UNIT I
ARCHITECTURAL ENGINEERING

Stairs - Materials - Terms Used - Types of Stairs - Functional Requirements of Good Stair Case - Layout of Stair Case Planning - Introduction to Ramps, Lifts, Escalators - Heat Transfer - Insulating Materials - Method of Applications - Acoustics Sound Insulations - General Principles - Sound Absorbing Materials - Acoustical Design of Auditorium - Class Rooms – Library- Sound Insulation of Walls and Floors - Ventilation - Requirements - Types of Ventilations - Air Conditioning - Fire Resisting Construction Materials - Guidelines for Fire Resisting Buildings - Fire Protection.

STAIRS

Staircase is an important component of a building providing us the access to different floors and roof of the building. It consists of a flight of steps (stairs) and one or more intermediate landing slabs between the floor levels. Different types of staircases can be made by arranging stairs and landing slabs.

Stairs can be made of **concrete, stone, wood, steel or combination of any of these**.

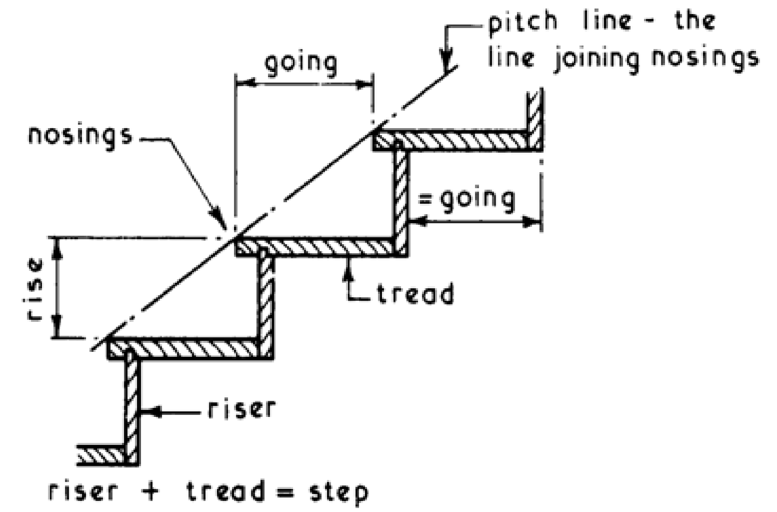
Primary functions of staircase

- Provide an access from one floor to another.
- Provide a safe means of travel between floors.
- Provide an easy mean of travel between floors.
- Provide a suitable means of escape in case of fire.
- Provide a mean of conveying fittings and furniture between floor levels.

General terminologies used in Staircase

1. Steps - A series of horizontal open treads with a space between the treads with a space between the treads or as enclosed steps with a vertical face between the treads as shown in the figure below.

- Tread – horizontal surface of a step
- Riser – vertical surface or near vertical of a step

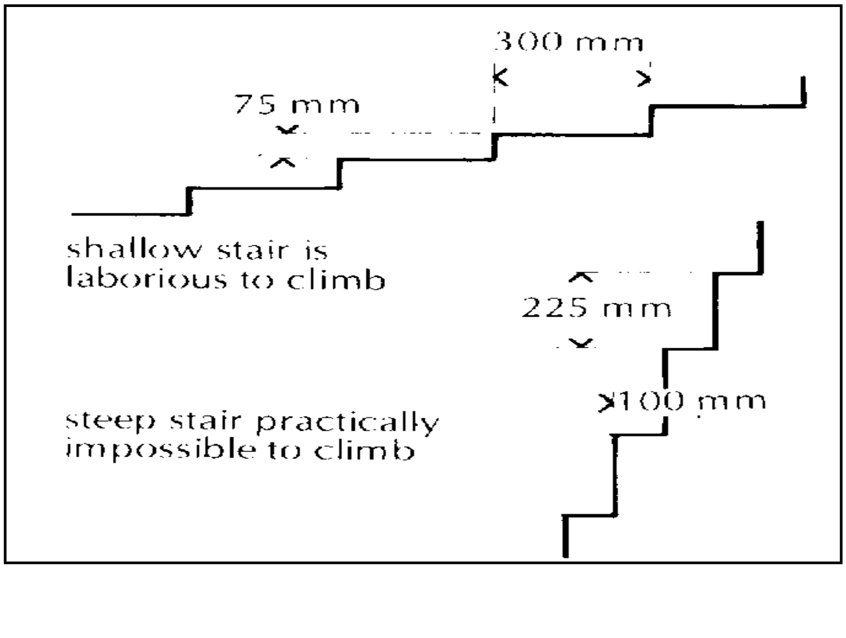


2. Nosing - In some cases the tread is projected outward to increase the space. This projection is designated as nosing

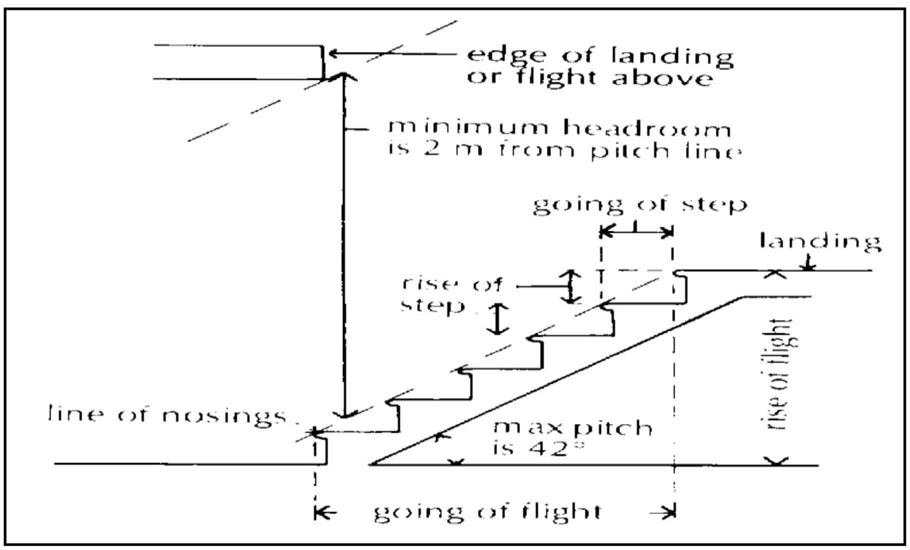
3. Waist - The thickness of the waist-slab on which steps are made is known as waist. The depth (thickness) of the waist is the minimum thickness perpendicular to the soffit (the underside) of the staircase. The steps of the staircase resting on waist-slab can be made of bricks or concrete.

4. Going - Going is the horizontal projection between the first and the last riser of an inclined flight.

5. Flight – It is an uninterrupted series of steps between floor and landing, or between landing and landing. A flight should have no fewer than 3 steps and no more than 16 risers. The rise and tread in one flight and landings between floors should be equal. The rise and tread should have the same size to avoid interruption in the rhythm of going up or down. The dimension of the riser and thread will determine whether the stair is steep or shallow. The steeper stair will save more space and is accepted for houses because the occupants are more familiar with the stair. The shallow stair requires more area but suitable for public building to minimize danger to the public escaping via stair during emergency.



6. **Head Room** – It is a clearance height between the pitch line of the stair and the underside of the stairs, landings and floors above the stair. Minimum 2 m clearance from the pitch line for a convenience of human and goods movement.

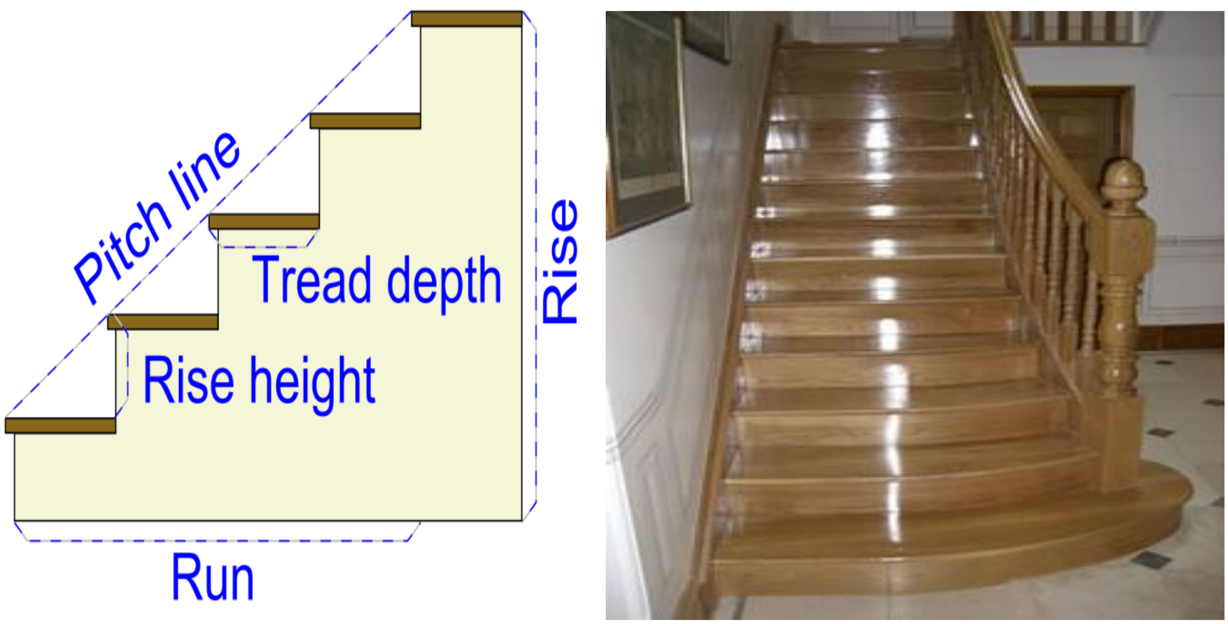


7. **Baluster –** It is a vertical stand that supports handrails for security purposes. It can be made from timber or steel. It is bolted to the sides of flights or through the material, grouted or set in mortises either cast or cut in the material.
8. **Handrail –** It is a horizontal member fixed on the top of series of balusters. It can be made from timber or steel.
9. **Balustrade-** A series of baluster, capped by a handrail.

Types of Stairs

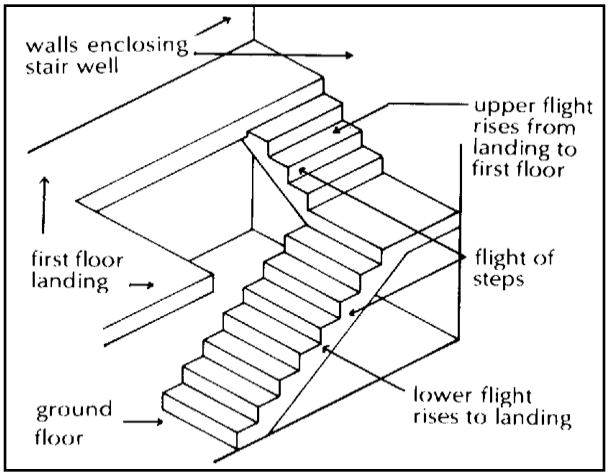
1. Straight flight/straight run
2. Quarter turn/L-shaped
3. Half turn (dog leg)/180 return
4. Spiral (helical) & elliptical
5. Winder

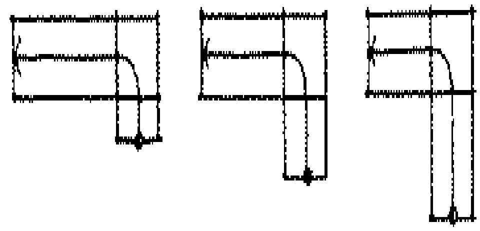
1. **Straight flight/straight run** – It rises from the floor to floor in one direction with or without an intermediate landing. It is also known as 'cottage stair'. It is commonly used in the traditional 'two-up two-down' cottage. The most economical use of the straight flight is to locate the stair in the centre of the plan running for front to back.



Straight flight/straight runs

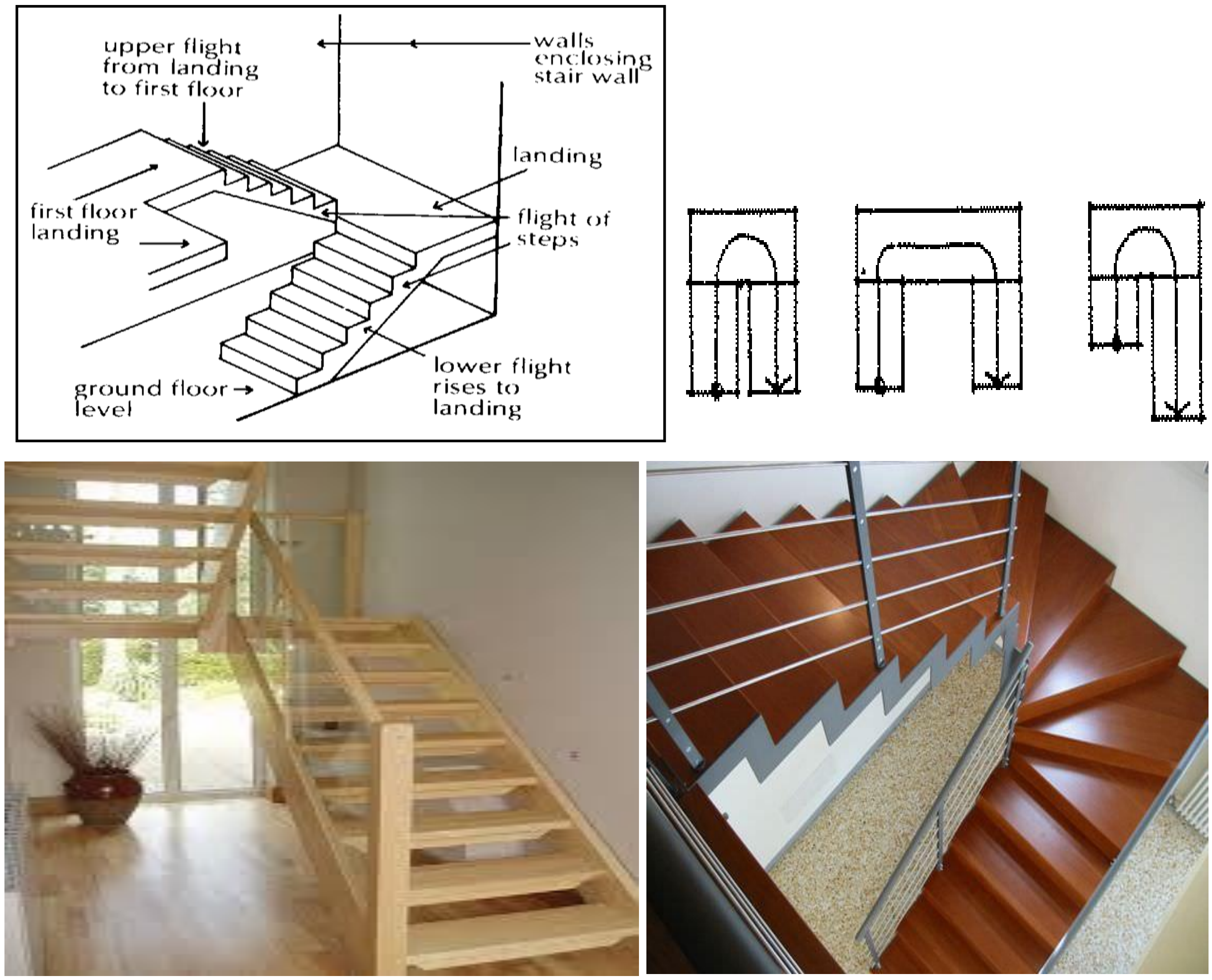
2. **Quarter turn/L-shaped** – It rises to a landing between two floors, turns through 90˚, then rises to the floor above. It is good in compact planning. The quarter turn sometime will be replaced with winders for economic use of space.





