UNIT 4

ENERGY CONSEVATION IN BUILDINGS THROUGH VENTILATION AND LIGHTING

Introduction to ventilation - Fresh air - Stack effect - Air movement through buildings - Air movement around buildings - layout planning for air movement - Traditional methods for aiding ventilation. Lighting - different types of lighting - study of interiors in lighting - their effects. Mandatory requirements - lighting control - exit signs - exterior building grounds lighting - Introduction to Energy conservation in buildings.

Ventilation

It is the process by which fresh air is introduced and ventilated air is removed from an occupied space. The primary aim of ventilation is to preserve the qualities of air. Sometimes, ventilation may also be used to lower the temperature inside an occupied area.

Fresh Air - Fresh air provides the steady supply of rich oxygen and it is free from pollutants.

There are two types of ventilation – natural and mechanical ventilation

a) Natural ventilation

Natural ventilation is the process of supplying and removing air by means of purpose-provided aperture (such as openable windows, ventilators and shafts) and the natural forces of wind and temperature-difference pressures.

Natural ventilation may be divided into two categories:

i) ***Controlled natural ventilation*** is intentional displacement of air through specified openings such as windows, doors, and ventilations by using natural forces (usually by pressures from wind and/or indoor-outdoor temperature differences). It is usually controlled to some extent by the occupant.

ii) ***Infiltration*** is the uncontrolled random flow of air through unintentional openings driven by wind, temperature-difference pressures and/or appliance-induced pressures across the building envelope. In contrast to controlled natural ventilation, infiltration cannot be so controlled and is less desirable than other ventilation strategies, but it is a main source of ventilation in envelope-dominated buildings.

b) Mechanical ventilation

Mechanical or forced ventilation is the process of supplying and removing air by means of mechanical devices, such as fans. It may be arranged to provide either supply, extract or balanced ventilation for an occupied space.

There are also specialised areas in which ventilation is vital, such as ventilation for industrial processes, mines, tunnels and underground development.

Fans and blowers cause the movement of air within buildings and through enclosures. By doing so, they can generate large pressures. If more air is exhausted from a building than is supplied, a net negative pressure is generated and vice versa.

If air is forced through the ducts that leave the building enclosure or pass outside the primary air barrier system (e.g., the very bad practise of placing ductwork in vented attics or crawlspaces) any leaks in the ductwork (and all ducts have some leakage, most ductwork is very leaky) will result in a net exhaust of air, and hence a net negative inward pressures on the building enclosure. The reverse can happen if leaky ducts outside the air barrier are under a net suction pressure.

Bathroom exhaust fans, clothes dryers, built-in vacuum cleaners, dust collection systems, and range hoods all exhaust air from a building. This creates a negative pressure inside the building. If the enclosure is airtight or the exhaust flow rate high, large negative pressures can be generated.

These negative pressures have the potential to cause several problems:

- by driving inward air leakage through the enclosure, outdoor air may transport moisture into the enclosure during hot humid outdoor weather conditions
- the negative pressures can cause back drafting of combustion appliances.
- the efficiency of most air handling devices will decrease with increasing back pressures.

Traditional methods for aiding ventilation

There are three common methods of traditional ventilation : courtyard, wind catcher and ventilation shaft

1. **Courtyard**

A **courtyard** or **court** is an enclosed area, often surrounded by a building or complex, that is open to the sky. Such spaces in inns and public buildings were often the primary meeting places for some purposes, leading to the other meanings of court.

Courtyards have historically been used for many purposes including cooking, sleeping, working, playing, gardening, and even places to keep animals.

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

At night, the warm roof surfaces get cooled by convection and radiation.

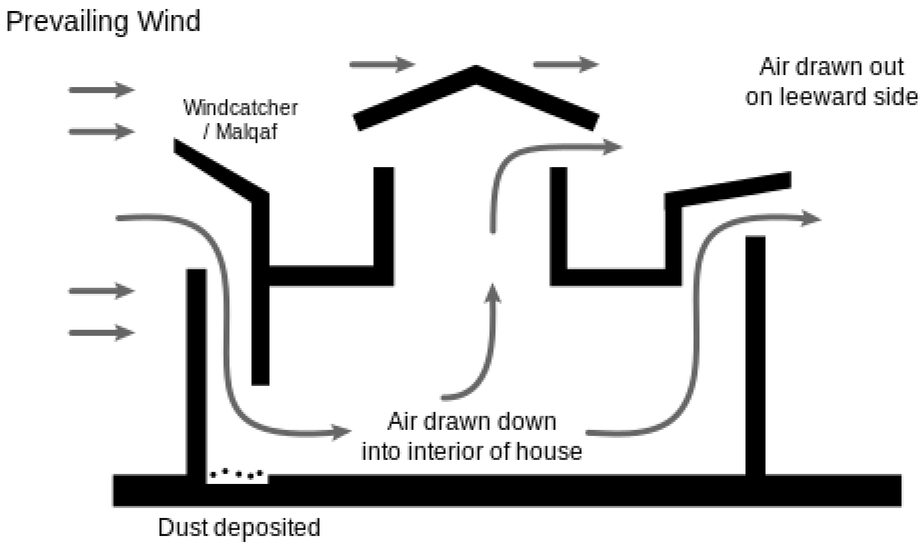
- If this heat exchange reduces roof surface temperature to wet bulb temperature of air, condensation of atmospheric moisture occurs on the roof and the gain due to condensation limits further cooling.
- If the roof surfaces are sloped towards the internal courtyard, the cooled air sinks into the court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

Courtyards

2. **Wind catcher**

A wind catcher is a traditional Persian architectural element to create natural ventilation in buildings.[3] Wind catchers come in various designs: uni-directional, bi-directional, and multi-directional. Wind catchers remain present in many countries and can be found in traditional Persian-influenced architecture throughout the Middle East.

The wind catcher can function in three ways: directing airflow downward using direct wind entry, directing airflow upwards using a wind-assisted temperature gradient, or directing airflow upwards using a solar-assisted temperature gradient.



Function of Wind catcher

- **Downward airflow due to direct wind entry**

One of the most common uses of the wind catcher is to cool the inside of the dwelling; it is often used in combination with courtyards and domes as an overall ventilation and heat-management strategy. It is essentially a tall, capped tower with one face open at the top. This open side faces the prevailing wind, thus "catching" it, and brings it down the tower into the heart of the building to maintain air flow, thus cooling the building interior.

