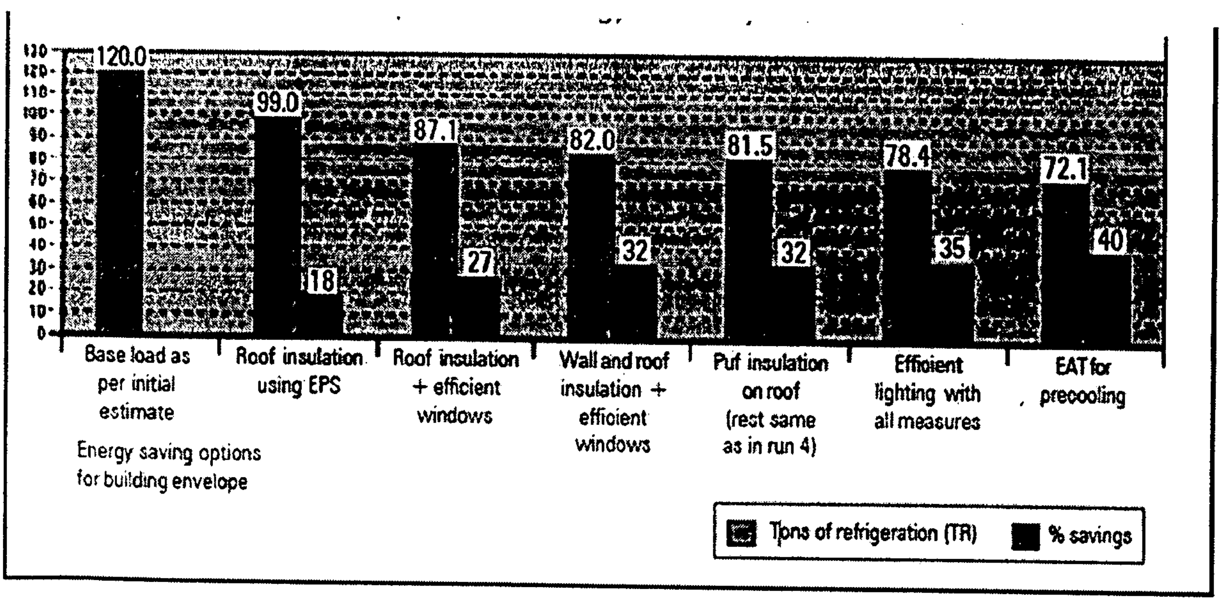
- **Energy Efficient Windows can decrease heating costs by 40%**



*Compared to the same 2000 sq. ft. house with clear single glazing in an aluminum frame.

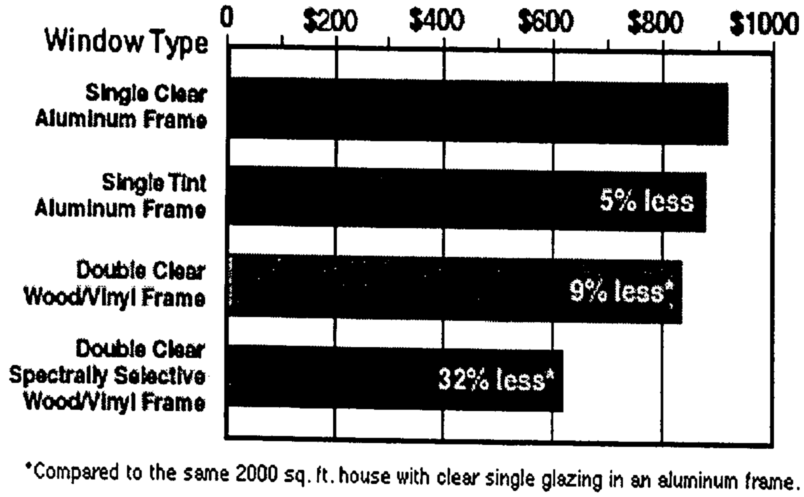
- **Energy Efficient Windows can decrease heating costs by 32%**

