MOHAMED SATHAK A.J. COLLEGE OF ENGINEERING

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DEPARTMENT OF PHYSICS

PH8201 – PHYSICS FOR CIVIL ENGINEERING

DEPARTMENT OF PHYSICS

MOHAMED SATHAK AJ COLLEGE OF ENGINEERING

CHENNAI – 603103

Syllabus:

PH8201 UNIT I THERMAL PERFORMANCE OF BUILDINGS 9

Heat transfer through fenestrations, thermal insulation and its benefits. Heat gain and heat loss estimation – factors affecting the thermal performance of buildings.

Thermal measurements, thermal comfort, indices of thermal comfort, climate and design of solar radiation, shading devices Central heating. Principles of natural ventilation – ventilation measurements, design for natural
ventilation. Window types and packaged air conditioners – chilled water plant – fan coil systems – water piping – cooling load. Air conditioning systems for different types of buildings – Protection
against fire to be caused by A.C.Systems.

PH8201 UNIT II ACOUSTICS 9

Classification of sound- decibel- Weber–Fechner law – Sabine's formula- derivation using growth and decay method. Absorption Coefficient and its determination –factors affecting acoustics of buildings and their remedies. Methods of sound absorptions – absorbing materials – noise and its measurements, sound insulation and its measurements, impact of noise in multi-storeyed buildings.

PH8201 UNIT III LIGHTING DESIGNS 9

Radiation quantitites – spectral quantities – relationship between luminescence and radiant quantities – hemispherical reflectance and transmittance – photometry: cosines law, inverse square law. Vision – photobic, mesophic, scotopic visions. Colour – luminous efficiency function – Visual field glare, colour – day light calculations – day light design of windows, measurement of day-light and use of models and artificial skies, principles of artificial lighting, supplementary artificial lighting.

PH8201 UNIT IV NEW ENGINEERING MATERIALS 9

Composites – definition and classification – Fibre reinforced plastics (FRP) and fiber reinforced metals (FRM). Metallic glasses – Shape memory alloys – Ceramics – Classification – Crystalline – Non Crystalline. Bonded ceramics, Manufacturing methods – Slip casting – Isostatic pressing – Gas pressure bonding. Properties – thermal, mechanical, electrical and chemical ceramic fibres – ferroelectric and ferromagnetic ceramics – High Aluminium ceramics.

PH8201 UNIT V HAZARDS 9

Seismology and Seismic waves – Earth quake ground motion – Basic concepts and estimation techniques – site effects. Probabilistic and deterministic Seismic hazard analysis. Cyclone and flood hazards – Fire hazards and fire protection, fire-proofing of materials, fire safety regulations and fire fighting equipment. Prevention and safety measures.

TEXT BOOKS

1. Alexander, D. “Natural disaster”, Springer (1993).
2. Budinski, K.G. & Budinski, M.K. “Engineering Materials Properties and Selection”, Prentice Hall, 2009.
3. Severns, W.H. & Fellows, J.R. “Air conditioning and refrigeration”, John Wiley and Sons, London, 1988.
4. Stevens, W.R., “Building Physics: Lighting: Seeing in the Artificial Environment, Pergaman Press, 2013.

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1. Gaur R.K. and Gupta S.L., Engineering Physics. Dhanpat Rai publishers, 2012.
2. Reiter, L. “Earthquake hazard analysis – Issues and insights”, Columbia University Press, 19913. Shearer, P.M. “Introduction to Seismology”, Cambridge University Press, 1999.

LECTURE NOTES

UNIT – I THERMAL PERFORMANCE OF BUILDINGS

Thermal performance of buildings

Thermal performance of a building refers about keeping the internal temperature lower than the external temperature. The comfortable range of room temperature is 19-22°C

FENESTRATION

Any opening in a building's envelope including windows, doors, curtain walls and skylights **designed to permit the passage of air, light**, vehicles, or people. Fenestrations**transmit solar radiation** into the building (normally filled with glazing).