- ***Wind-assisted temperature gradient***

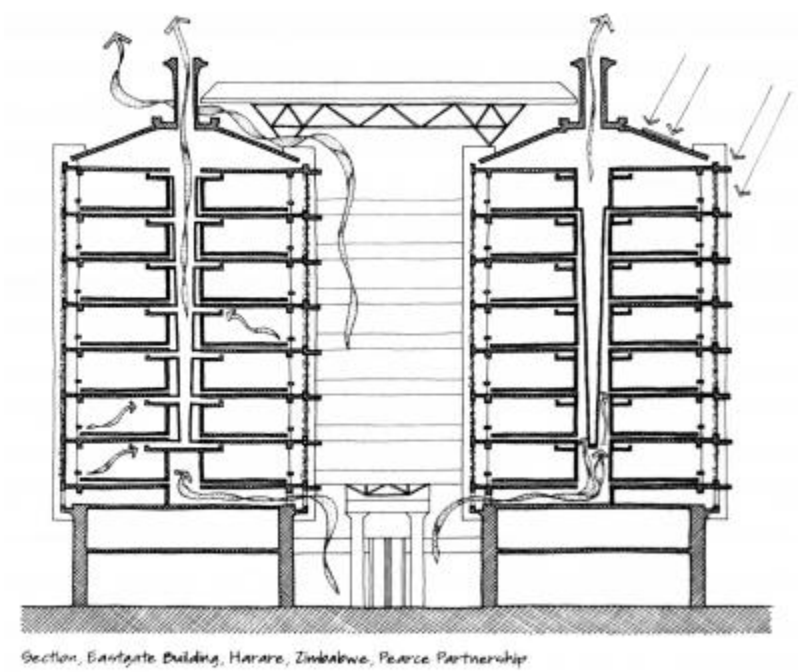
  Wind catchers are also used in combination with underground canal. In this method, the open side of the tower faces away from the direction of the prevailing wind (the tower's orientation can be adjusted by directional ports at the top). By keeping only this tower open, air is drawn upwards.

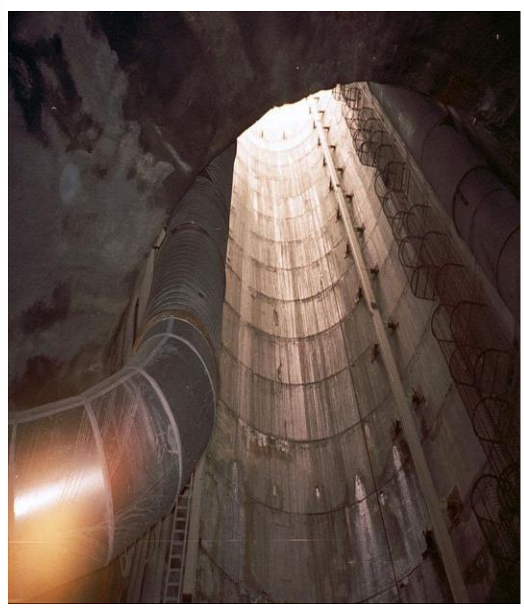
- ***Solar-produced temperature gradient***

  In a windless environment or waterless house, a windcatcher functions as a solar chimney. It creates a pressure gradient which allows hot air, which is less dense, to travel upwards and escape out the top.

3. Airshaft

It is the vertical space within a tall building which permits ventilation of the building's interior spaces to the outside. The floorplan of a building with an airshaft is often described as a "square donut" shape. Alternatively, an airshaft may be formed between two adjacent buildings. Windows on the interior side of the donut allow air from the building to be exhausted into the shaft, and, depending on the height and width of the shaft, may also allow extra sunlight inside.



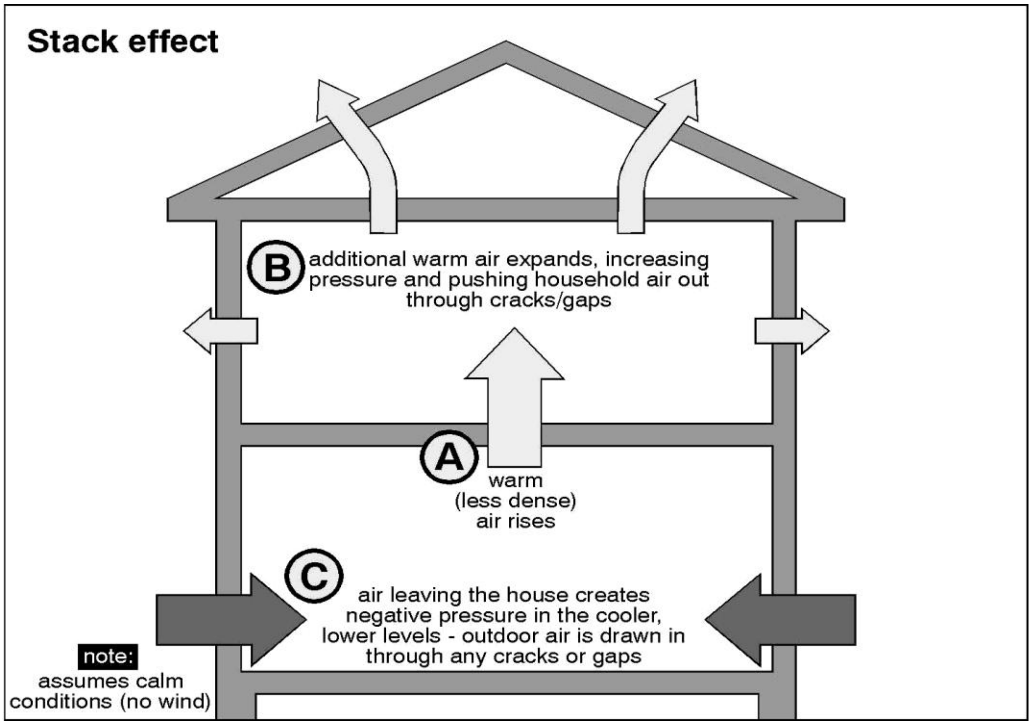


Ventilation shaft in a multistorey building

Ventilation shaft in a tunnel

Stack effect

Since buildings are not totally sealed (at the very minimum, there is always a ground level entrance), the stack effect will cause air infiltration. During the heating season, the warmer indoor air rises up through the building and escapes at the top either through open windows, ventilation openings, or unintentional holes in ceilings, like ceiling fans and recessed lights. The rising warm air reduces the pressure in the base of the building, drawing cold air in through either open doors, windows, or other openings and leakage. During the cooling season, the stack effect is reversed, but is typically weaker due to lower temperature differences.