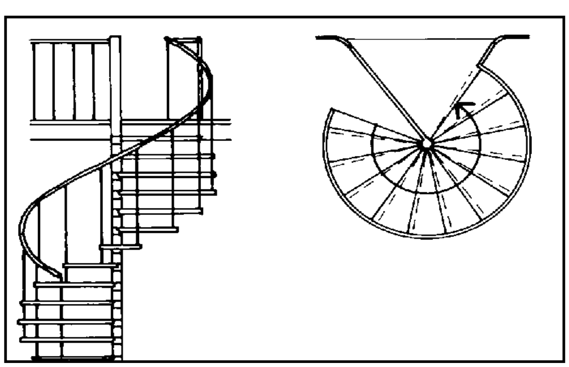
Quarter turn/L-shaped

3. **Half turn (dog leg)/180 return** – It rises to a landing between floors, turns through 180˚, then rises parallel to the lower flight to the floor above. It is said to be the most common arrangement of stairs. The main advantage of this type is, it can be constructed within the confined vertical stair well.

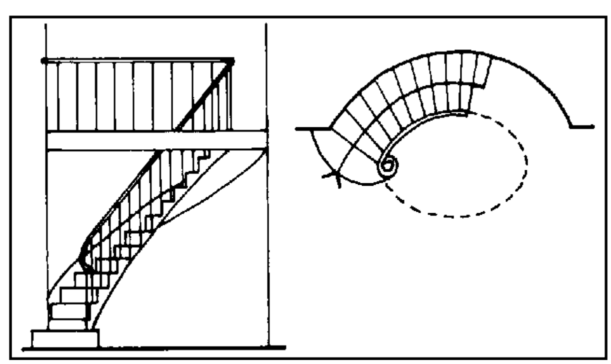


Half turn (dog leg)/180 return

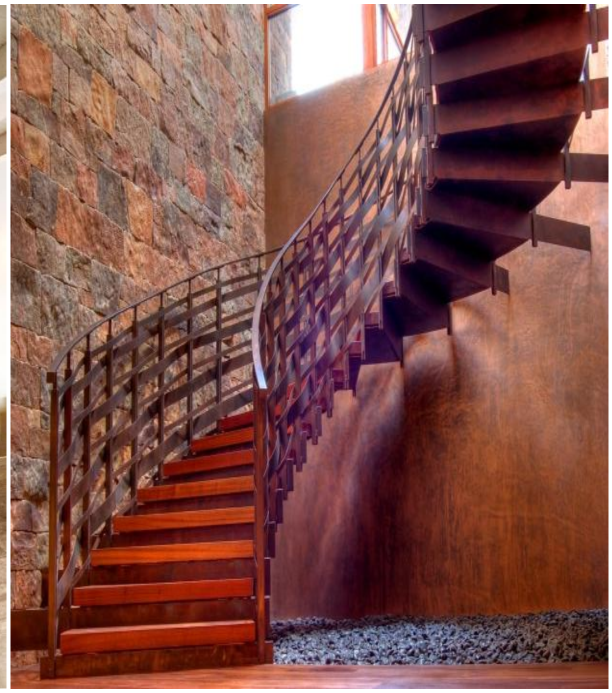
4. **Spiral (helical) & Elliptical** - It is constructed as either a spiral (helical) stair or an ellipse stair. It is the most economical way to save space, but difficult to use due to the sharp turns. Very dangerous for the very young and elderly. Usually use where the space is very limited for access to an intermediate floor of one room.



Spiral (Helical)

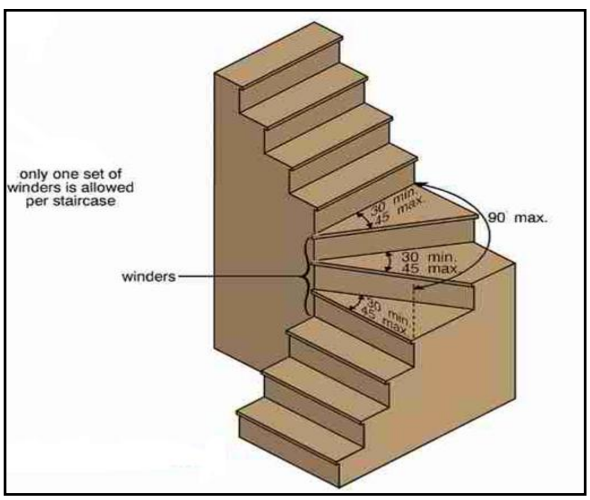


Elliptical

Spiral (Helical) **Elliptical**

5. **Winder Stairs** – It is a triangular treads or tapered treads that wind around quarter of half turn in place of landings. It is adopted to reduce the number of steps required in the rest of the stair and to economize in space. It is usually used in domestic stairs. It can be hazardous as they only offer little foothold at the interior corner. It is not recommended for public buildings in the means of escape stairs especially for the very young and elders.



Winder Stairs

Materials used for staircase construction

1. Timber –It is constructed from timber board and it is commonly used for domestic work. The design of stairs flight landings or tapered steps is depend on the space to accommodate it. The handrail balustrade is of mere importance which provides visual and practical safety barrier to the side of stairs.

2. Precast Concrete – Using this kind of material variety of stair types and arrangements are possible, which of having its own appearance, characteristic and method of construction. It is commonly use as it is non-combustible, stronger and hardwearing. Will maintain its strength and integrity for a reasonable period during an outbreak of fire. Therefore, it is more suitable than timber stair as an escape route.

3. Cast-in situ – There is a possibility of framing variety of stair types and arrangements, which of having its own appearance, characteristic and method of construction. It is non-combustible, stronger and hard wearing. It can maintain its strength and integrity for a reasonable period during an outbreak of fire. Therefore, it is more suitable than timber stair as an escape route.

Typical in-situ RC stairs are:

a. Inclined slab stair
b. Cranked slab stair
c. String beam stair
d. Cantilever stair

4. Metal – It can be produced in cast iron, mild steel or aluminium alloy for both external and internal used. It is usually is custom made, therefore is more expensive. The steel channel section serves as stringer. The treads can be in the form of steel pan filled with concrete, steel flat plate with textured top surface or bar grating. It can be painted or covered with concrete for fire safety reason. The main advantage is there is no need of formwork during construction but the main disadvantage is regular maintenance is required in the form of painting.

5. Stone – It is traditionally constructed using natural stone as the steps. It can be formed as Rectangular or stepped soffit and Flush soffit. The end of the steps are built into the walls. The landings are constructed using one or more large slab of natural stone built into enclosing walls and bearing on the steps below.

Functional Requirements of Good Stair Case

A good stair should provide an easy, quick and safe mode of communication between the various floors of the building. General requirements of good stairs are as mentioned below.

Location - it should preferably be located centrally, ensuring sufficient light and ventilation.

Width of stair - the width of stairs for public buildings should be 1.8 m and for residential buildings 0.9 m.

Length - the flight of the stairs should be restricted to a maximum of 12 and minimum of 3 steps.

Pitch of stair - the pitch of long stairs should be made flatter by introducing landing. The slope should not exceed 400 and should not be less than 250.

Head room - the distance between the tread and soffit of the flight immediately above it, should not be less than 2.1 to 2.3 m. this much of height is maintained so that a tall person can use the stairs with some luggage on its head.

Materials - stairs should be constructed using fire resisting materials. Materials also should have sufficient strength to resist any impact.

Balustrade - all open well stairs should be provided with balustrades, to avoid accidents. in case of wide stairs it should be provided with hand rails on both sides.

Landing - the width of the landing should not be less than the width of the stair.

Winders - these should be avoided and if found necessary, may be provided at lower end of the flight.

Step proportions - the ratio of the going and the rise of a step should be well proportioned to ensure a comfortable access to the stair way.

Following empirical rules may be followed.

- Treads/Goings in cm + 2 (rise in cm) = 60
- Treads/Goings in cm x (rise in cm) = 400 to 450 appx.
- Treads/Goings in cm + (rise in cm) = 40 to 45 appx.
- Standard sizes: Tread 30 cm, Rise 14 cm

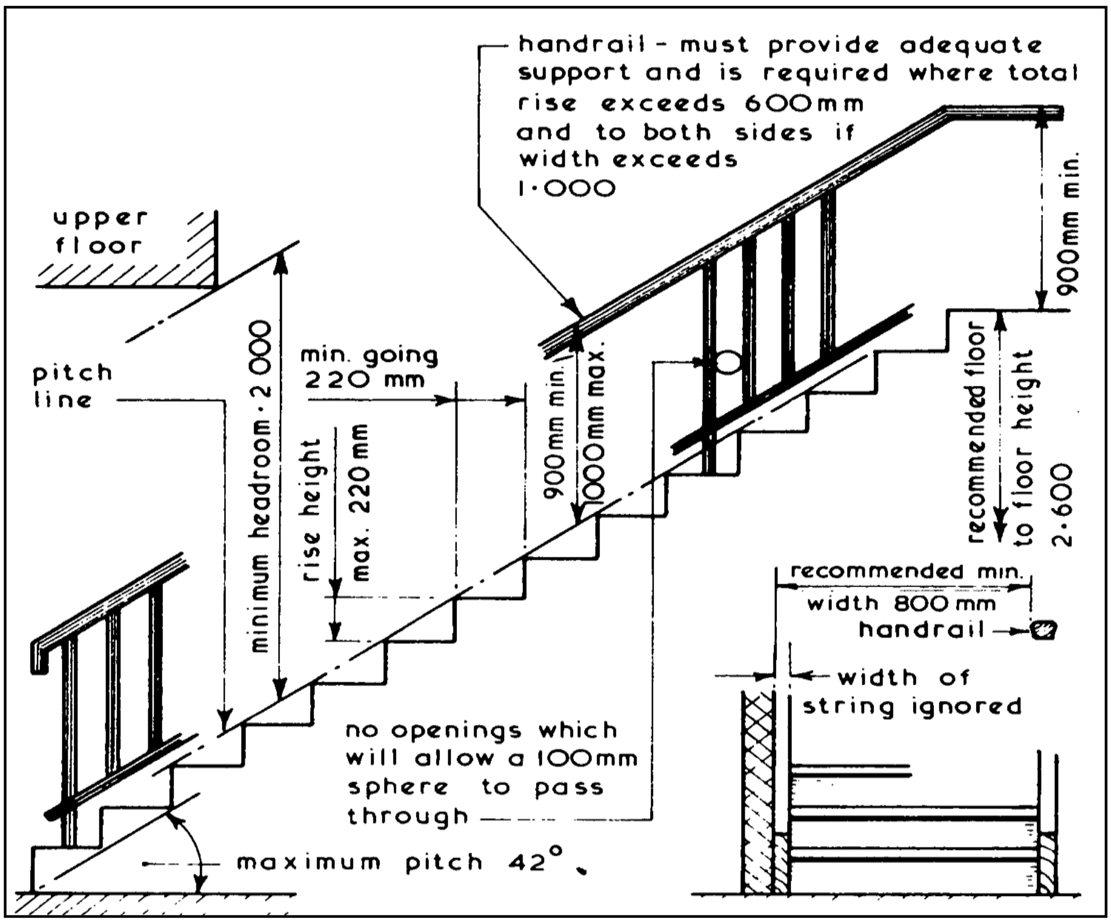
Other combinations of rise and going can be calculated by subtracting 20 mm from going and adding 10 mm to rise. Thus other combinations of rise and going would be

- Rise 15 cm x Tread 28 cm
- Rise 16 cm x Tread 26 cm
- Rise 17 cm x Tread 24 cm

Generally adopted sizes of steps are:

- Public buildings: (27 cm x 15 cm) to (30 x 14 cm)
- Residential buildings: 25 cm x 16 cm

Layout of Stair Case Planning



Introduction to Ramps, Lifts, Escalators

RAMPS

Ramps are sloped pathways used both inside and outside buildings used to provide ease of access and manoeuvrability. Ramps are required to assist wheelchair users, people with mobility issues and people with prams, bicycles and other wheeled items.

The gradient, slope or steepness of a ramp the angular relationship between the rise (vertical height) to the horizontal projection or length (run), often expressed as a ratio. The rise is frequently set at a unit of one, such that a slope of 1:20 means that as each dimensional unit of height rises or falls, the dimensional unit of length runs out or retracts 20 units. A ramp that has too steep a slope will prove difficult for people to use and could even be unsafe.

There are a wide range of issues that must be considered in the design of ramps, including:

- The appropriate steepness, length and width.
- The distance between landings.
- Identifying the primary user, and the mode of assistance they are likely to use.
- Surface material.
- The entryway that is most suitable for a ramp.
- The position of handrails and barriers.
- Placement of existing door handles and swing direction of doors.
- Impact of a ramp on available space, existing trees, vegetation, poles, etc.
- Cost of installing a ramp.
- Compliance with the building regulations.
- Alternative means of access.