Fenestration Systems

There are various fenestration systems like,

- **i) Glazing**
- **ii) Windows**
- **iii) Curtain walls**
- **iv) Sloped glazing**
- **v) Exterior doors**

Glazing

Good glazing properties are important because they control the amount of daylight, quality of light, and amount of solar heat gain let into the building, along with other factors. When that opening is covered with a translucent or transparent surface (like windows or skylights), that's called glazing.

Glazing Factor is the **ratio of interior illuminance at a given point on a given plane**(usually the work plane) **to the exterior illuminance** under known overcast sky conditions.

Windows

Windows predominantly use wood frame, with custom metal windows in construction.

Curtain walls

A curtain wall system is an outer covering of a building in which the outer walls are non-structural, utilized to keep the weather out and the occupants in.

Sloped glazing

Sloped glazing is a system of **exterior cladding which is attached to the main force resisting system (structure) of a building roof or sloped façade** and usually supported by an elevated curb.

Exterior doors

It includes entrance & exit doors.

THREE MAIN COMPONENTS OF FENESTRATION

1. Glazing – light is transmitted or penetrated through glass rarely in plastic.
2. Framing – holds the glazing.
3. Shading devices/screens – inhibit the solar radiation incident on a building.

FUNDAMENTAL MODES OF HEAT TRANSFER

- **Conduction** is the process of **transmission of heat** from one point to another through substance **without the actual motion of the particles**. Conduction always requires some material medium. The material medium may be solid, liquid, gas.
- The **transfer of heat** energy between an object and its environment, **due to fluid motion** is called as **convection**.
- The **transfer of heat** energy by the emission of electromagnetic radiation **without any original contact between the bodies** is called as **radiation.**

HEAT TRANSFER THROUGH FENESTRATION

Energy flows through fenestration via

- Conductive and convective **heat transfer caused by the temperature difference between outdoor and indoor air**,
- Net long-wave (above 2500 nm) **radiative exchange between the fenestration and its surrounding and between glazing layers**, and
- Short-wave (below 2500 nm) solar radiation incident on the fenestration product, **either directly from the sun or reflected from the ground or adjacent objects**
- Simplified calculations are based on the observation that the **temperatures of the sky, ground, and surrounding objects** (and hence their radiant emission) correlate with the exterior air temperature.
- The radiative interchanges are then approximated by assuming that **all the radiating surfaces** (including the sky) **are at the same temperature** as the outdoor air.
- With this assumption, the basic equation for the instantaneous energy flow Q through a fenestration is

$$Q = UA_{pf}(t_{out} - t_{in}) + (SHGC)A_{pf}E_t$$

where

Q = instantaneous energy flow, (W)

U = overall coefficient of heat transfer (U-factor), (W/ (m^2·K)

) t_{in} = interior air temperature, (°C)

t_{out} = exterior air temperature, (°C)

A_{pf} = total projected area of fenestration, (m^2)

SHGC = Solar Heat Gain Coefficient, (No Unit) ,

E_t = incident total irradiance, (W/m^2 **)**

The quantities U and SHGC are instantaneous performance indices.

The principal justification for Equation (1) is its simplicity, achieved by collecting all the linked radiative, conductive, and convective energy transfer processes into U and SHGC. These quantities vary because

- convective heat transfer rates vary as fractional powers of temperature differences or free-stream speeds,
- variations in temperature due to the weather or climate are small on the absolute temperature scale (°R) that controls radiative heat transfer rates,
- fenestration systems always involve at least two thermal resistances in series, and
- Solar heat gain coefficients depend on solar incident angle and spectral distribution.

Heat gain through fenestration consists of two components

$$Q = Q_{thermal} + Q_{solar}$$

Where,

$Q_{thermal}$ is instantaneous energy flow due to indoor-outdoor temperature difference (thermal energy flow),

Q_{solar} is instantaneous energy flow due to solar radiation (solar energy flow).

THERMAL INSULATION

The materials which are used to insulate the building thermally are known as thermal insulating materials.