There is a pressure difference between the outside air and the air inside the building caused by the difference in temperature between the outside air and the inside air. That pressure difference (***ΔP***) is the driving force for the stack effect and it can be calculated with the equations presented below. The equations apply only to buildings where air is both inside and outside the buildings. For buildings with one or two floors, ***h*** is the height of the building. For multi-floor, high-rise buildings, ***h*** is the distance from the openings at the neutral pressure level (NPL) of the building to either the topmost openings or the lowest openings.

$$\Delta P = C\, a\, h \left(\frac{1}{T_o} - \frac{1}{T_i}\right)$$

where:

ΔP = available pressure difference, in Pa

C = 0.0342

a = atmospheric pressure, in Pa

h = height or distance, in m

T_o = absolute outside temperature, in K

T_i = absolute inside temperature, in K

Mechanism for Air movement through Buildings:

There are three primary mechanisms which generate the pressure differences required for air flow within and through buildings :

1. wind,
2. stack effect or buoyancy, and
3. mechanical air handling equipment and appliances.

For air flow to occur, there must be both:

1. a pressure difference between two points, and
2. a continuous flow path or opening connecting the points.

Air movement through the buildings

Successful design of naturally ventilated building requires a good understanding of the air flow patterns around it and the effect of the neighboring buildings. The objective is to ventilate the largest possible part of the indoor space. Fulfillment of this objective depends on window location, interior design and wind characteristics.

As wind approaches the face of a building the airflow is slowed, creating positive pressure and a cushion of air on the building's windward face. This cushion of air, in turn, diverts the wind toward the building sides. Airflow as it passes along the sidewalls separates from building wall surfaces and, coupled with high-speed airflow, creates suction (negative pressure) along these wall surfaces. On the building leeward side a big slow-moving eddy is created. Suction on the leeward side of the building is less than on the sidewalls (Figure 1).

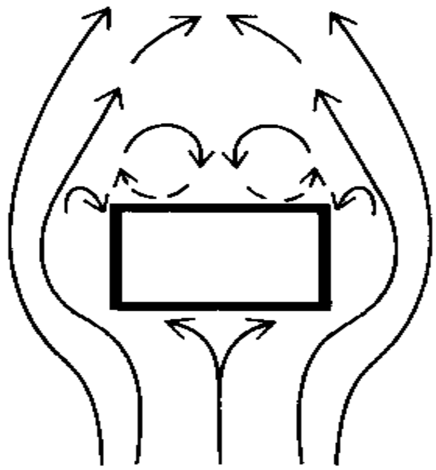


FIGURE 1

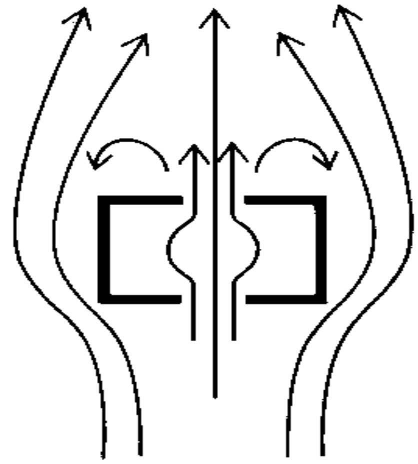


FIGURE 2

If windows are placed in both windward and leeward faces, the building would be cross ventilated and eddies will develop against the main airflow direction (Figure 2).

Ventilation can be enhanced by placing windows in sidewalls due to the increased suction at this location; also, greater air recirculation within the building will occur due to air inertia (Figure 3). Winds often shift direction, and for oblique winds, ventilation is best for rooms with windows on three adjacent walls (Figure 4) than on two opposite walls (Figure 5).

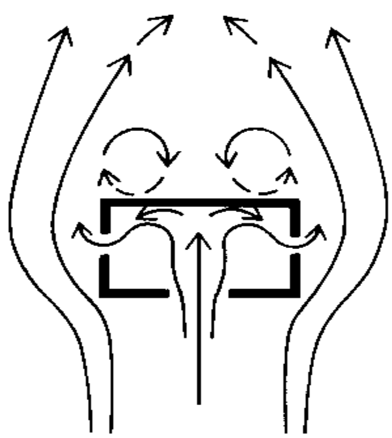


FIGURE 3

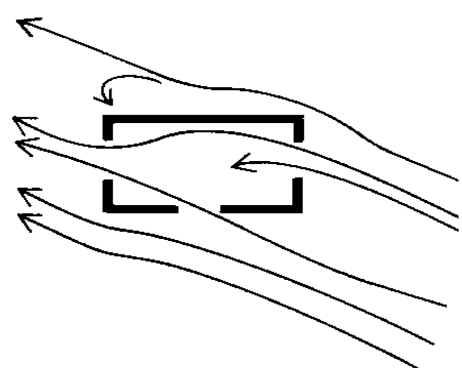


FIGURE 4

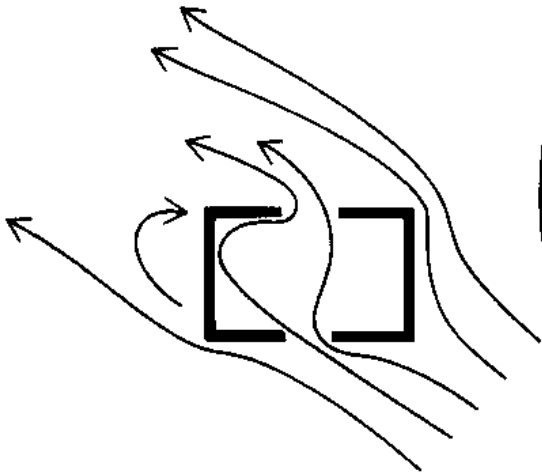


FIGURE 5

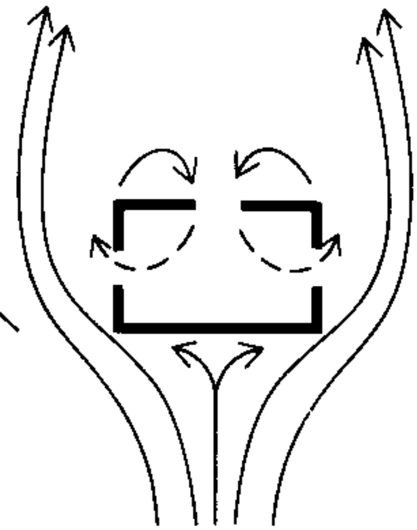


FIGURE 6

However, if wind is from the one windowless side, then ventilation is poor, since all openings are in suction (Figure 6).