In all cases, it is recommended that stair access also be provided since ramps are not necessarily safe or convenient for all people with mobility issues. Where the total rise is greater than 2 metres, alternative means of access for wheelchair users should be made available such as a lift.

The gradient of a ramp and its going (horizontal distance) between landings must be in accordance with the following table:

Max. going of ramp	Max. gradient	Max. rise
10m	1:20	500mm
9m	1:19	473mm
8m	1:18	444mm
7m	1:17	411mm
6m	1:16	375mm
5m	1:15	333mm
4m	1:14	285mm
3m	1:13	230mm
2m	1:12	166mm

External ramps

The requirements are as follows:

- Gradients should be as shallow as is practicable.
- The surface should be firm and even.
- Stairs should also be provided as adverse weather conditions can increase the risk of slipping on a ramp.
- Landings should be at least 1.2 metres long at both the foot and head of the ramp.
- Support in the form of handrails should be provided on both sides of the ramp.
- The approach to the ramp should be clearly marked.
- Flights should have a going of less than 10 metres and a rise of less than 500 mm.
- The surface width of a ramp between walls, upstands or kerbs must be at least 1.5 metres.

- The surface of the ramp must be slip resistant and of a colour that contrasts visually with that of the landings. However, the frictional characteristics of the ramp and landing should be similar.
- Immediate landings should be provided as passing places (at least 1800 mm wide x 1800 mm long) when it is not possible to see from one end of the ramp to the other, or where the ramphas 3 or more flights.
- All landings should be level, subject to a maximum gradient of 1:60 along the length, and a maximum cross-fall gradient of 1:40.

Internal ramps

The design considerations for internal ramps are the same as those above for external ramps, excluding the issues relating to the external environment.

Steps should be provided as well as a ramp unless one of the following criteria can be fulfilled:

- The ramp is sufficiently short.
- The ramp has a shallow gradient.
- The rise is no more than the minimum that can be provided by two risers.

LIFTS

A lift (or elevator) is a form of vertical transportation between building floors, levels or decks, commonly used in offices, public buildings and other types of multi-storey accommodation.

Lifts can be essential for providing vertical circulation, particularly in tall buildings, for wheelchair and other non-ambulant building users and for the vertical transportation of goods. Some lifts may also be used for firefighting and evacuation purposes.

It is defined as ‘a lifting appliance serving specific levels, having a car moving along rigid guides or a fixed course and inclined at an angle of more than 15 degrees to the horizontal, intended for the transport of:

- People.
- People and goods.
- Goods alone, if a person may enter without difficulty and fitted with controls inside the car or within reach of a person inside.’

There are several different types of lift, including:

- **Hydraulic**: An above ground or in-ground piston is used for raising and lowering under hydraulic pressure. Hydraulic lifts are generally only suitable in buildings of up to 8 storey.
- **Traction**: Electrically-powered cable-operated lifts driven by steel ropes rolled over a pulley and balanced by a counterweight (often a second lift moving in the opposite direction).
- **Roped hydraulics or hybrid lifts**: Using both ropes and hydraulic power.
- **Climbing lifts**, which include their own means of propulsion, rather than being pulled or pushed from elsewhere.

Lifts that include glass panels, and are within a shaft that includes glass panels, or are not within a shaft, sometimes on the outside of buildings may be referred to as ‘scenic lifts’. Where a lift is within a class enclosure, this might be described as a 'capsule lift'.

In very tall buildings, sky lobbies may be provided, which are intermediate floors allowing passengers to transfer from an express lift that only stops at the sky lobby, to another lift that serves storey above the lobby. In such cases two different types of lifts are used as follows:

Evacuation lifts and Firefighting lifts

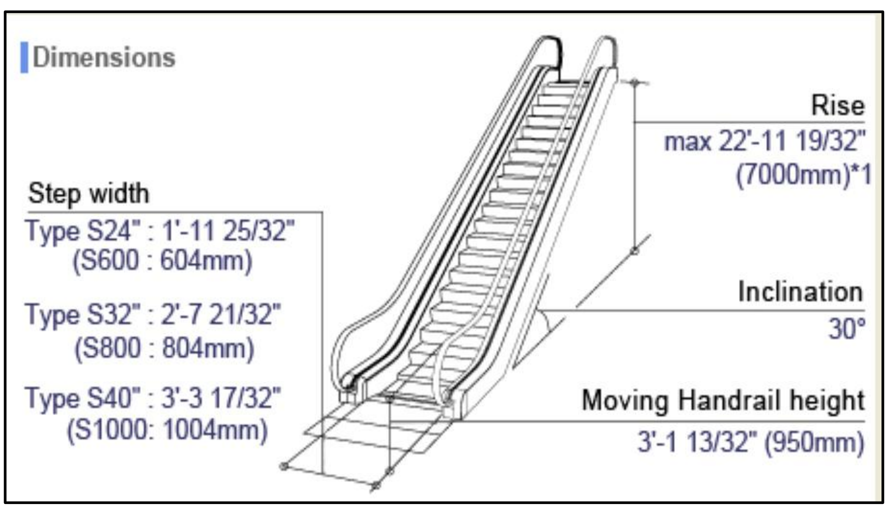
In general it is not appropriate to use lifts when there is a fire in the building because there is always the danger of people being trapped in a lift that has become immobilized as a result of the fire. However, in some circumstances a lift may be provided as part of a management plan for evacuating people. In such cases the lift installation may need to be appropriately sited and protected and may need to contain a number of safety features that are intended to ensure that the lift remains usable for evacuation purposes during the fire. The firefighting lift has been exclusively provided for evacuating disabled people. A lift designed to have additional protection, with controls that enable it to be used under the direct control of the fire and rescue service in fighting a fire. A firefighting lift is required if the building has a floor more than 18m above, or more than 10m below fire service vehicle access level.

ESCALATORS

An escalator is a moving staircase – a conveyor transport device for carrying people between floors of a building. The device consists of a motor-driven chain of individual, linked steps that move up or down on tracks, allowing the step treads to remain horizontal. Escalators are used around the world to move pedestrian traffic in places where elevators would be impractical. Principal areas of usage include department stores, shopping malls, airports, transit systems, convention centers, hotels, arenas, stadiums and public buildings.

Design and layout consideration

Escalators, like moving walkways, are often powered by constant-speed alternating current motors and move at approximately 1–2 feet (0.3–0.6 m) per second. The typical angle of inclination of an escalator to the horizontal floor level is 30 degrees with a standard rise up to about 60 feet (18 m). Modern escalators have single-piece aluminum or stainless steel steps that move on a system of tracks in a continuous loop.



Design and layout consideration

Factors affect escalator designs are:

1. Physical requirements
2. Location
3. Traffic patterns
4. Safety considerations, and
5. Aesthetic preferences.

Components of escalators

Landing platform: These two platforms house the curved sections of the tracks, as well as the gears and motors that drive the stairs. The top platform contains the motor assembly and the main drive gear, while the bottom holds the step return idler sprockets.

Floor plate: It provides a place for the passengers to stand before they step onto the moving stairs. This plate is flush with the finished floor and is either hinged or removable to allow easy access to the machinery below.

Truss: The truss is a hollow metal structure that bridges the lower and upper landings. It is composed of two side sections joined together with cross braces across the bottom and just below the top. The ends of the truss are attached to the top and bottom landing platforms via steel or concrete supports. The truss carries the entire straight track

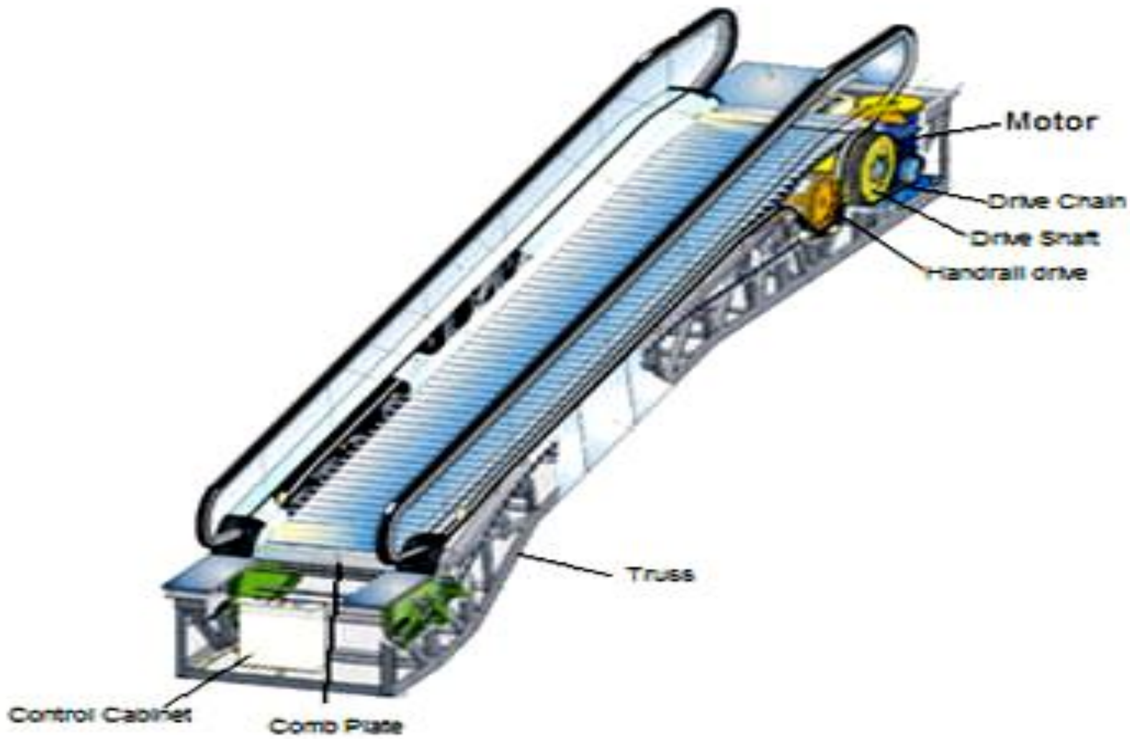
Steps: The steps themselves are solid, one piece, die-cast aluminum or steel. The steps are linked by a continuous metal chain that forms a closed loop. The front and back edges of the steps are each connected to two wheels. The rear wheels are set further apart to fit into the back track and the front wheels have shorter axles to fit into the narrower front track. These are basically moving platform on which escalator passenger’s ride.

Handrail: The handrail provides a convenient handhold for passengers while they are riding the escalator. In an escalator, the handrail is pulled along its track by a chain that is connected to the main drive gear by a series of pulleys. It is constructed of four distinct sections. At the center of the handrail is a "slider", also known as a "glider ply", which is a layer of a cotton or synthetic textile.

Deck board: These are used for preventing clothing from getting caught and other such problems.

Balustrade: The side of an escalator extending above the Steps, which includes Skirt Guard, Interior Panel, Deck Board and Moving Handrails.

Tracks: The track system is built into the truss to guide the step chain, which continuously pulls the steps from the bottom platform and back to the top in an endless loop. There are actually two tracks: one for the front wheels of the steps (called the step-wheel track) and one for the back wheels of the steps (called the trailer-wheel track). The relative positions of these tracks cause the steps to form a staircase as they move out from under the comb plate. This right angle bends the steps into a shape resembling a staircase.



Components of escalators

Types of escalators

1. ***Parallel:*** These types of escalator go up and down simultaneously.
   - Speed: 0.5m/s
   - Inclination: 30, 35
   - Step width: 800 / 1000
   - Power: 50 Hz / 3p
   - Handrails: Rubber /Stainless steel
   - Step: stainless steel
   - Landing plate: anti skid stainless steel.
   - Operation: Emergency stop button/ Key switch / Inspection operation.
   - Illumination: lighting under upper and lower landing steps.
   - Indicator: Failure indicator on control cabinet.

Parallel Escalator

2. ***Multi parallel:*** These types of escalator go up and down simultaneously with more than two.
   - Speed: 0.5m/s
   - Inclinations: 30, 35
   - Step widths: 800 / 1000
   - Power: 50 Hz / 3p
   - Handrails: Rubber /Stainless steel
   - Step: stainless steel
   - Landing plate: anti skid stainless steel
   - Operation: Emergency stop button/ Key switch / Inspection operation.
   - Illumination: lighting under upper and lower landing steps.
   - Indicator: Failure indicator on control cabinet.

Multi Parallel Escalator

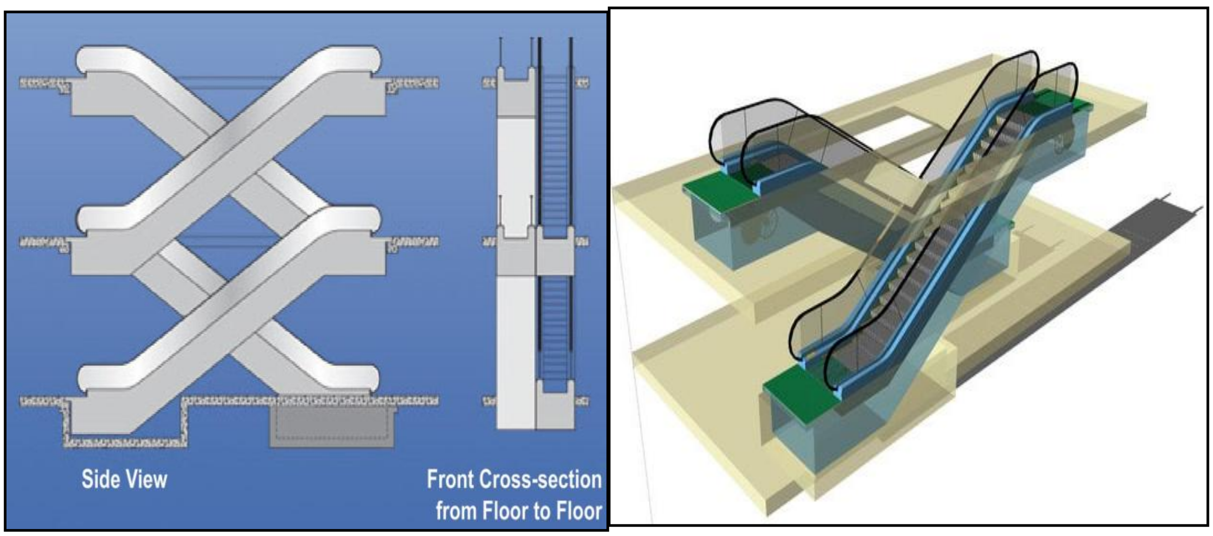
3. ***Spiral type escalators:*** These are used to enhance the architectural beauty and to save the space.