- Thermal insulation is to resist the flow of heat to and from a body. It is a material that reduces the rate of heat flow.
- The aim of thermal insulation is to minimize the transfer of heat between inside & outside of building.

GENERAL PRINCIPLES OF THERMAL INSULATION

- The thermal resistance of an insulating material is directly proportional to its thickness.
- The provision of an air gap is a very important insulating agent.
- The thermal resistance of a building depends on its orientation also.
- Heat energy that flows from one region to another is due to the difference in temperature between the two regions. The heat is transferred by conduction, convection or radiation.

CLASSIFICATION OF THERMAL INSULATING MATERIALS

Thermal insulating materials are classified as

- Organic materials
  Silk, Wool, Cardboard, Paper, Leather
- Inorganic materials
  Air, Mineral wool, Glass wool, Charcoal

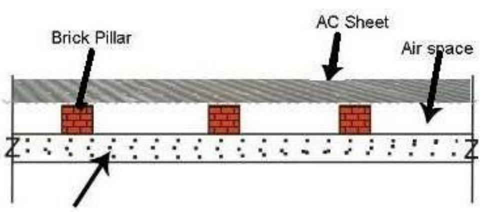
METHODS OF ACHIEVING THERMAL INSULATION

- Use of materials with low conductivity
- Thickness of walls & roofs
- Provision of air spaces
- Heat insulation by orientation
- Thermal insulation by shading
- Providing sufficient height of ceiling

By using thermal insulating materials, it is possible to achieve the desired degree of thermal insulation. The methods of such thermal insulation of roof, external walls, doors & windows.

THERMAL INSULATION OF ROOFS

Method of external insulation is by providing asbestos sheets on bricks.



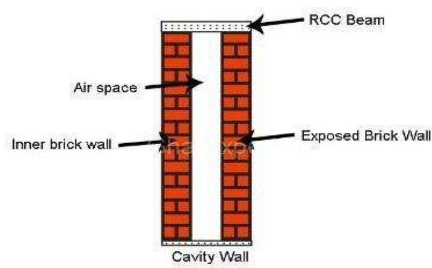
Method of include fixing shiny & reflective materials to the top surface.

A false ceiling of insulating material may be provided to leave an air gap between the roof & ceiling.

THERMAL INSULATION OF WALLS

Walls should not have thermal transmittance more than 2 kcal/m^{2}h°C and should not have thermal damping less than 60%. The following treatments may be adopted for thermal insulation of walls

- Fixing heat insulating materials on the inside & outside of the exposed walls.
- Applying light coloured whitewash or distemper on the wall.
- Creating air space in partition walls by fixing the sheathing of hardboards.
- The suitable thickness of wall may be provided.
- The hollow wall or cavity wall construction may be adopted.
- For partitions, an air space may be created by fixing hardboard & battens.



THERMAL INSULATION IN DOORS & WINDOWS

Heat transmittance through doors & windows may be reduced by

- Providing sunshades
- Using louvered shutters
- Using insulating glass or double glass with air space between them.

BENEFITS OF THERMAL INSULATION

- Due to thermal insulation, the room remains cooler in summer & warmer in winter than outside. It gives thermal comfort.
- Due to thermal insulation transfer of heat between inside & outside of the room is

restricted. This results in less quantity of energy required for maintaining the desired temperature in the room.

- Due to thermal stress roof decks tend to crack, these would be reduced to a great extent.
- Non-toxic, environmental friendly solutions.
- No heat absorption & subsequent dissipation.
- Expansion joints, can be avoided.
- Temperature drop of 5°C to 10°C depending on outside temperature.