If the building configuration only allows for windows in one wall, then negligible ventilation will occur with the use of a single window, because there is not a distinct inlet and outlet. Ventilation can be improved slightly with two widely spaced windows. Airflow can be enhanced in these situations by creating positive and negative pressure zones by use of architectural features such as wing walls (Figure 7). Care must be exercised in developing these features to avoid counteracting the natural airflow, thereby weakening ventilation (Figure 8).

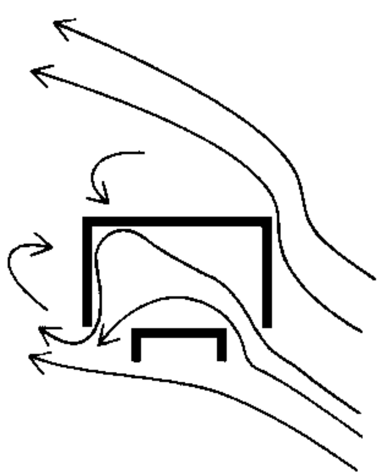


FIGURE 7

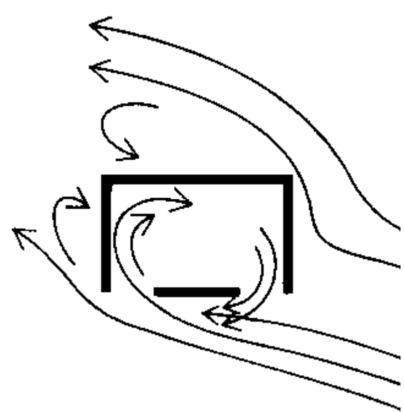


FIGURE 8

As airflow passes through a well-ventilated room, it forms an "air jet." If the windows are centered in a room, it forms a free jet (Figure 9). If, however, the openings are near the room walls, ceiling, or floor, the air stream attaches itself to the surface, forming a wall jet (Figure 10). Since heat removal from building surfaces is enhanced with increased airflow, the formation of wall jets is important in effecting rapid structure cooling. To improve the overall airflow within a room, offsetting the inlet and outlet will promote greater mixing of room air (Figure 11).

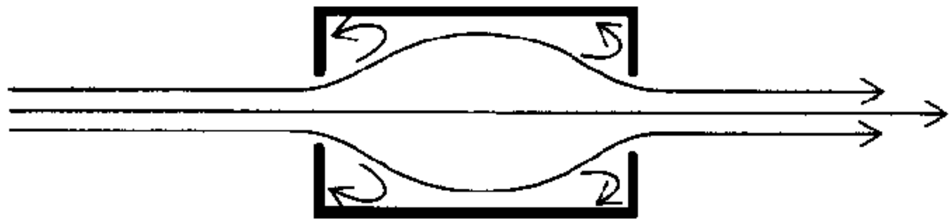


FIGURE 9

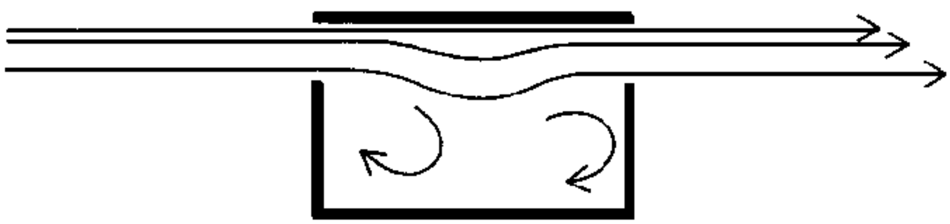


FIGURE 10

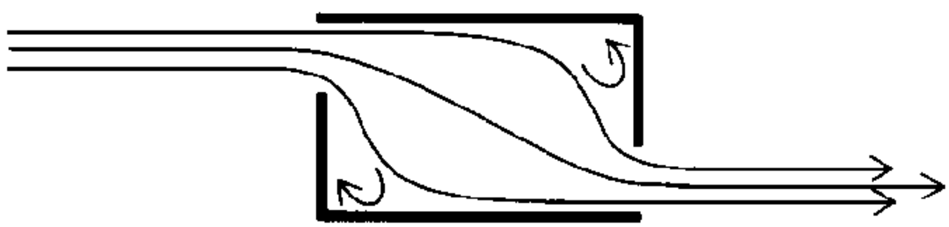
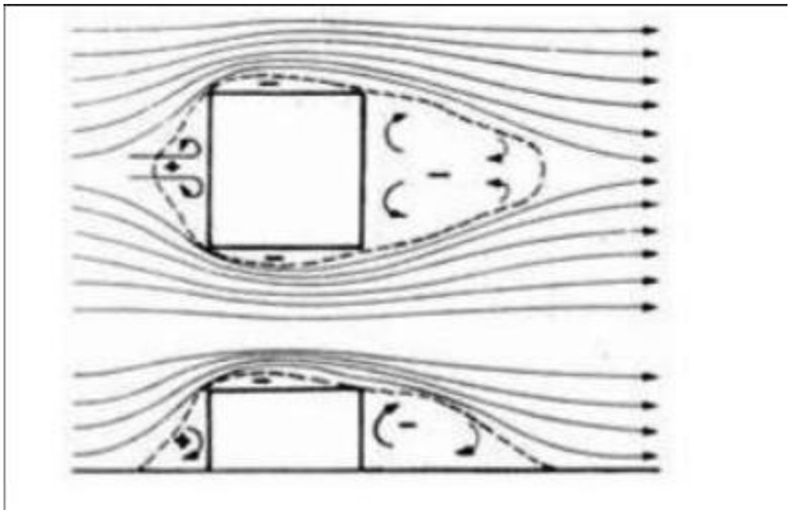