- Inclined Angle: 30''
- Rated Speed [m/sec]: 25
- Number of Persons: 6300 per hour
- Rated Speed (meters/sec.): 25 m/ min
- Vertical Rise (m): 3500 ~ 6600

Spiral type escalators

4. ***Criss-cross:*** They stack the escalators that go in single direction and reduces structural space requirement.

➢ Step width: 600 / 800 / 1000
➢ Power: 300V / 50 Hz / 3p
➢ Handrails: Rubber /Stainless steel.
➢ Step: stainless steel.
➢ Landing plate: anti skid stainless steel.
➢ Operation: Emergency stop button / Key switch / Inspection operation.
➢ Illumination: lighting under upper and lower landing steps.
➢ Indicator: Failure indicator on control cabinet.



Criss-cross Escalator

Advantages of Escalators

➢ It helps a large no. of people in moving from one place to another at the same time and they reduce the need of elevator because people would not have to wait for elevator and escalator can carry a large no. of people at the same time.
➢ It is helpful for the people that have pain in their legs and joints i.e it provide comfort to the people
➢ Escalators are effective when used as a mean of guidance and circulation.
➢ Their speed can be adjusted which is helpful in managing the crowd.
➢ When turned off they can be used a staircase.

Disadvantages of Escalators

- Waste of energy when not in use.
- Possible injuries when stopped suddenly
- Source of fear for small children

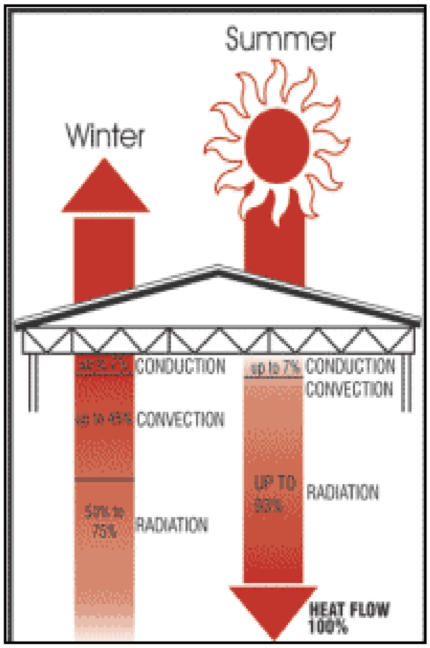
HEAT TRANSFER

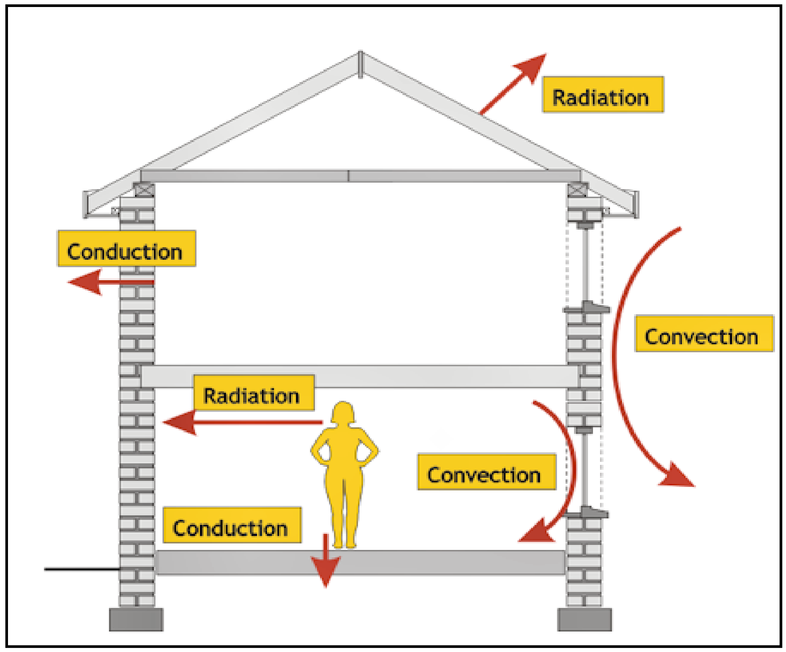
Heat transfer is the process of thermal exchange between different systems. Generally the net heat transfer between two systems will be from the hotter system to the cooler system. It is particularly important in buildings for determining the design of the building fabric, and for designing the passive and active systems necessary to deliver the required thermal conditions for the minimum consumption of resources.

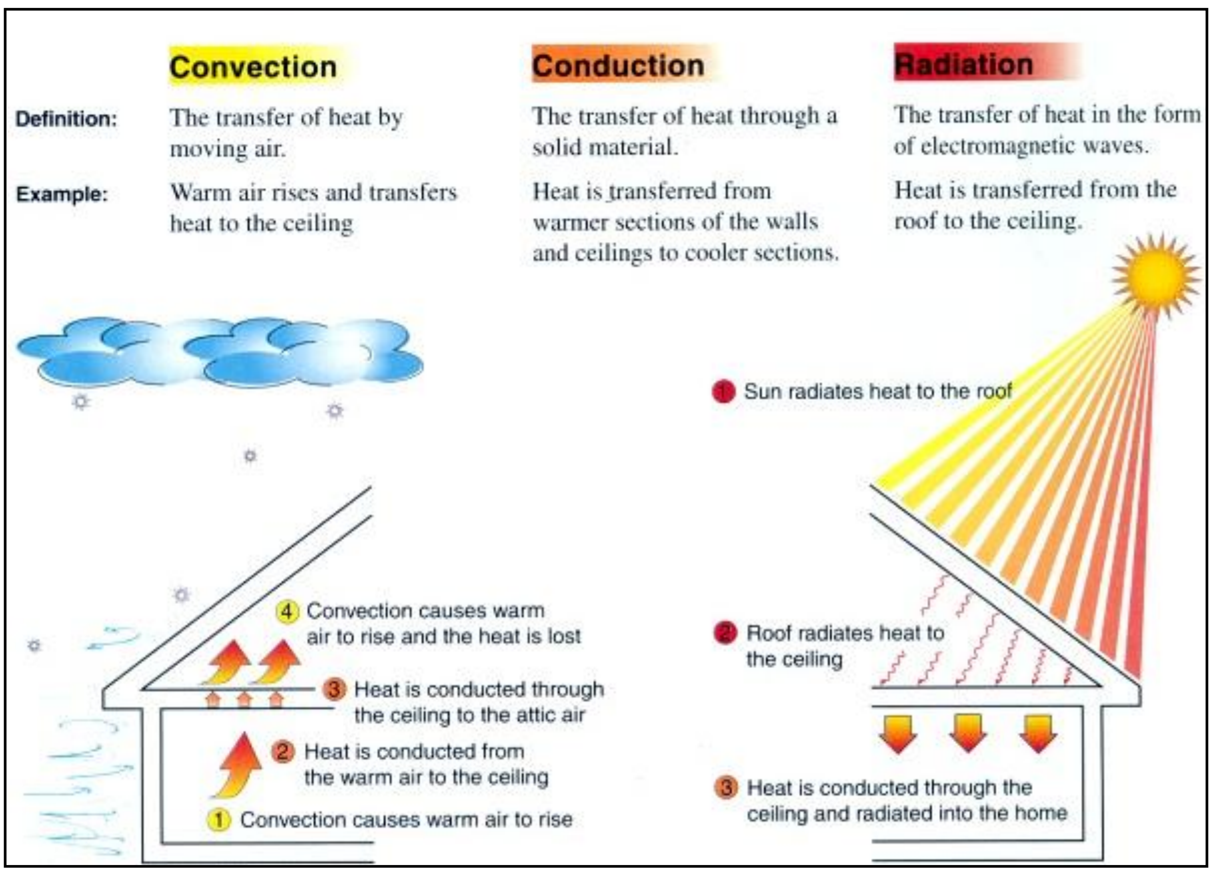
The mechanisms of heat transfer can be described as:

- Conduction.
- Convection.
- Radiation.
- Phase change.

The thermal behavior of a system is a function of the dynamic relationship between these mechanisms.







Mechanisms of heat transfer

Conduction – It is the diffusion of internal heat within a body as a result of a temperature difference across it. This is particularly important in buildings where there may be a temperature difference between the inside and outside of a building, such as in a heated building during winter. Conduction is one of the main potential heat transfer mechanisms by which the internal heating or cooling can be lost to the outside, resulting in high operating costs, high carbon emissions and occupant discomfort.

Convection - It is the movement of a fluid, such as the air, by advection and diffusion. This is a very important mechanism in the design of buildings, where air movement is necessary to:

- Moderate internal temperatures.
- Reduce the accumulation of moisture, odors and other gases that can build up during occupied periods.
- Improve the comfort of occupants.

Convection – It is also a heat transfer mechanism, resulting from the movement of air of different temperatures. Air movement in buildings can be 'forced' (for example driven by fans), or 'natural' resulting from pressure differences from one part of a building to another. Natural air movement can be either wind driven, or buoyancy driven.

Radiation - All bodies which are hotter than 0° Kelvin emit thermal radiation. They also absorb thermal radiation emitted by their surroundings. The difference in the total amount of radiation emitted and absorbed by a body at any given moment may result in a net heat transfer which will produce a change in the temperature of that body.

The range of terrestrial temperatures experienced within the built environment is relatively small, and relative to the temperature of the sun this range is 'cold' and so radiating at a 'long' wavelength compared to the sun. This anomaly allows us to categorize thermal radiation as short-wave solar radiation and terrestrial or long wave infra-red radiation. Surfaces in the built environment will tend to absorb solar radiation and emit long wave infra-red radiation.

Phase Change - When substances change phase, for example changing from liquid to gas, they absorb or release heat energy. For example, when water evaporates, it absorbs heat, producing a cooling effect, and when it condenses it releases heat. So when water evaporates from the surface of a building, or when sweat evaporates from the skin, it has a cooling effect.

This is also important in refrigeration, where refrigerant gases absorb heat from the cooling medium (typically water) as they evaporate, and when they condense, they release heat which is rejected to the outside (or recovered).

Phase change materials can also be used in construction to reduce internal temperature changes by storing latent heat in the solid-liquid or liquid-gas phase change of a material.

INSULATING MATERIALS

Definition for Insulation

Insulation refers to an energy savings measure, which provides resistance to heat flow. Naturally, heat flows from a warmer to a cooler space. By insulating a house, one can reduce the heat loss in buildings in cold weather or climate, and reduce the heat surplus in warmer weather or climate. Insulating a house has several benefits such as energy savings, cost savings and increased comfort. Barriers to undertake energy savings measures may be split incentives, relatively high investment costs, and the time and effort required to realize the energy savings.

There are several types of insulation against heat loss in cold climates, each with its own technical characteristics and financial costs and benefits. Insulation measures are generally one of the most cost effective energy savings measures. The temperature range, within which the term thermal insulation will apply, is from -75°C to 815°C. All applications below -75°C are termed **cryogenic**, and those above 815°C are termed **refractory**.

Principles of Thermal Insulations

1. The **materials used** in the construction should have a **high degree of heat resistance per unit of thickness** i.e. the materials should have adequate heat insulation value and low heat conductivity.
2. The **thermal resistance of the material** directly **varies with its thickness** and hence depending upon the insulation desired, the material of an adequate heat insulation values and adequate thickness should be used.

3. The **provision of air space** in materials for walls roof, ceiling etc. offers very **good insulation** against heat transmission. The presence of air spaces in materials incenses thermal insulation; where as the **presence of the moisture decreases** the value.
4. The **thermal insulation** of the building in general and of doors and windows in particular **depends on its orientation with respect to movement of sun**. The building should be so located that there is min transfer of solar heat during the day in summer and max transfer of solar heat during the day in winter.
5. Thermal insulation to some extent can be achieved by adopting **general measures** such as –use of **sun shading devices** like **sun breakers**, etc., increasing the **height of ceiling** (about 1 to 1.3 m above. The occupants' height), increase the height of the parapet walls when the altitude angle of the sun is low etc.

<u>Insulating Materials and Methods of application</u>

TYPE	WHAT IS IT?	WHERE DOES IT GO?	WHY DO YOU NEED IT?	DIY TIPS
BATTING	Glass fibers in puffy strips with or without a paper face.	Attics, walls, and between crawl space joists.	Stop heat loss into your attic. Wall insulation keeps out cold.	Don't compress or flatten the batting. It reduces the R-value.
BLOWN-IN	Loose cellulose or fiberglass that's blown into attics.	Attics and some walls where there's no existing insulation.	Loose insulation fills in around odd shapes and cavities.	Ask a Lowe's associate about blowers to rent or borrow.
SPRAY FOAM	Expanding foam enlarges as it cures; other types cure in the shape they're sprayed.	Where pipes or wires enter a house and around windows where batting can't reach.	Plugs hard-to-fill gaps.	Non-expanding foam around windows and doors prevents bowing the frames.
RIGID FOAM	Sheets of extruded or expanded polystyrene.	Tuck between joists above the basement or crawlspace.	Foam boards insulate while providing a partial vapor barrier.	Seal rigid foam panels between foundation joists using spray foam.
SPECIALTY	Pipe insulation, duct insulation, and water heater jackets.	Around objects that store or distribute hot water and indoor air.	Keeps water hot; insulates ducts that pass through cold attics.	Insulate pipes wherever condensation is a problem.