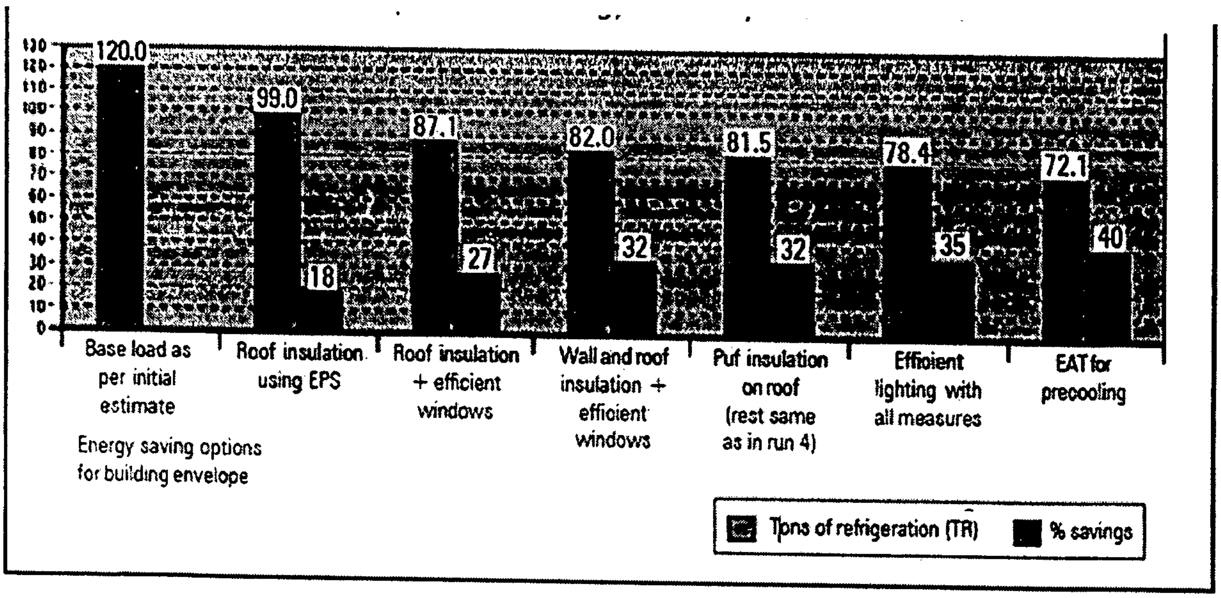




% Savings By Using Energy Efficient Options In The Building

- **Energy Efficient Windows can decrease heating costs by 32%**





% Savings By Using Energy Efficient Options In The Building

Bibliography

1. http://earthtrends.wri.org
2. Census of India (2001): Results, http://www.censusindia.net/results/
3. CMIE (2001): Economic Intelligence Service Report 2001, Centre for monitoring Indian economy, Mumbai, India.
4. TERI 2001. 'RETREAT: Resource Efficient TERI Retreat for Environmental Awareness and Training'
5. Energy Efficient Buildings in India (ed. Mili Majumdar) pp 111-118. New Delhi
6. IPCC 1996. Technologies, Policies and Measures for Mitigating Climate Change – IPCC Technical Paper 1
7. www.eren.doe.gov/buildings/comm_energyeff.html
8. http://earthtrends.wri.org
9. Census of India (2001): Results, http://www.censusindia.net/results/
10. CMIE (2001): Economic Intelligence Service Report 2001, Centre for monitoring Indian economy, Mumbai, India.
11. TERI 2001. 'RETREAT: Resource Efficient TERI Retreat for Environmental Awareness and Training'
12. Energy Efficient Buildings in India (ed. Mili Majumdar) pp 111-118. New Delhi
13. IPCC 1996. Technologies, Policies and Measures for Mitigating Climate Change – IPCC Technical Paper 1
14. www.eren.doe.gov/buildings/comm_energyeff.html
15. U.S. Department of Energy (DOE)
16. http://www.energy.gov
17. International Organization for Standardization (ISO)
18. http://www.iso.ch/iso/en/ISOOnline.frontpage
19. International Energy Agency (IEA)
20. http://www.iea.org
21. American Institute of Architects (AIA)
22. http://www.aia.org
23. The American Society of Heating, Refrigerating and Air-Conditioning Engineers
24. (ASHRAE)
25. http://www.ashrae.org
26. Illuminating Engineering Society of North America (IESNA)
27. http://www.iesna.org
28. Links: Energy Efficiency Research Organizations
29. Environmental Energy Technologies Division