FIGURE 11

Air movement around the building

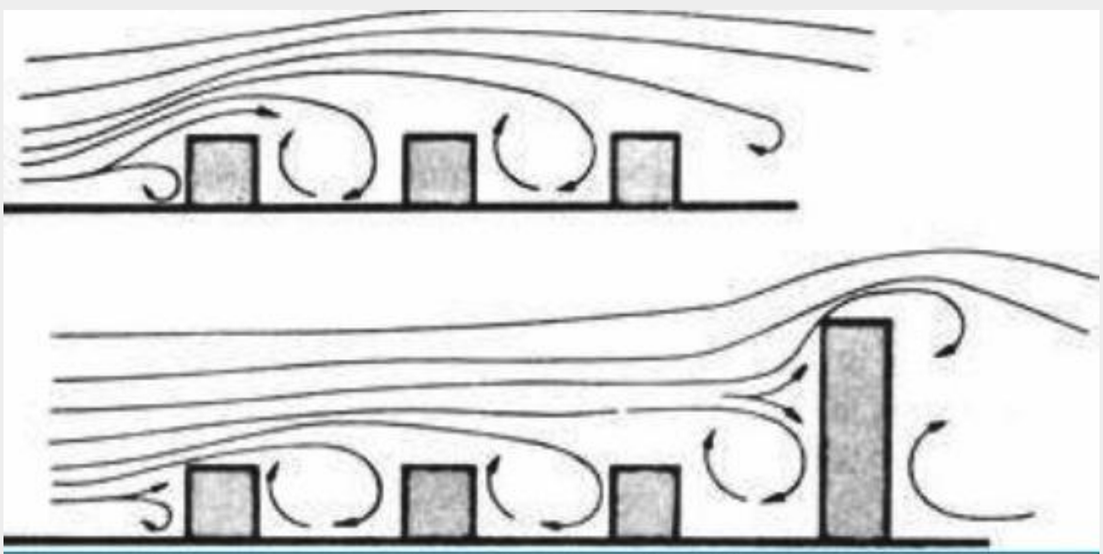
Thermal forces are rarely sufficient to create appreciable air movements. The only natural force that can be relied on is the dynamic effect of winds as shown in fig.



Air flow around the buildings in plan

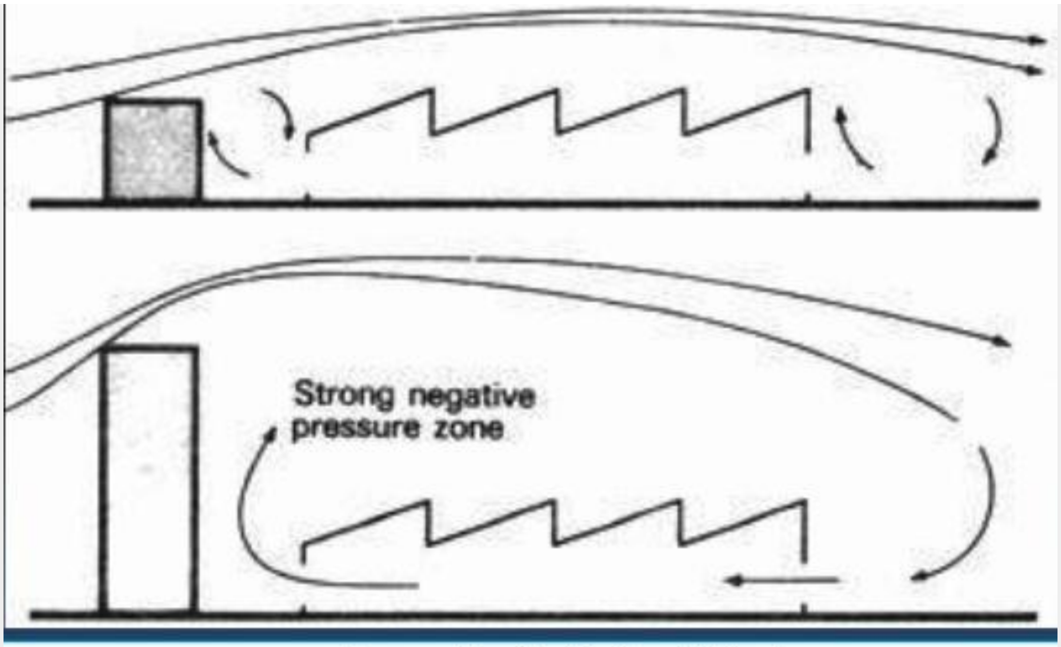
1. **Air stream separation at the face of buildings**

The effect of tall blocks in mixed developments is shown in figure. Figure shows how the air stream separates on the face of a tall block, part of it moving up and over the roof part of it down, to form a large vortex leading to a very high pressure build-up. An increased velocity is found at ground level at the sides of the tall block. This could serve a useful purpose in hot climates, although if the tall block is not fully closed but is permeable to wind, these effects may be reduced.



Air stream separation at the face of buildings

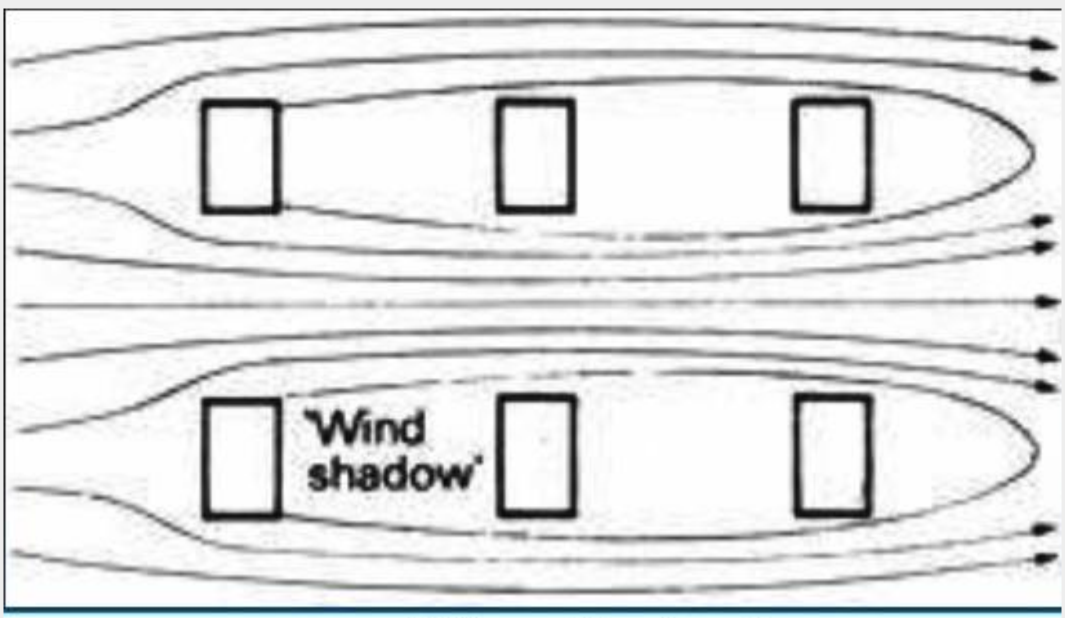
2. **Reverse flow behind a tall block** If a low building is located in the wind shadow of a Tall block , the increase in height of the obstructing block will increase the air flow Through the low building in a direction opposite to that of the wind. The lower (return-) wing of a Large vortex would pass through the building.