(Note: DIY – Do It Yourself)

Type	Insulation Materials	Where Applicable	Installation Method(s)	Advantages
Blanket: batts and rolls	•Fiberglass •Mineral (rock or slag) wool •Plastic fibers •Natural fibers	•Unfinished walls, including foundation walls •Floors and ceilings	Fitted between studs, joists, and beams.	Suited for standard stud and joist spacing that is relatively free from obstructions. Relatively inexpensive.
Concrete block insulation and insulating concrete blocks	Foam board, to be placed on outside of wall (usually new construction) or inside of wall (existing homes): Some manufacturers incorporate foam beads or air into the concrete mix to increase R-values	•Unfinished walls, including foundation walls, for new construction or major renovations •Walls (insulating concrete blocks)	Require specialized skills Insulating concrete blocks are sometimes stacked without mortar (dry-stacked) and surface bonded.	Insulating cores increases wall R-value. Insulating outside of concrete block wall places mass inside conditioned space, which can moderate indoor temperatures. Autoclaved aerated concrete and autoclaved cellular concrete masonry units have 10 times the insulating value of conventional concrete.
Foam board or rigid foam	•Polystyrene •Polyisocyanurate •Polyurethane	•Unfinished walls, including foundation walls •Floors and ceilings •Unvented low-	Interior applications: must be covered with 1/2-inch gypsum board or other building-code approved material for fire safety.	High insulating value for relatively little thickness. Can block thermal short circuits when installed continuously over

		slope roofs	Exterior applications: must be covered with weatherproof facing.	frames or joists.
Insulating concrete forms (ICFs)	•Foam boards or foam blocks	•Unfinished walls, including foundation walls for new construction	Installed as part of the building structure.	Insulation is literally built into the home's walls, creating high thermal resistance.
Loose-fill and blown-in	•Cellulose •Fiberglass •Mineral (rock or slag) wool	•Enclosed existing wall or open new wall cavities •Unfinished attic floors •Other hard-to-reach places	Blown into place using special equipment, sometimes poured in.	Good for adding insulation to existing finished areas, irregularly shaped areas, and around obstructions.
Reflective system	•Foil-faced kraft paper, plastic film, polyethylene bubbles, or cardboard	•Unfinished walls, ceilings, and floors	Foils, films, or papers fitted between wood-frame studs, joists, rafters, and beams.	Suitable for framing at standard spacing. Bubble-form suitable if framing is irregular or if obstructions are present. Most effective at preventing downward heat flow, effectiveness depends on spacing.
Rigid fibrous or fiber	•Fiberglass •Mineral (rock or	•Ducts in unconditioned	HVAC contractors fabricate the	Can withstand high temperatures.

insulation	slag) wool	spaces •Other places requiring insulation that can withstand high temperatures	insulation into ducts either at their shops or at the job sites.	
Sprayed foam and foamed-in-place	•Cementitious •Phenolic •Polyisocyanurate •Polyurethane	•Enclosed existing wall •Open new wall cavities •Unfinished attic floors	Applied using small spray containers or in larger quantities as a pressure sprayed (foamed-in-place) product.	Good for adding insulation to existing finished areas, irregularly shaped areas, and around obstructions.
Structural insulated panels (SIPs)	•Foam board or liquid foam insulation core •Straw core insulation	•Unfinished walls, ceilings, floors, and roofs for new construction	Construction workers fit SIPs together to form walls and roof of a house.	SIP-built houses provide superior and uniform insulation compared to more traditional construction methods; they also take less time to build.

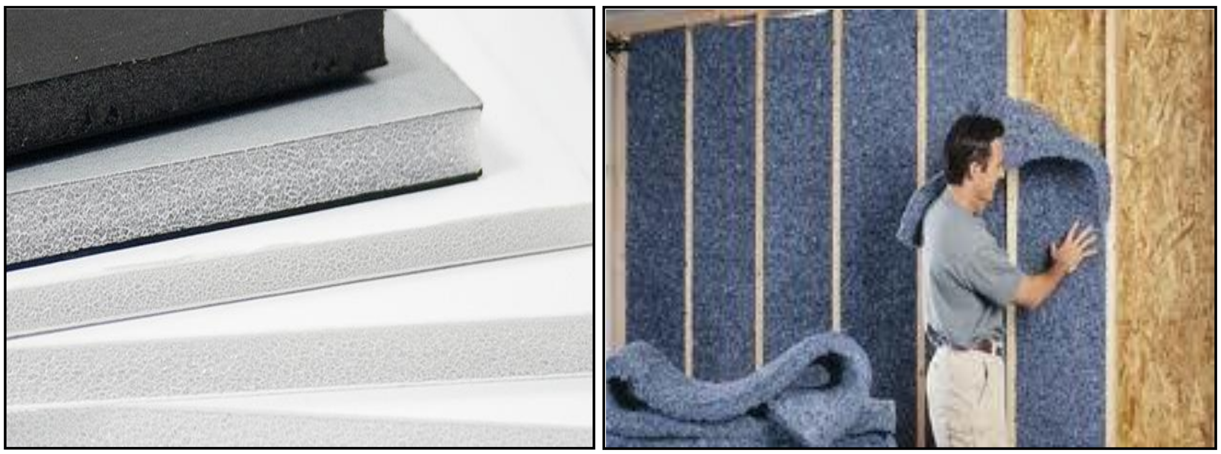
Materials used for insulation


Fiberglass

Mineral (rock or slag) wool


Plastic fibers

Natural fibers



Foam board or blocks

Straw core insulation

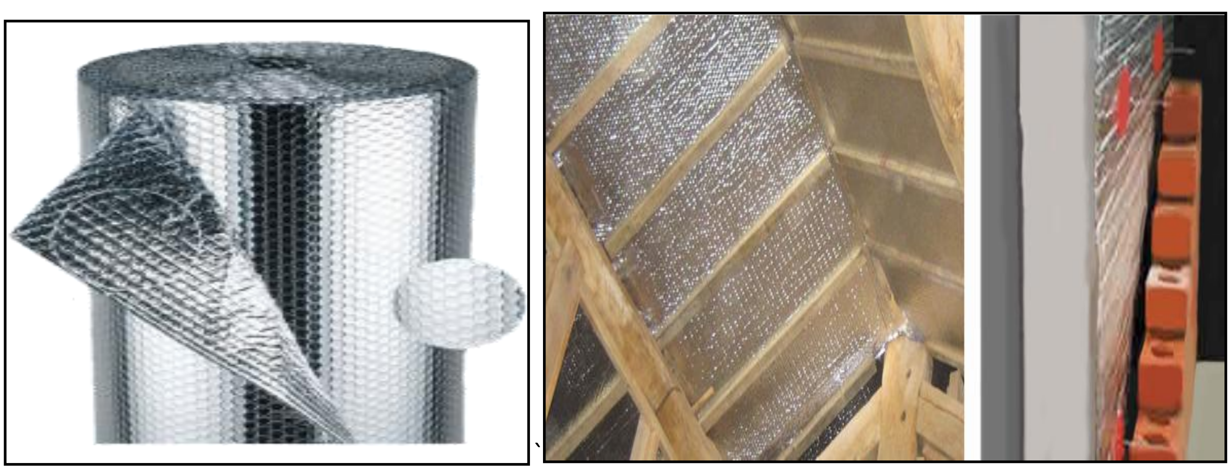
Polystyrene

Polyisocyanurate

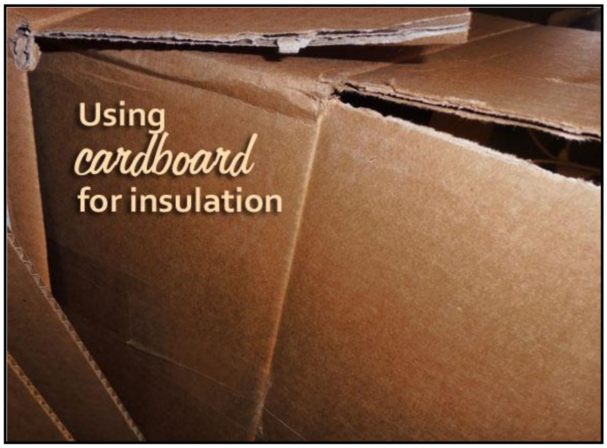
Polyurethane

Cellulose

Foil-faced Kraft paper



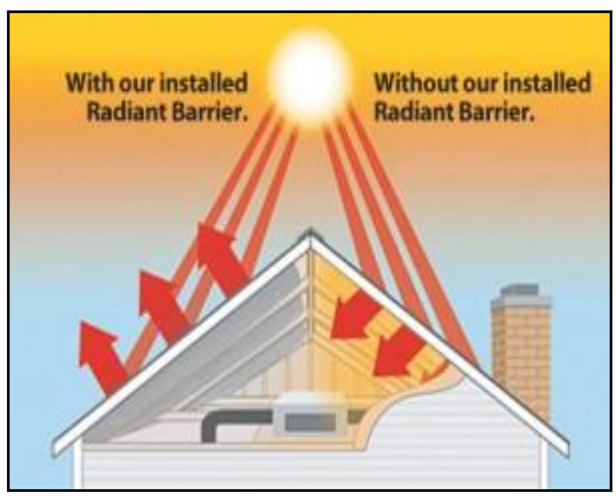
Polyethylene bubbles



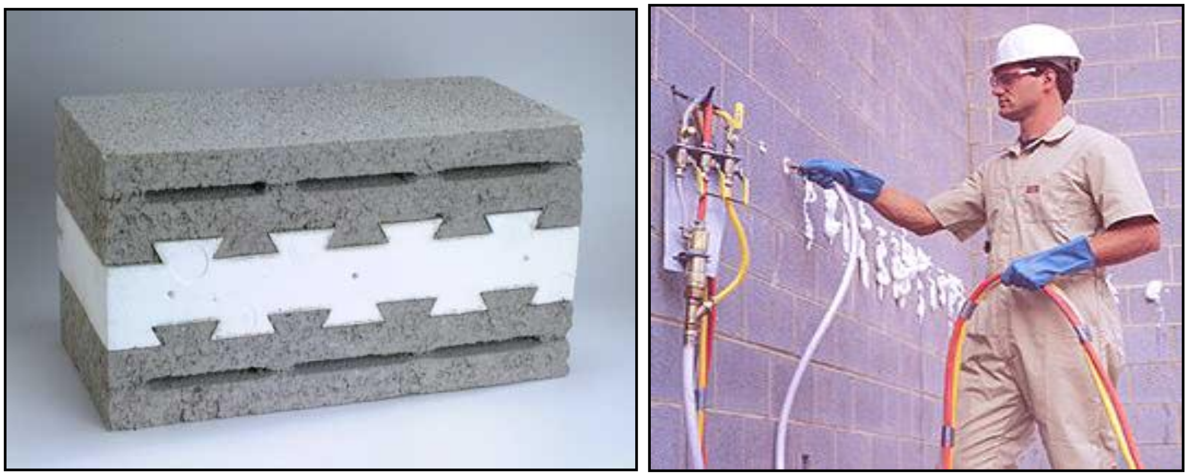
Cardboard

Methods of application

Structural insulated panels



Reflective system



Concrete block insulation method

Blanket batts and rolls insulation method

Sprayed foam

ACOUSTICS SOUND INSULATIONS

Acoustics **-** It is the interdisciplinary science that deals with the study of all mechanical waves in gases, liquids, and solids including vibration, sound, ultrasound and infrasound. The study of acoustics revolves around the generation, propagation and reception of mechanical waves and vibrations.

Sound **-** It is a mechanical wave and therefore requires a medium in which it can travel. Acoustics is classically divided into sound and vibration. **Sound** refers to waveforms traveling through a fluid medium such as air. **Vibration** describes energy transmitted through denser materials such as wood, steel, stone, dirt, drywall or anything besides a fluid.

Reverberation Time - It refers to the amount of time required for the sound field in a space to decay 60dB, or to one millionth of the original power. In simple terms this refers to the amount of time it takes for sound energy to bounce around a room before being absorbed by the materials and air

General Principles of Sound Insulations

Good sound insulation depends upon the following general principles:

1. **Mass** — use heavy materials
2. **Air-tightness** — cover the whole enclosure airtight
3. **Flexibility** — keep it limp, better to overlap, than stretch tight
4. **Isolation** — separate (decouple) from surrounding structure

Although each project has to be considered individually, the above principles are relevant in most cases.

Mass - Massive, heavyweight barriers will block more sound energy than lightweight barriers. (Less noise will go through it.) This is because the high density of heavyweight materials suppresses sound vibrations inside the material, to a degree that the inside wall of a room, vibrates with less movement. Therefore, the amplitude of the sound waves re-radiated into the air inside the room, loudness is also minimized.

Mass Law

The Mass Law states that ***the sound insulation of a single-layer partition has a linear relationship with the surface density (mass per unit area) of the partition, and increases with the frequency of the sound.***

Single-layer construction includes composite barriers such as plastered brickwork, as long as the layers are bonded together. The heavier the barrier; the better the sound reduction. In theory for each doubling of mass, sound insulation increases by 6 dB.

For example, the average sound reduction of a brick wall increases from 45 dB to 50 dB when the thickness is increased from 4 inch to 8.4 inch. This doubling of mass does not have to be achieved by a doubling of thickness, as the mass of a wall for sound insulation purposes is specified by its **surface density** measured in lbs per square foot (rather than per cubic foot). Similar sound reduction can be achieved by adding thinner, but heavier materials, like a layer of Mass Loaded Vinyl. The higher the frequency the easier it is to block it.

Sound insulation increases by about 6 dB whenever the frequency is doubled.

Any doubling of frequency is a change of one octave. For example, a brick wall provides about 10 dB more insulation against 400 Hz sounds than against 100 Hz sounds. (100Hz = bass note, 400 Hz = Voice). This change, from 100 to 200 Hz and then 200 to 400 Hz, is a rise of two octaves. In extreme cases you might not even hear the sound but can feet the wall vibrating to the touch.

But increasing the mass alone is not enough. If you feel that Mass law does not work in your construction that is because other factors such as air-tightness, rigidity and isolation have an Effect.

Air-Tightness

Areas of reduced insulation or small gaps in the construction of a wall have a far greater effect on overall insulation than you might think. The effective soundproofing of a structure depends on air-tightness and uniformity

For example, if a brick wall contains a hole or crack which in size represents only 0.1 per cent of the total area of the wall, the average sound reduction of that wall is reduced from 50 dB to 30 dB by about 40% (!).

Common air gaps: *Wall floor gaps, Gaps around doors, Poor window seals, Unsealed pipe runs, Unsealed cable runs, Porous barrier material (Cinder blocks)*

Another aspect of soundproofing, that is often overlooked is consistency of the material□ ™s STC (Sound Transmission Coefficient) used in construction. Your construction is only as soundproof as its weakest point. For example, an unsealed door occupying 25 per cent of the area of a half-brick wall reduces the average sound reduction efficiency of that wall from around 45 dB to 23 dB.

Flexibility

Rigidity is a physical property of a partition and depends upon factors such as the elasticity of the materials and the way the partition is installed. High rigidity of the barrier can cause loss of insulation at certain frequencies due to resonances and coincidence effects. These effects diminish the expected results according to the Mass Law.