HEAT GAIN & HEAT LOSS ESTIMATION

Heat gain estimation -Solar heat gain

Solar heat gain through transparent elements

$Q_S = \propto_S \sum_{i=1}^{m} A_i S_{gi} \tau_i$

Where

Q_S $mean\ absorptivity\ of\ the\ space$

A_i $area\ of\ i^{th}\ transparent\ element$

S_{gi} $daily\ average\ value\ of\ solar\ radiation\ on\ the\ i^{th}\ transparent\ element$

τ_i $transmissivity\ of\ i^{th}\ transparent\ element$

M $number\ of\ the\ transparent\ element$

Heat loss estimation

The heat loss is divided into two groups

- The conductive heat losses through the building walls, floor, ceiling, glass, or other surfaces and
- The convective infiltration losses through cracks, ventilators.

Heat loss from building envelope (Walls, roof, glass)

Heat loss primarily due to conduction. The heat moves in all directions. When calculating the heat loss of a building, all surfaces that divide the inside, heated space from the outside are considered. The dividing line is referred as the building envelope. Total hourly rate of heat loss through walls roof, glass etc is

$Q = AU(T_i - T_o)$

Where

A is net area of walls, roof, ceiling floor or glass

U is overall heat transfer coefficient of walls, roof, ceiling floor or glass

T_i is inside design temperature in °C

T_o is outside design temperature in °C

Heat loss from floors or slab

Heat loss from floors or slab can be estimated by equation

$Q = F * P * (T_i - T_o)$

Where

F is heat loss coefficient for the particular construction

P is perimeter of slab in meter

T_i is inside design temperature in °C

T_o is outside design temperature in °C

Heat loss from slab-on-grade foundations is a function of the slab perimeter rather than the floor area. Perimeter is the part of the foundation or slab nearest to surface of the ground outside. The losses are from the edges of the slab and insulation on these edges will significantly reduce the heat losses. For basement walls, the paths of the heat flow below the grade line are approximately concentric circular patterns centered at the intersection of the grade line & basement wall.

The thermal resistance of the soil and the wall depends in the path length through the soil and the construction of the basement wall. Heat loss through basement walls and floor is given by $Q = AU_{base}(T_{base} - T_o)$

Where

A is area of basement wall or floor below grade

U_{base} is overall heat transfer coefficient of wall or floor and soil T_{base} is temperature at basement wall in °C

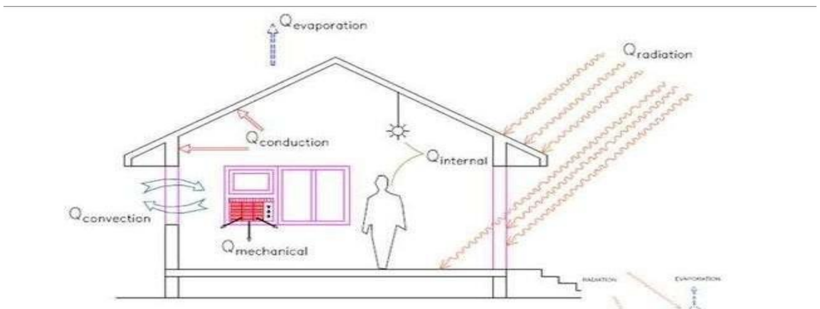
T_o is outside design temperature in °C

THERMAL PERFORMANCE OF BUILDINGS

The thermal performance of a building refers to the process of modeling the energy transfer

between a building and its surroundings.

Various heat exchange processes are possible between a building and the external environment. These are shown in Fig.

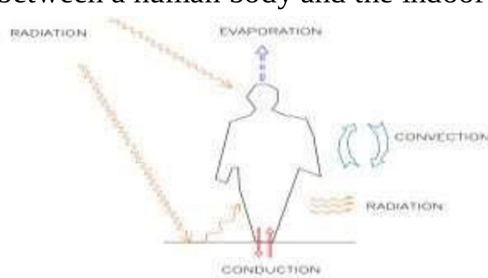


Heat Exchange Processes Between A Building And External Environment

Heat flows by conduction through various building elements such as walls, roof, ceiling, floor, etc. Heat transfer also takes place from different surfaces by convection and radiation. Besides, solar radiation is transmitted through transparent windows and is absorbed by the internal surfaces of the building.