Reverse flow behind a tall block

3. **Air flow: grid-iron lay-out**

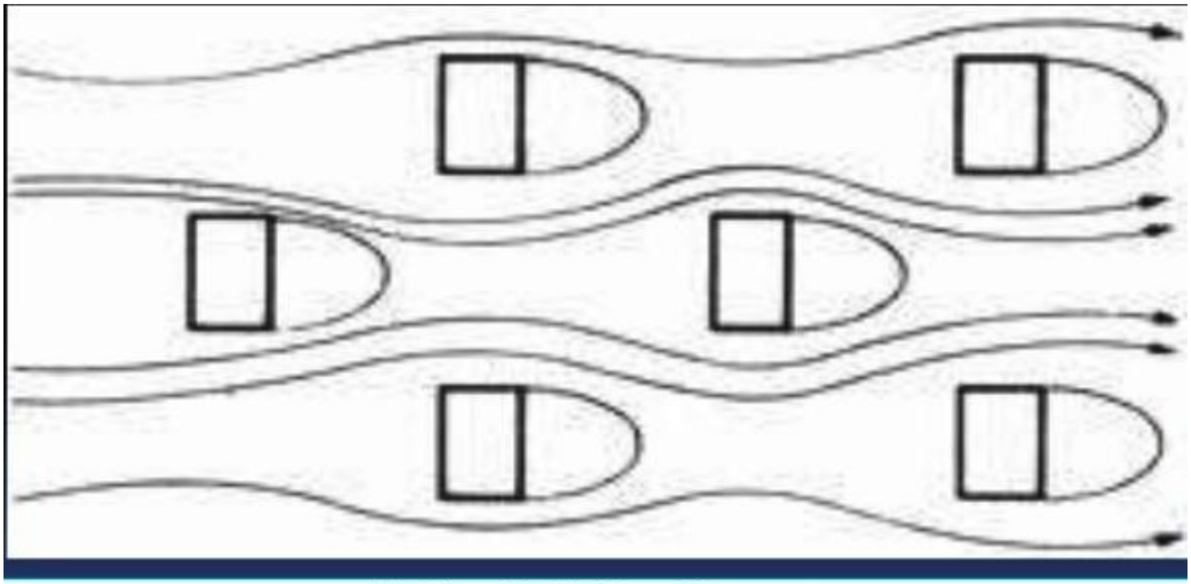
   if in a rural setting in open country, single storey buildings are placed in rows in a grid-iron pattern, stagnant air zones leeward from the first row will overlap the second row. A spacing of six times the building height is necessary to ensure adequate air movement for the second row. Thus the 'five times height' rule for spacing is not quite satisfactory



Air flow: grid-iron lay-out

4. **Air flow: checkerboard lay-out :**

   In a similar setting, if the buildings are staggered in a checker-board pattern, the flow field is much more uniform, stagnant air zones are almost eliminated.



Air flow: checkerboard lay-out

Lighting Types:

Ambient lighting

Accent lighting

Task lighting

Aesthetic Lighting

Natural lighting

i. Ambient lighting:

A hidden source of light that washes a room with a glow. It flattens an interior and creates very little shadow. A wall sconce is an example of ambient lighting. So are those Japanese paper shades you find in stores. Use of a dimmer also can provide ambient light.

ii. Accent lighting:

Directional lighting or lighting that adds interest or highlights a certain object or unusual architectural feature in a room. A bulb and some kind of shield to direct the light are all that's needed for this type of lighting. Halogen spotlights and table lamps with opaque shades are good ways to achieve accent lighting.

iii. Task lighting:

Task lighting is just that; lighting that's used to perform daily activities such as reading, cooking, shaving, putting on makeup, etc. It needs to be glare-free. Effective task lighting enhances visual clarity and keeps the eyes from getting tired.

Different banks of task light are useful in the kitchen -- near the stove and chopping areas are places for this type of lighting. Task-lighting sources are never seen and any task light should have a reflective shield. Ambient lighting and task lighting go hand in hand. Pools of light created by several spots produce a lovely effect.

iv. Aesthetic lighting:

Lighting itself can be a work of art. A neon sculpture would be purely decorative and an example of aesthetic lighting. A spotlight illuminating a statue on a pedestal or portrait on the wall is also artistic. This type of lighting also needs to be used along with other lighting types.

v. Natural lighting:

Sunlight, candlelight and firelight; this is light that moves and is sometimes referred to as kinetic. The quality of natural light, sunlight in particular, depends on many things -- time of day, weather, what season it is. Fall has a different light than summer, for instance. The setting sun gives a different kind of light than midday sun.

Exterior Building grounds lights:

Outdoor lighting can make a home look warm and inviting or majestic and regal depending on the type and placement of the lights. At the same time outdoor lighting can light driveways and pathways for guests while providing security and a deterrent to intruders. Choosing the right outdoor lighting for your home is easier to do when you have a basic understanding of the different types of outdoor lighting fixtures available. Then you can decide what lights will work best for your purpose.