Resonance

Loss of insulation by resonance occurs if the incident sound waves have the same frequency as the natural frequency of the partition. The increased vibrations that occur in the structure are passed on to the air and so the insulation is lowered. Resonant frequencies are usually low and most likely to cause trouble in the air spaces of cavity construction.

Coincidence

Loss of insulation by coincidence is caused by the bending flexural vibrations, which can occur along the length of partition. When sound waves reach a partition at angles other than 90°, their transmission can be amplified by the flexing inwards and outwards of the partitions. The sound-wave frequency and the bending-wave frequency coincide at the critical frequency. For several octaves above this critical frequency the sound insulation tends to remain constant and less than that predicted by the Mass Law. Coincidence loss is greatest in double-layer constructions, such as cavity walls or hollow blocks.

Flexible (limp) materials, combined with high mass, are best for high sound insulation. But even if you get the flexible high mass material such as Mass Load Vinyl, it needs to be installed in a way that keeps it limp: for example attached only at the top and allowed to hang freely, or installed in a loose wave-like manner, especially if sandwiched between two rigid surfaces, to keep its limp properties.

Isolation

Sound transfers through any medium air, structural elements of buildings such as floors, walls. As the sound converts to different wave motions at the junction of different materials, energy is lost and an incremental amount of insulation is gained. This is the principle behind the effectiveness of air cavities in windows, of floating floors, of carpets and of resilient mountings for vibrating machines. Decoupling of elements of construction can be effective in reducing the transmission of sound through a structure. Some broadcasting and concert buildings, and acoustic labs, achieve very high insulation by using completely discontinuous construction of a double structure separated by resilient mountings and rested on a springy support mounts.

Sound isolation can be easily ruined by strong flanking transmissions through rigid links, even by a single nail. Cavity constructions must be sufficiently wide for the air to be flexible, otherwise resonance and coincidence effects can cause the insulation to be reduced at certain frequencies. In small air gaps in conjunction with rigid walls air gaps couples with the walls and separation effect gets lost.

Soundproofing and sound isolation need to be looked at as an integral complex approach where all principals are observed. Even an incremental increase in sound isolation can have a great effect on how it is being perceived. Because sound levels are measured using a logarithmic scale, a reduction of nine decibels is equivalent to elimination of about 80 percent of the unwanted sound.

Sound Absorbing Materials

The following are the various forms of materials

- Sound Absorbers
- Sound Diffusers
- Noise Barriers
- Sound Reflectors

Sound Absorbers

These **sound absorbing acoustical panels** and **soundproofing materials** are used to eliminate sound reflections to improve speech intelligibility, reduce standing waves and prevent comb filtering.

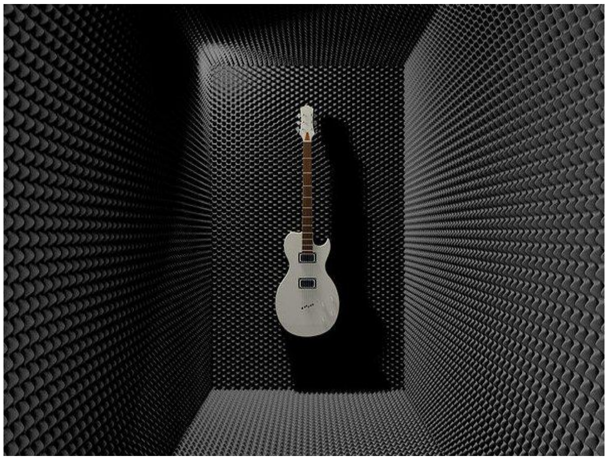
Typical materials are **open cell polyurethane foam**, **cellular melamine**, **fiberglass**, **fluffy fabrics** and other **porous materials**. A wide variety of materials can be applied to walls and ceilings depending on your application and environment.

These materials vary in thickness and in shape to achieve different absorption ratings depending on the specific sound requirements

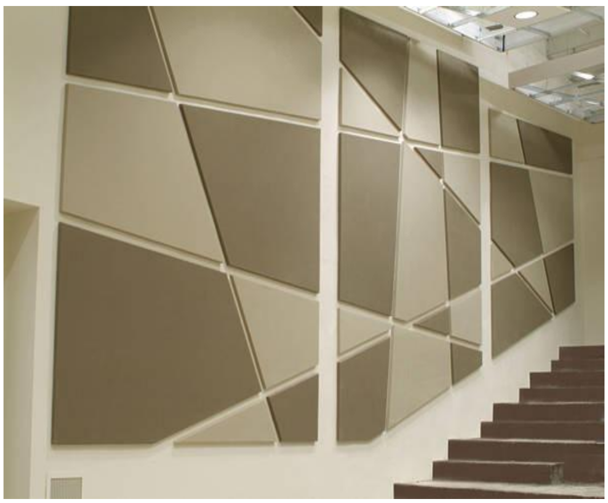
Types of sound absorbers are:

- Acoustical foam panels
- White paintable acoustical wall panels
- Fabric wrapped panels
- Acoustical wall coverings
- Ceiling tiles
- Baffles and banners for ceiling
- Fibre glass blankets and roll

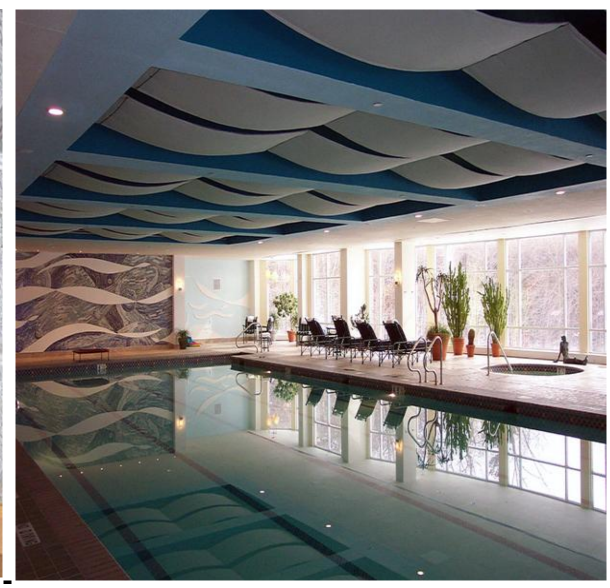
Fiber glass blankets and rolls



Acoustical foam panels ***White paintable acoustical wall panels***



Fabric wrapped panel ***Acoustical wall coverings***



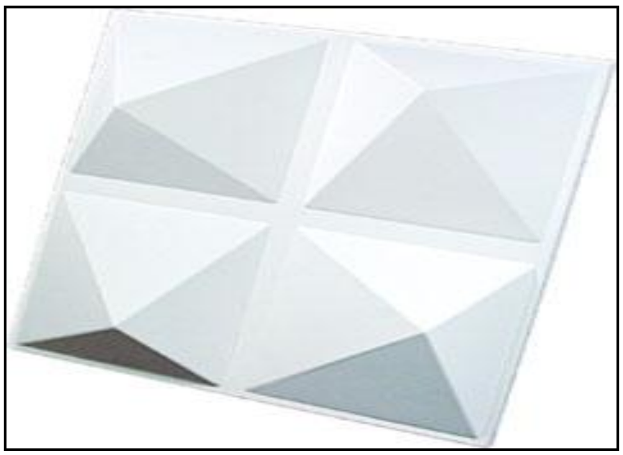
Ceiling tiles Baffles and banners for ceiling

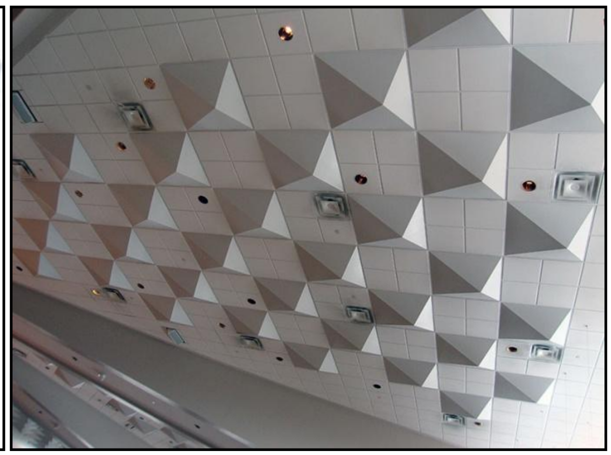
Sound Diffusers

These devices reduce the intensity of sound by scattering it over an expanded area, rather than eliminating the sound reflections as an absorber would. Traditional spatial diffusers, such as the **poly cylindrical** (barrel) shapes also double as low frequency traps. Temporal diffusers, such as binary arrays and quadratics, scatter sound in a manner similar to diffraction of light, where the timing of reflections from an uneven surface of varying depths causes interference which spreads the sound.

Types of sound diffusers are:

- Quadra pyramid diffuser
- Pyramidal diffuser
- Double duty diffuser
- Quadratic diffuser



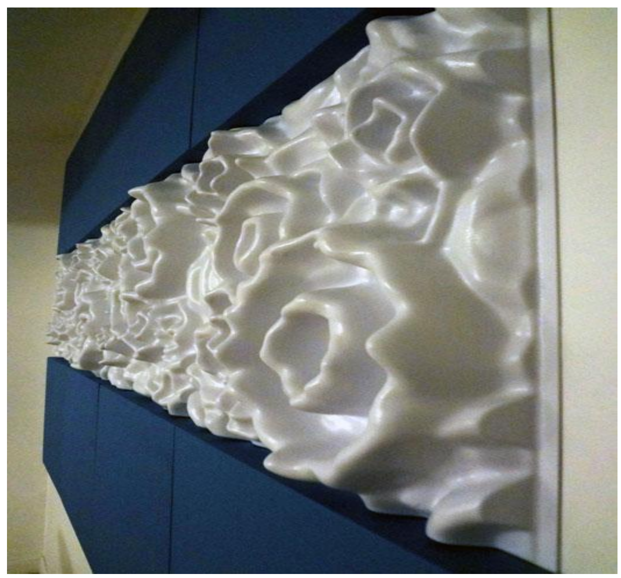


Quadra pyramid diffuser ***Pyramidal diffuser***

Double duty diffuser ***Quadratic diffuser***

Noise barriers

These materials range from dense materials to block the transmission of airborne sound to devices and compounds used to isolate structures from one another and reduce impact noise. Sound barrier materials are used to reduce the transmission of airborne sound. Composite materials are manufactured from combinations of various materials from open and closed celled foams to quilted fiberglass and barrier. These products are used to block and absorb sound for machine enclosures as well as blocking airborne sound and impact noise. Some of these products include **Composite Foams**, **StratiQuilt Blankets** and **Floor Underlayment**.



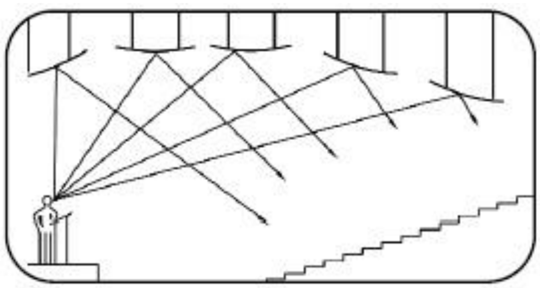
Composite Foams ***StratiQuilt Blankets***

Floor Underlayment.

Sound reflectors

It is very important to provide as much natural reinforcement for the unamplified voice as possible. This applies equally in smaller rooms, classrooms, meeting rooms etc, but is particularly important for larger spaces where the distance between the speaker and the listener is greater.

Natural reinforcement is achieved by the strategic placement of reflective surfaces. For example in theatres it is common to place reflectors above the stage, and to angle these to give useful reflections, particularly to the back of the auditorium. **Hard flat surfaces** can be considered to reflect sound in a similar manner to the way that a mirror reflects light (i.e the angle of incidence equals the angle of reflection.

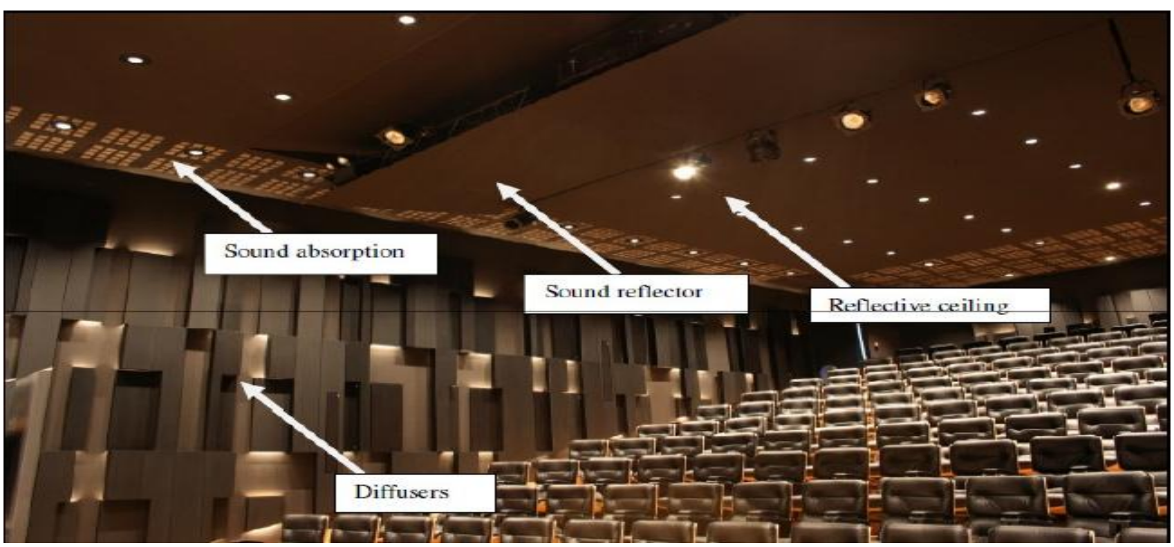


Convex surfaces will scatter sound and concave surfaces can cause focusing of sound. Focusing of sound is usually avoided because, whilst it increases the sound level for listeners at the focus, those outside the focus do not benefit. The sound level would therefore vary considerably throughout the auditorium. For this reason, **convex surfaces** are usually used.