There may be evaporation of water resulting in a cooling effect. Heat is also added to the space due to the presence of human occupants and the use of lights and equipments.

The interaction between a human body and the indoor environment is shown in Fig.



: Heat exchange processes between a human body and the indoor environment

Due to metabolic activities, the body continuously produces heat, part of which is used as work, while the rest is dissipated into the environment for maintaining body temperature. The body exchanges heat with its surroundings by convection, radiation, evaporation and conduction.

If heat is lost, one feels cool. In case of heat gain from surroundings, one feels hot and begins to perspire. Movement of air affects the rate of perspiration, which in turn affects body comfort.

The thermal performance of a building depends on a large number of factors. They can be summarised as

- design variables (geometrical dimensions of building elements such as walls, roof and windows, orientation, shading devices, etc.;
- material properties (density, specific heat, thermal conductivity, transmissivity, etc.;
- weather data (solar radiation, ambient temperature, wind speed, humidity, etc.); and
- a building's usage data (internal gains due to occupants, lighting and equipment, air exchanges, etc..

A block diagram showing various factors affecting the heat balance of a building is presented in Fig.

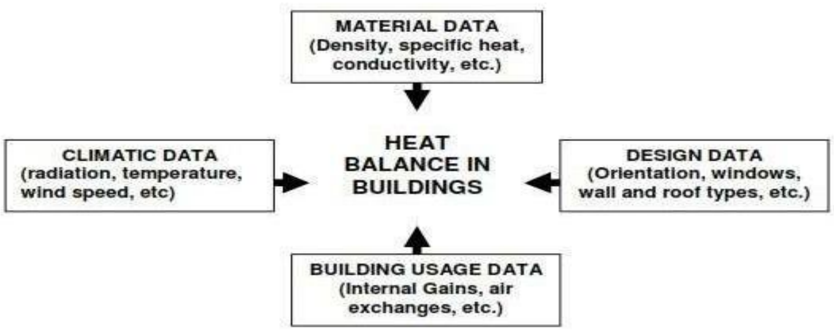


Fig. Thermal simulation flow paths of a building

THERMAL MEASUREMENTS

- THERMAL CONDUCTIVITY (K)
- THERMAL CONDUCTANCE (C)
- U-FACTOR
- THERMAL RESISTANCE (R-VALUE)
- THERMAL MASS
- DENSITY
- SPECIFIC HEAT
- THERMAL CAPACITY

<u>THERMAL CONDUCTIVITY (K)</u>

It is material's ability to conduct heat. The faster heat flows through a material the more conductive.

THERMAL CONDUCTANCE (C)

It is conductivity per unit area. It has unit of W/m^2K.

ACTOR

In layered assemblies, conductance is combined into a single number called the U-factor or U-value. Lower U factor means worse conduction, which means better insulation. It has unit W/m^2K.

$$Q = \frac{K\ A\ \Delta t}{d}$$

$$Q = U \Delta t \text{ Where } U = \frac{K \ A}{d}$$

U-factor is the reciprocal of the sum of resistances, $U = \frac{1}{\sum R}$

THERMAL RESISTANCE (R-VALUE = 1/U)

It indicates how an effective a material is as an insulator. It is the reciprocal of thermal conductance. Higher R value indicates better insulating properties.

THERMAL MASS

Thermal mass is a material's resistance to change temperature as heat is added or removed. It is a key factor in dynamic heat transfer.

DENSITY

Density is the mass of a material per unit volume. It stores more heat.

SPECIFIC HEAT

It is a measure of the amount of heat required to raise the temperature of given mass of a material by 1 K. It has unit of J/kg K.

THERMAL CAPACITY

It is ability of a material to store heat per unit volume.

Density X Specific heat = heat is stored per unit volume.

THERMAL COMFORT

Thermal comfort is a method of maintaining a constant air movement and removal of saturated air from inside.

The factors that influence thermal comfort are

- Metabolic rate
- Clothing insulation
- Air temperature
- Mean radiant temperature
- Air speed
- Relative humidity

Metabolic rate

It is level of transformation of **chemical energy into heat** by metabolic activities. It is equal to the **energy produced per unit surface area** of an average person at rest. It is expressed as **met** units.