There are five different types of outdoor lighting options to choose from. Each creates a certain effect and will work best in particular types of situations. The most important thing to remember when choosing outdoor lights is that light is fluid and the way it is encased and directed will have a major impact on the way the light is diffused and therefore how well it realizes your goals.

i. Path Lights or Spot Lights:

Path lights are the most commonly used outdoor lights. Placed along the sides of a walkway, path or driveway, path lights are low to the ground and spread the light down and out so that you can see where you are walking and not stray off the path. You don’t need as many lights as you might think and using too many can make your driveway look like the local airport.

Path lights work as well in the back yard as they do in the front yard and provide a warm, soft light without producing glare. Solar powered path lights are a popular option as they do not require any additional wiring or power to operate which can save on your power bill.

ii. Down lights or Flood Lights:

Motion detector lights that are placed on the house or garage are down lights. They are placed high and pointed down toward the ground and are most often used for security purposes. Down lights are very bright and create a glare so if you are using them to create natural lighting you may want to place the lights in a tree or in some other way shield them so the light is diffused and you can’t see the bulb.

iii. Up Lights:

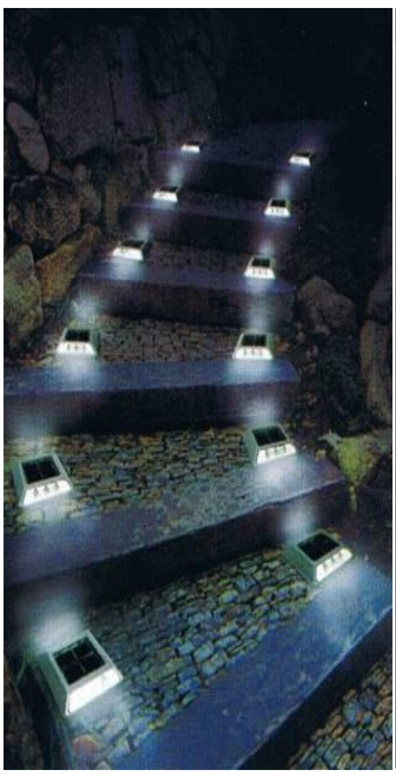
Up lights are most often spot lights that are placed on the ground and pointed upward toward a tree or fountain or anything you wish to use as a focal point with your outdoor lighting. The ambient light of up lights create can also be useful for patios and walkways as well depending on how they are placed.

iv. Backlights :

Backlights are an outdoor lighting option and are used to enhance your landscape in some artistic manner. For example, a backlight might be placed behind a plant in such a way as to cast a shadow on a wall while bringing attention to the plant. Backlights create drama and are usually placed behind an object and out of sight.

v. Specialty Lights:

specialty lights have become a popular option in outdoor lighting when creating an outdoor living space on a deck or patio. They include string lights, torches, underwater lights, lanterns and the like and are used to create mood and ambiance wherever they are placed.



Path light

Down lights

Uplights ***Speciality lights***

Backlight

Types of lights

There are four basic types of lights:

1. Incandescent,
2. Fluorescent,
3. High-intensity discharge, and
4. Low-pressure sodium

1. Incandescent Light

Light is produced by a tiny coil of tungsten wire that glows when it is heated by an electrical current. They have shortest lives and they are Inefficient

2. Fluorescent lights

- It is filled with an argon or argon-krypton gas and a small amount of mercury.
- Fluorescent lamps last about 10 times longer than incandescent bulbs

- Fluorescent lights need ballasts (i.e., devices that control the electricity used by the unit) for starting and circuit protection
- Compact Fluorescent lamps (CFL) can replace incandescents that are roughly 3 to 4 times their wattage. They last 10 to 15 times as long. Cost from 10 to 20 times more than comparable incandescent bulbs. One of the best energy efficiency investments available.

3. **High-intensity discharge light**

   High-intensity discharge (HID) lamps provide the highest efficacy and longest service life of any lighting type

   a. **mercury vapor**
   b. **metal halide**, and **high-pressure sodium**

They also require ballasts, and they take a few seconds to produce light when first turned on because the ballast needs time to establish the electric arc

4. **Low-pressure sodium light**

   - Low-pressure sodium (LPS) lamps have a borosilicate glass gas discharge tube (arc tube) containing solid sodium, a small amount of neon, and argon gas in a Penning mixture to start the gas discharge.

     - Very efficient lamp

     - Powerful lamp for use of large areas

     - Despite a warm up time of 5-10 minutes it restarts immediately if there is a brownout

     - Lumen output does not drop with age (such as in LEDs or incandescents)
   - Worst color rendering of any lamp
   - Sodium is a hazardous material which can combust when exposed to air

Study of interiors in lighting and their effects:

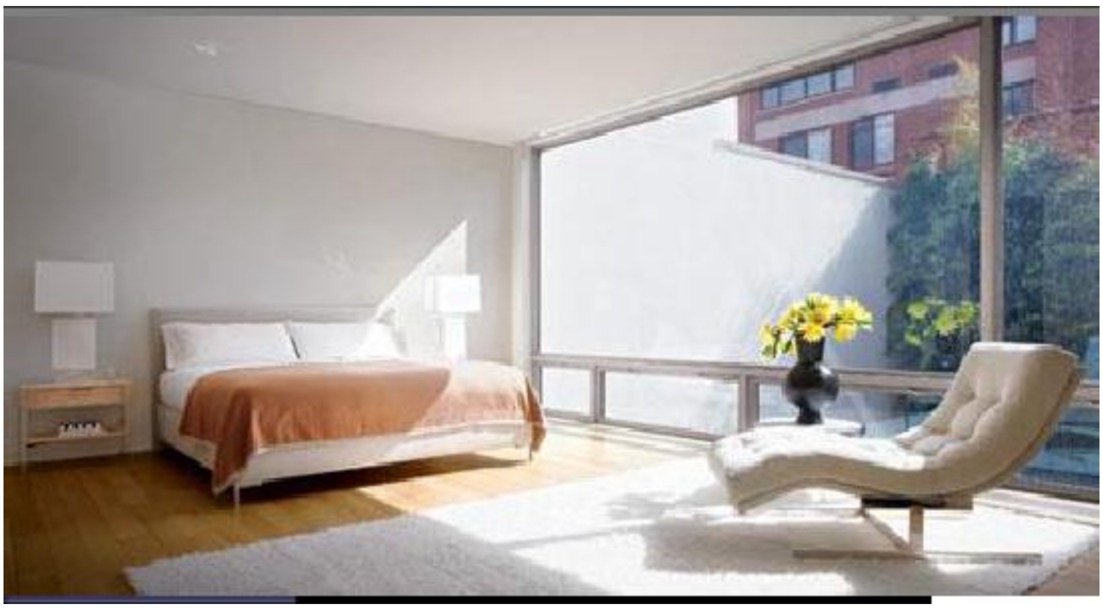
1.Begin by planning the building such that every regularly occupied work or Living space has access to a window, skylight, or other source of natural light. Give high priority to windows that provide a view. Remember that the effective day lighted area extends into the building only about 2 times the width of a window and about 2 to 2.5 times its height.