Any reflected sound that arrives within 50 milliseconds of the direct sound will help to reinforce the speech. Reflections arriving later than 50 milliseconds might be heard as a distinct echo and will degrade intelligibility. 50 milliseconds is the time it takes sound to travel 17 meters, so reflective surfaces/panels should be designed so that the reflective sound has to travel no more than 17 meters further than the direct sound to reach the listener.

In smaller rooms like meeting rooms, the main reflections come from the central part of the ceiling. This therefore should be made reflective. Architects often specify **acoustically absorbing ceiling tiles** in meeting rooms to reduce the reverberant sound levels, but listening conditions would be improved by making the central portion non-absorbing.

Sound reflectors



Pictorial representation of absorption, reflection and diffusion of sound

Acoustical Design of Auditorium, Class Rooms and Library

Auditorium

The acoustical design has few factors as follows:

- *Audience Size*
- *Range of Performance Activities*
- *Audience Sophistication*

The parameters for acoustical design are:

- *Audience Size*
- *Reverberation time*
- *Ceiling Height*
- *Typical Dimensions*
- *Stage opening*
- *Shape of Walls and Ceilings*
- *Check Echoes*

Following are some requirements or conditions to observe when designing an auditorium for good listening:

1. Avoidance of strong echoes and focusing of sound rays. Strong echoes and focusing lead to a non uniform sound level within the room which is not desirable. These features of the auditorium design can help: scatterers, convex (non-focusing) surfaces on balcony fronts, sound absorption materials on concave surfaces and flat surfaces, carpets, and upholstered seats. Note - convex surfaces diverge sound rays and concave surfaces converge rays to a focal point depending on the radius of the surface.
2. Intimacy - This implies a short time between the first reflection of sound to the ear and the direct sound from the source.
3. Clarity. Here the sound level of the source needs to be distinctly higher than the background sound. This promotes, for example, good speech intelligibility.
4. Reduction of sounds and vibrations coming into the auditorium. This keeps the background noise level down. Thick heavy walls and doors help to reduce the background noise. Seals on doors are important. It is also important to reduce noise from air handling systems, walking on floors, and also talking outside the room.

5. Proper reverberation time. This is the time it takes sound, after it ceases, to drop in intensity by 60 decibels or to 10^{-6} of its original intensity. Acceptable values for the reverberation time (TR) depend on the size of the room and the use of the room (for a speech, organ recital, orchestra concert, etc). There are charts and tables to help determine the TR proper for the room at each measurement frequency (e.g. 100, 256, 512, 1024, 2000, 4000 etc. in Hertz). For organ music in a room of 10^5 cubic feet the reverberation time should be approximately 1.4 sec. For a speech in a 8 x 10^3 cubic feet room 0.9 sec. might be good. These are values for 512 Hertz.

Class Room

General approach to classroom design:

To develop rooms with good sight lines and efficient seating layouts, design should proceed from the "inside out:"

- ❖ Determine screen size and location, seat size and orientation, and size of the instructor area at room front.
- ❖ Draw viewing angles from each screen and insure that all seats fit within them.
- ❖ Determine location and width of access aisles.
- ❖ Only after these steps, determine where walls should be located.

Designs in which seating capacities are reduced because rooms are too small, or which have inefficient shapes, obstructions, narrow aisles, seats or work surfaces that are too small, or seats placed too close together for comfort are unacceptable.

Acoustics design

Design walls and ceilings to evenly distribute sound through the classroom. Voices must be heard easily and accurately. Design must prevent unwanted background or outside noise. The room must be designed to foster effective sound transmission not only from a speaker at room front to an audience, but to allow student comments to be easily heard as well. All walls must extend to the floor above or to the roof construction, and not stop at ceiling. Select system components (fans, ductwork and diffusers) that will meet the acoustical criteria for classrooms. Walls between classrooms will have a Sound Transmission Class (STC) rating of at least 50. Walls separating classrooms from common spaces or restrooms must have an STC of at least 53. Walls separating classrooms from mechanical spaces or other areas with high noise levels must have at least an STC of 60. Ambient noise level should not exceed 35 decibels when measured with the A-scale of a sound level meter. Reverberation time in rooms with under 10,000 cubic feet of space should not exceed .5 seconds. Spaces larger than 10,000 cubic feet should be designed for maximum reverberation time of .7 seconds. Walls and ceilings may require angling and/or applied acoustical treatment. Materials at room front should be reflective to project sound to the back of the room. Sound absorbing materials should be placed beyond arm's reach.

Ceiling height is based on the classroom capacity, depth and design. In particular, the ceiling must be high enough to accommodate the projection screen when the bottom of screen is no lower than 40" from floor and screen height is 1/5 the distance from front wall to last row of seats. Ceiling height requirements may differ for seminar rooms, classrooms, and auditoria within the same building.

Library

The acoustical design issues for libraries involve the following principal issues:

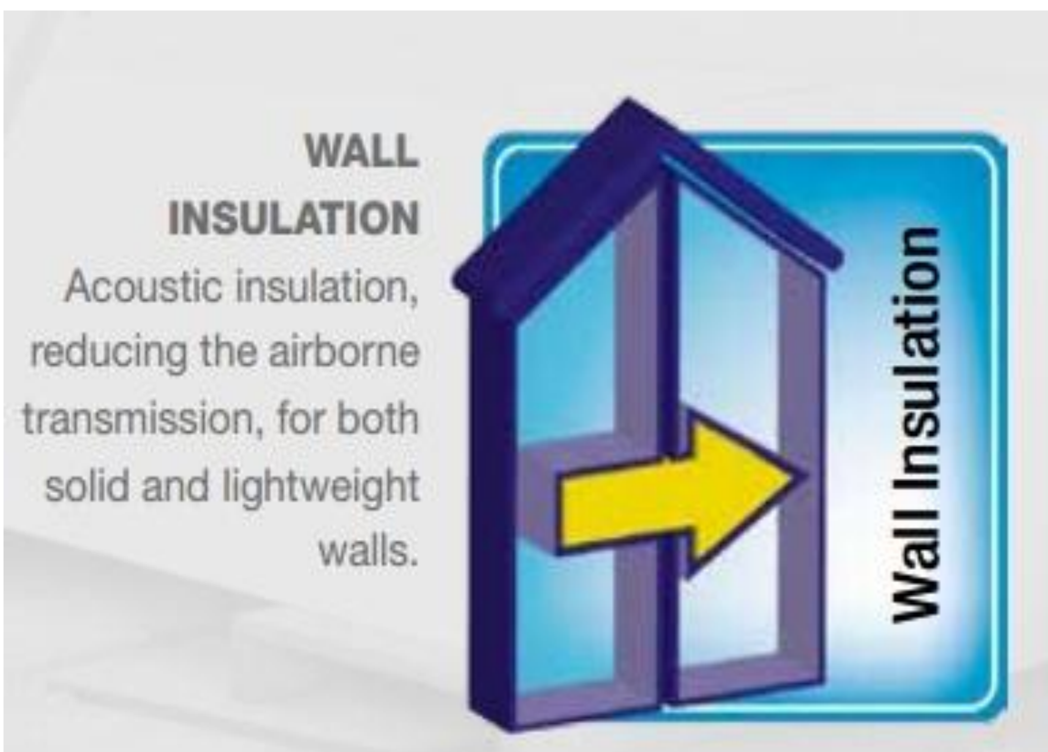
- Site noise considerations, including the control of noise transfer to a project's neighbors, particularly if they are residential.
- Establishing noise standards for each use space, including limitation of excessive ventilation noise.
- Room acoustics considerations.
- Sound isolation between various use spaces.
- Vibration control for mechanical equipment.
- Audio/visual system considerations.

Factors to be considered

- Changes in ceiling height and configuration
- Textured wall coverings
- Acoustical banners
- Acoustical dampers in ductwork
- Avoidance of smooth, hard surfaces

Sound Insulation of Walls and Floors

Floor Insulation



Wall Insulation

Ventilation

Ventilation moves outdoor air into a building or a room, and distributes the air within the building or room. The general purpose of ventilation in buildings is to provide healthy air for breathing by both diluting the pollutants originating in the building and removing the pollutants from it

Building ventilation has three basic elements:

- *ventilation rate* — the amount of outdoor air that is provided into the space, and the quality of the outdoor air
- *airflow direction* — the overall airflow direction in a building, which should be from clean zones to dirty zones; and
- *air distribution or airflow pattern* — the external air should be delivered to each part of the space in an efficient manner and the airborne pollutants generated in each part of the space should also be removed in an efficient manner.

Types of ventilation

1. Natural ventilation
2. Mechanical ventilation
3. Mixed-mode or Hybrid ventilation

Natural Ventilation

Natural forces (e.g. winds and thermal buoyancy force due to indoor and outdoor air density differences) drive outdoor air through purpose-built, building envelope openings. Purpose-built openings include windows, doors, solar chimneys, wind towers and trickle ventilators. This natural ventilation of buildings depends on climate, building design and human behavior.

Mechanical Ventilation

Mechanical fans drive mechanical ventilation. Fans can either be installed directly in windows or walls, or installed in air ducts for supplying air into, or exhausting air from, a room. The type of mechanical ventilation used depends on climate.

For example, in warm and humid climates, infiltration may need to be minimized or prevented to reduce interstitial condensation (which occurs when warm, moist air from inside a building penetrates a wall, roof or floor and meets a cold surface). In these cases, a positive pressure mechanical ventilation system is often used. Conversely, in cold climates, exfiltration needs to be prevented to reduce interstitial condensation, and negative pressure ventilation is used. For a room with locally generated pollutants, such as a bathroom, toilet or kitchen, the negative pressure system is often used.

<u>Components involved</u>

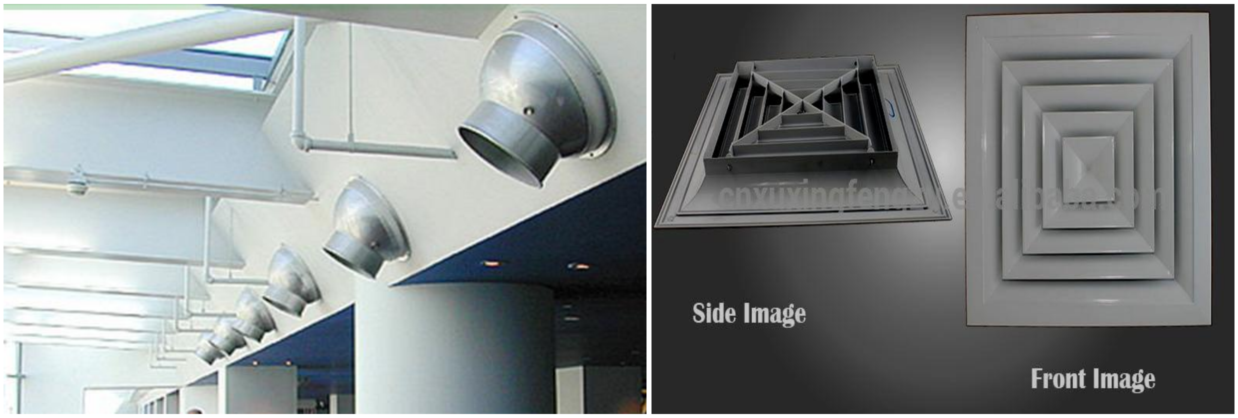
- ❖ Fan
- ❖ Filters
- ❖ Ductwork
- ❖ Fire dampers
- ❖ Diffusers

Fans

Filters

Ductwork

Fire dampers



Diffusers

Hybrid or Mixed-Mode Ventilation

Hybrid (mixed-mode) ventilation relies on natural driving forces to provide the desired (design) flow rate. It uses mechanical ventilation when the natural ventilation flow rate is too low. When natural ventilation alone is not suitable, exhaust fans (with adequate pre-testing and planning) can be installed to increase ventilation rates in rooms housing patients with airborne infection. However, this simple type of hybrid (mixed-mode) ventilation needs to be used with care. The fans should be installed where room air can be exhausted directly to the outdoor environment through either a wall or the roof. The size and number of exhaust fans depends on the targeted ventilation rate, and must be measured and tested before use.

Problems associated with the use of exhaust fans include installation difficulties (especially for large fans), noise (particularly from high-power fans), increased or decreased temperature in the room and the requirement for non-stop electricity supply. If the environment in the room causes thermal discomfort spot cooling or heating systems and ceiling fans may be added.

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Comparision of three methods of ventillation

There are three methods that may be used to ventilate a building: natural, mechanical and hybrid (mixed-mode) ventilation.

Mechanical ventilation	Natural ventilation	Hybrid (mixed-mode) ventilation	Remarks
Advantages	Suitable for all climates and weather with air-conditioning as climate dictates	Suitable for warm and temperate climates — moderately useful with natural ventilation possible 50% of the time	Suitable for most climates and weather
	More controlled and comfortable environment	Lower capital, operational and maintenance costs for simple natural ventilation	Energy-saving
	Smaller range of control of environment by occupants	Capable of achieving high ventilation rate Large range of control of environment by occupants.	More flexible
Disadvantages	Expensive to install and maintain	Easily affected by outdoor climate and/or occupant's behaviour	May be expensive
	Reported failure rate in delivering the required outdoor ventilation rate	More difficult to predict, analyze and design	May be more difficult to design

	Potential for noise from equipment	Reduces comfort level of occupants when hot, humid or cold Inability to establish negative pressure in isolation areas, but may be provided by proper design; depends on situation Potential for noise intrusion High-tech natural ventilation shares some of the limitations and disadvantages of mechanical ventilation	

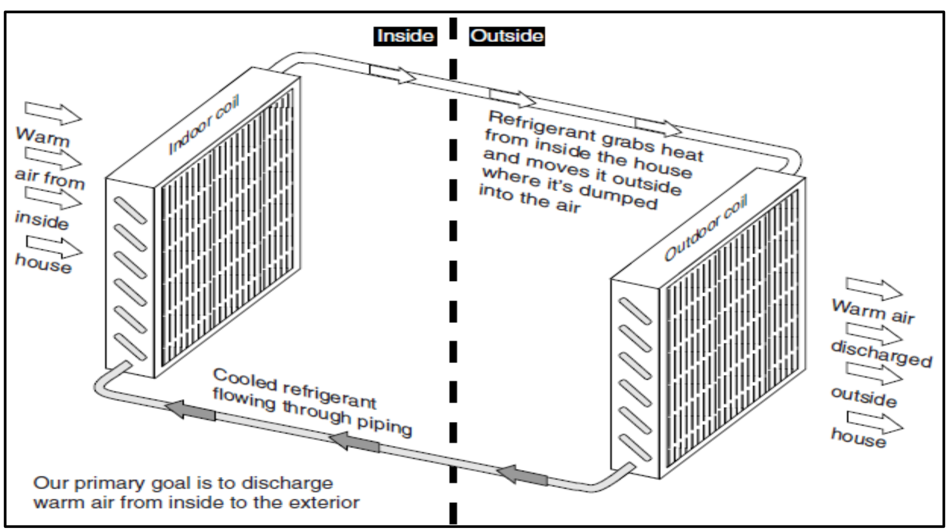
AIR CONDITIONING

Definition

Air conditioning is the process of altering the properties of air (primarily temperature and humidity) to more favorable conditions. The control of these conditions may be desirable to maintain the health and comfort of the occupants, or to meet the requirements of industrial processes irrespective of the external climatic conditions

Principles of air-conditioning

The goal is to keep it more comfortable inside the house than it is outside.