Clothing insulation

Clothing insulation **prevents heat loss** and consequently the **thermal balance**. It can either help to keep a person as warm or lead to overheating.

Air temperature

It is the **average temperature** of the air surrounding to the occupant with respect to location and time.

Mean radiant temperature

It is the **amount of radiant heat transferred from a surface**. It depends upon ability to absorb or emit heat by the materials.

Air speed

It is defined as the **rate of the air movement at a point, without regard to direction.**

Relative humidity

It is the ratio of the **amount of water vapor in the air to the amount of water vapor at specific temperature and pressure of that air.**

INDICES OF THERMAL COMFORT

Thermal Index (or) Comfort Scale

A single scale which combines the effects of various thermal comforts such as air temperature, humidity, air movement and radiation is called a Thermal Index or Comfort Scale.

The effective temperature is adjusted by considering the loss or gain of heat by radiation to arrive at a **C**orrected **E**ffective **T**emperature (CET). It is determined by

- Air temperature
- Humidity
- Air movements
- Heat radiation

CET is measured using

- Globe thermometer : to measure air temperature adjusted for heat radiated
- Wet bulb thermometer : to measure humidity.

SHADING DEVICES

The primary objective of shading devices is creating a comfortable internal environment.

Sun shading devices inhibit the solar radiation incident on a building. Sun shading devices are any mechanical equipment or textiles that are used either internally or externally or in between the internal and the external building space.

Shading devices can be fixed, manual and automatic movable.

IMPORTANCE OF SUN SHADING DEVICES

- To provide greater comfort for occupants.
- It can improve building energy performance.
- To prevent glare
- To increase useful daylight availability.
- To create a sense of security

SOLAR SHADING

When sunlight hits a pane of glass, it splits into three components, if it is reflected, then there is no effect on heating. If it is absorbed then glass heats up which would transfer heat by conduction and also emits. If it is transmitted, heat up surface behind it.

The proportion between the three components is determined by the angle of incidence and by the type of glazing. For most types of glazing, the transmitted light is very small if the angle of incidence is larger than 45^{o} from the normal to the glazing. If the angle is 60^{o}, most of the radiation is reflected.

TYPES OF SUN SHADING DEVICES

Shading devices is classified into two types

- Internal shading devices
- External shading devices

Internal shading devices

Internal shading devices such as curtains form of vertical or horizontal blinds attached above the window, can reduce heat energy passing through a window. It limits the glare resulting from solar radiation. Usually it is adjustable and occupants to allow & regulate the amount of direct light entering their space. Mostly they are attached above windows either horizontally or vertically. It should be made or designed to be durable.

Curtains

It is the most commonly used shading device, mostly used on residential buildings. It is cheaper and can be found in various varieties colors and texture.

Venetian blind

Venetian blinds are basic slatted blinds made of metal or plastic or wood. Suspended by a strip of cloth called tapes, all slats in unions can be rotated through nearly 180 degrees.

Curtains

Venetian blinds

Vertical Louvre blinds

It is used in commercial and public buildings, it controls the heat, light and glare. It can be used in larger windows and doors.

Roller blinds

Roller blinds are usually stiffened polyester, mounted on a metal pole and operated with a side chain or spring mechanism. It is used for block outs, sun screens. Translucent with a metal or plastic chain available that operates the blind through an aluminium tube to roll up and down.

Pleated blinds

Pleated blinds are shades made from a pleated fabric (which helps to add texture to a room) that pull up to sit flat at the top of a window to hide from sight when open.

Blackout blinds

It is made up of tight woven fabric to help the control the light levels in a room. It is designed to block the external lights to enter the room.

External shading devices

External sun shading devices is considered better than internal shading devices. It is in horizontal, vertical or inclined projections, vegetation in buildings.