2. Minimize the size of the east and west sides of the building and maximize. The south and north sides of the building. Because of the seasonally varying Paths of the sun in the sky, it is difficult to design east- and west-facing windows. North-facing windows in the northern hemisphere present no solar Heating problems, and south-facing windows are the easiest to protect with Passive elements like overhangs, awnings, and light shelves.

3. If a large area of the building is not near a window, investigate top-light skylights in one-story buildings or the top floor of multistory buildings. Simple Top-light skylights should occupy 3% to 5% of the total roof area in order to provide adequate levels of interior lighting.

4. Protect the interior from too much natural light 2.5 times or higher the Level of ordinary electric light — by employing appropriate window glass, Exterior shading devices, interior shading devices, or a combination of these.

5. Provide an electric lighting system and/or automatic lighting controls to permit harvesting of the energy savings. The best way is to dim the electric lights rather than switch them on and off. Modern fluorescent dimming systems allow day lighting controls and fundamentally energy-efficient fluorescent and compact fluorescent lighting



The day lighting area for the bed room

Exit sign:

- An **exit sign** is a device in a public facility (such as a building, aircraft or boat) denoting the location of the closest emergency exit in case of fire or other emergency.
- Electrically powered exit signs normally use incandescent bulbs.
- Most **LED** and some **CFL** exit signs can meet ECBC requirement.
- Due to their low power consumption, LED exit signs can be purchased with built-in backup power supplies (i.e., batteries).
- With an estimated service life of 10 years or more, LEDs require significantly fewer lamp replacements than exit signs equipped with either incandescent lamps or CFLs.

Exit Signs

Introduction to Energy conservation

- It refers to reducing energy consumption through using less of an energy service. Energy conservation differs from efficient energy use, which refers to using less energy for a constant service.
- **Energy conservation** includes any behavior that results in the use of less energy.
- It focuses on the behavior of people.
- One example is using day lighting through windows rather than turning on the lights. Another example is, driving less is an example of energy conservation.
- Driving the same amount with a higher mileage vehicle is an example of energy efficiency.
- Energy conservation and efficiency are both energy reduction techniques.
- **Energy efficiency** involves the use of technology that requires less energy to perform the same function. It focuses on the equipment or machinery being used. Eg. LED light bulbs throughout the house

Energy Conservation in Lighting System (Lighting Control)

The mandatory requirements for lighting mostly relate to interior and exterior lighting controls:

i. Lighting controls allow lighting to be turned down or completely off when it is not needed – the simplest way to save energy.
ii. It includes on-off controls, dimming controls, and systems that combine the use of both types of equipment.
iii. Controls include time clocks, occupant and motion sensors, automatic or manual day lighting controls, and astronomical time switches (the automatic switches that adjust for the length of the day as it varies over the year).

iv. They perform two basic functions:1) they turn lights off when not needed, and 2) they modulate light output so that no more light than necessary is produced.
v. Use a time scheduling device to control lighting systems according to predetermined schedules.
vi. Control the lights in response to the presence or absence of people in the space.
vii. Switch or dim electric lights in response to the presence or absence of daylight illumination in the space.
viii. Gradually adjust electric light levels over time to correspond with the depreciation of light output from aging lamps.
ix. Minimum one control device per 250 m^2 coverage area is required for the total area upto 1000 m^2.
x. Minimum one control device per 1000 m^2 coverage area is required for the total area more than 1000 m^2.
xi. Lighting for all exterior applications shall be controlled by a photosensor or astronomical time switch that is capable of automatically turning off the exterior lighting when daylight is available or the lighting is not required.
xii. Display or accent lighting greater than 300 m2 (3,000 ft2) area shall have a separate control device.
xiii. Lighting in cases used for display purposes greater than 300 m2 (3,000 ft2) area shall be equipped with a separate control device.
xiv. Hotel and motel guest rooms and guest suites shall have a master control device at the main room entry that controls all permanently installed luminaires and switched receptacles.
xv. Supplemental task lighting including permanently installed under-shelf or under cabinet lighting shall have a control device integral to the luminaires or be controlled by a wall-mounted control device.
xvi. Lighting for non-visual applications, such as plant growth and food-warming, shall be equipped with a separate control device.
xvii. Lighting equipment that is for sale or for demonstrations in lighting education shall be equipped with a separate control device accessible only to authorized personnel

Energy Conservation in Ventilation System

Maximum possible use should be made of wind-induced natural ventilation. This may be accomplished by following the design guidelines

i. Adequate number of circulating fans should be installed to serve all interior working areas during the summer months in the hot dry and warm humid regions to provide necessary air movement at times when ventilation due to wind action alone does not afford sufficient relief.
ii. The capacity of a ceiling fan to meet the requirement of a room with the longer dimension D meters should be about 55D m3/min.
iii. The height of fan blades above the floor should be (3H + W)/4, where H is the height of the room, and W is the height of the work plane.

iv. The minimum distance between fan blades and the ceiling should be about 0.3 meters.

v. Electronic regulators should be used instead of resistance type regulators for controlling the speed of fans.

vi. When actual ventilated zone does not cover the entire room area, then optimum size of ceiling fan should be chosen based on the actual usable area of room, rather than the total floor area of the room. Thus smaller size of fan can be employed and energy saving could be achieved.

vii. Power consumption by larger fans is obviously higher, but their power consumption per square meter of floor area is less and service value higher. Evidently, improper use of fans irrespective of the rooms dimensions is likely to result in higher power consumption. From the point of view of energy consumption, the number of fans and the optimum sizes for rooms of different dimensions are taken from ECBC.