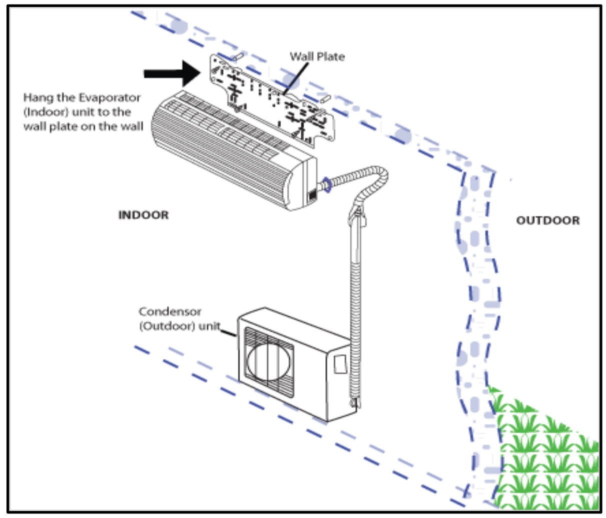
Type of Air-Conditioning

1) Window air-conditioning system
2) Split air-conditioning system
3) Centralized air-conditioning system
4) Package air-conditioning system

1. ***Window air-conditioning system***- Window air conditioners are one of the most commonly used and cheapest types of air conditioners. To install one of these units, we need the space to make a slot in the wall, and there should also be some open space behind the wall. Window air-conditioner units are reliable and simple-to-install solution to keep a room cool while avoiding the costly construction of a central air system. Better yet, when the summer heat dies down, these units can be easily removed for storage, and you can use the window sill for other purpose

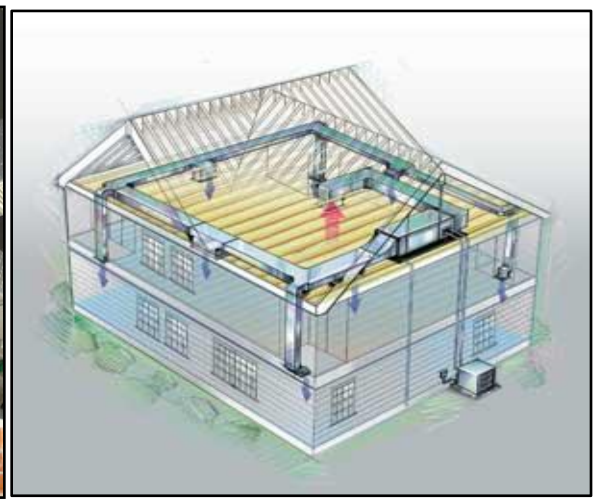
Window air-conditioning system

2. ***Split air-conditioning system -*** The split air conditioner comprises of two parts: the outdoor unit and the indoor unit. The outdoor unit, fitted outside the room, houses components like the compressor, condenser and expansion valve. The indoor unit comprises the evaporator or cooling coil and the cooling fan. For this unit there is no need to make any slot in the wall of the room. Further, the present day split units have aesthetic looks and add to the beauty of the room. The split air conditioner can be used to cool one or two rooms



Split air-conditioning system

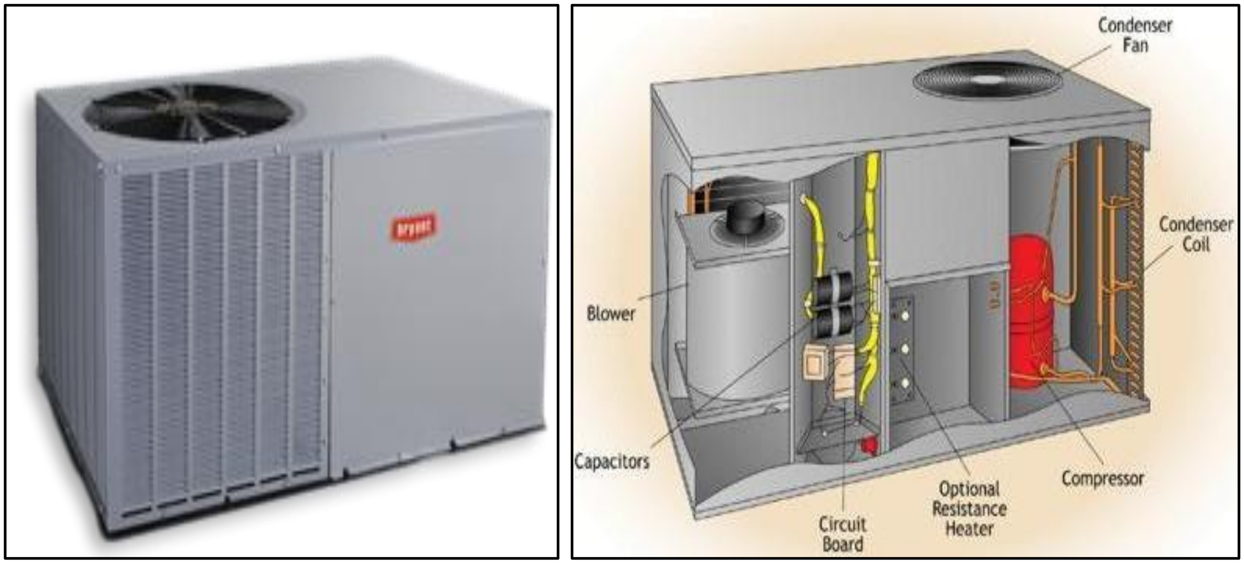
3. ***Centralized air-conditioning system -*** The central air conditioning plants or the systems are used when large buildings, hotels, theaters, airports, shopping malls etc. are to be air conditioned completely. The window and split air conditioners are used for single rooms or small office spaces. If the whole building is to be cooled it is not economically viable to put window or split air conditioner in each and every room. Further, these small units cannot satisfactorily cool the large halls, auditoriums, receptions areas etc.

Centralized air-conditioning system

4. ***Package air-conditioning system*** - The window and split air conditioners are usually used for the small air conditioning capacities up to 5 tons. The central air conditioning systems are used for where the cooling loads extend beyond 20 tons. The packaged air conditioners are used for the cooling capacities in between these two extremes. The

packaged air conditioners are available in the fixed rated capacities of 3, 5, 7, 10 and 15 tons. These units are used commonly in places like restaurants, telephone exchanges, homes, small halls, etc.



Package air-conditioning system

FIRE RESISTING CONSTRUCTION

All the building materials used for construction are not perfectly fire proof. Every building contains some materials (such as furniture, clothing, eatables etc.) which can either easily catch fire or which are vulnerable to fire.

A wider interpretation of fire safety may be deemed to cover the following aspects:

- Fire prevention and reduction of number of outbreaks of fire,
- Spread of fire, both internally and externally,
- Safe exit of any and all occupants in the event of an out-break of fire, and
- Fire extinguishing apparatus.

Significance of Using Suitable Materials

The fire resisting material is having the following characters:

(a) It should not disintegrate under the effect of heat

(b) It should not expand under heat so as to introduce unnecessary stresses in the building

(c) The material should not catch fire easily

(d) It should not lose its strength when subjected to fire.

Characteristics of Fire Resisting Materials

An ideal fire resisting material should possess the following characteristics:

- The material should not disintegrate under the effect of great heat.
- The expansion of the material due to heat should not be such that it leads to instability of the structure of which it forms a part.
- The contraction of the material due to sudden cooling with water (during fire extinguishing process) after it has been heated to a high temperature should not be rapid.

Building materials for fire resistance:

1. Non-combustible materials

These materials do not contribute to the growth or spread of fire, but are damaged and decomposed when high temperatures are reached. Examples of non- combustible materials are: stones and bricks, concrete, clay products, metal, glass etc.

2. Combustible materials

Combustible materials are those which, during fire, combine exothermically with oxygen, resulting in evolution of lot of heat and giving rise to flame or glow. Such materials burn and also contribute to the growth of fire. Examples of these materials are: wood and wood products, fiberboard, straw board etc.

Properties of some Fire Resisting Building Materials

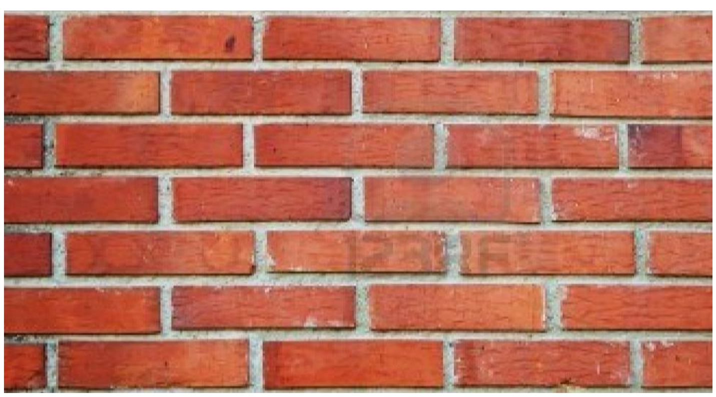
Stone

Stone is a non-combustible building material and also a bad conductor of heat and does not contribute to the spread of fire. It is a bad fire-resisting material since it is liable to disintegrate into small pieces when heated and suddenly cooled, giving rise to failure of structure. ***Granite***, on exposure to severe heat, explodes and disintegrates. ***Limestone*** is the worst, since it is easily crumbled even under ordinary fire. ***Sand stone*** of compact composition (fine grained) can, however, stand the exposure to moderate fire without serious cracks. In general, the use of stone in a fire-resisting construction should be restricted to a minimum.

Stone

Brick

Brick is a poor conductor of heat. First class bricks moulded from good clay can stand exposure to fire for a considerable length of time, up to temperatures of about 1200°C. Brick masonry construction, with good mortar and better workmanship, is the most suitable for safeguarding the structure against fire hazards.



Bricks

Asbestos cement

It is formed by combining fibrous asbestos with Portland cement. It has low coefficient of expansion and has property of incombustibility. Asbestos cement products are largely used for construction of fire-resistant partition walls, roofs, etc. It is also used as protective covering to other structural members.

.Asbestos cement

<u>Concrete</u>

The behavior of concrete during exposure to heat varies with the nature of coarse aggregate and its density, and the quality of cement. Aggregates expand on heating while ordinary cement shrinks on heating. These two opposite actions may lead to spalling of the concrete surface. Aggregates obtained from igneous rocks containing higher calcareous content, tend to crack more while the aggregates like foamed slag, cinder and bricks are better. Concrete offers a much higher resistance to fire than any other building material. Reinforced concrete structures can withstand fire lasting for several hours with a temperature of 1000°C without serious damage.

Concrete

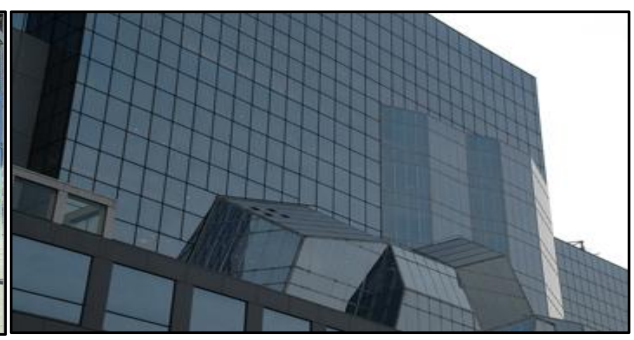
Steel

Though steel is non-combustible, it has very low fire resistance, since it is a good conductor of heat. During fire, it gets heated very soon, its modulus of elasticity reduces and it loses its tensile strength rapidly. Unprotected steel beam sags and unprotected columns or struts buckle, resulting in the collapse of structures. If the surface paint on these steel components is not fire resistant structure, it is essential to protect structural steel members with some coverings of insulating materials like brick, terra-cotta, concrete etc.


Steel

Glass

Glass is poor conductor of heat and its thermal expansion is also less. When it is heated and then suddenly cooled, cracks are formed. These cracks can be minimized if glass is reinforced with steel wire netting. Reinforced glass is more fire resistant, and can resist variations in temperature without serious cracks. Reinforced glass has higher melting point. Even if cracks are formed, the embedded wires hold the cracked portion in position. Commonly used for fire-resisting doors, windows, done skylights, etc.

Glass

Timber

Timber is a combustible material. It ignites and gets rapidly destroyed during fire, if the section is small. If timber is used in thick sections, it possesses the properties of self- insulation and slow burning. During exposure to fire, timber surface gets charred; this charred portion acts as protective coating to the inner portion. If the temperatures are higher than 500°C, timber gets dehydrated under continued exposure, giving rise to combustible volatile gases which readily catch fire.

Timber

Aluminium

It is very good conductor of heat. It has very poor fire-resistant properties. Its use should be restricted to only those structures which have very fire risks.

Aluminium

Cast-iron and wrought iron

Cast iron behaves very badly in the event of fire. On sudden cooling, it gets contracted and breaks down into pieces or fragments, giving rise to sudden failure. It is rarely used in fire-resistant building unless suitably covered by bricks, concrete etc. Wrought iron behaves practically in the same way as mild steel.

Cast-iron and wrought iron

Plaster or mortar

Plaster is non-combustible. Hence it should be used to protect walls and ceilings against fire risk. Cement plaster is better than lime plaster since the latter is likely to be calcined during fire. Using it in thick layers or reinforcing it with metal laths can increase the fire-resistance of plaster. Gypsum plaster, when used over structural steel members, makes them better fire-resistant**.**

Plaster or mortar