Horizontal devices

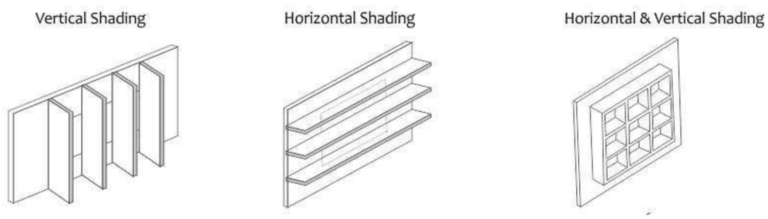
To shade a window during hot summer months, but to allow sunlight to shine through a window in the winter, to help warm a building.

Vertical devices

Primarily useful for east and west exposures to improve the insulation value of glass in winter months by acting as a windbreak.

The egg-crate

A combination of vertical and horizontal shading elements used in hot climate regions because of their high shading efficiencies. The horizontal elements control ground glare from reflected solar rays.



DESIGN ING SHADING DEVICES

Given the wide variety of buildings and the range of climates in which they can be found, it is difficult to make sweeping generalizations about the design of shading devices. However, the following design recommendations generally hold true:

1. Use fixed overhangs on south-facing glass to control direct beam solar radiation. Indirect (diffuse) radiation should be controlled by other measures, such as low-e glazing.
2. To the greatest extent possible, limit the amount of east and west glass since it is harder to shade than south glass. Consider the use of landscaping to shade east and west exposures.
3. Do not worry about shading north-facing glass in the continental United States latitudes since it receives very little direct solar gain. In the tropics, disregard this rule-of-thumb since the north side of a building will receive more direct solar gain. Also, in the tropics consider shading the roof even if there are no skylights since the roof is a major source of transmitted solar gain into the building.
4. Remember that shading effects daylighting; consider both simultaneously. For example, a light shelf bounces natural light deeply into a room through high windows while shading lower windows.
5. Do not expect interior shading devices such as Venetian blinds or vertical louvers to reduce cooling loads since the solar gain has already been admitted into the work space. However, these interior devices do offer glare control and can contribute to visual acuity and visual comfort in the work place.
6. Study sun angles. An understanding of sun angles is critical to various aspects of design including determining basic building orientation, selecting shading devices, and placing Building Integrated Photovoltaic (BIPV) panels or solar collectors.

7. Carefully consider the durability of shading devices. Over time, operable shading devices can require a considerable amount of maintenance and repair.
8. When relying on landscape elements for shading, be sure to consider the cost of landscape maintenance and upkeep on life-cycle cost.
9. Shading strategies that work well at one latitude, may be completely inappropriate for other sites at different latitudes. Be careful when applying shading ideas from one project to another.

VENTILATION

Ventilation is the movement of air within a building and between the building and the outdoor. The removal of all vitiated air from a building and its replacement with fresh air is known as ventilation.

Types of ventilation

- Natural ventilation
- Mechanical or artificial ventilation

Natural ventilation

Natural ventilation is the process of supplying air to and removing air from an indoor space without using mechanical systems.

- The location, size and type of windows play a great role in imparting natural ventilation to the room
- The efficiency of roof ventilators depends on their location, wind direction and height of building.
- The window ventilation with a combination of radiator, deflector and exhaust can give better results.
- The radiators are situated below the sill level of the windows and they extend for the full length of the window.
- The exhaust duct is provided near the ceiling of the opposite wall.
- The windows open from bottom and the deflectors may be of curved vanes.
- The velocity of wind creates pressure differences between inside & outside surfaces of a room.
- The rate of air change in a room mainly depends on the designing of the opening, location of inlet and outlet and the difference in temperature between the inside and outside air.
- The natural ventilation when inlets are at the bottom and roof ventilator is at the top.
- Cross ventilation is used to indicate the position of outlets just opposite to inlets
- Natural ventilation depends on the direction of wind and it is very difficult to control the entry of air containing smoke, dust. To keep control over the quantity, velocity and temperature of the incoming air is also not very easy.

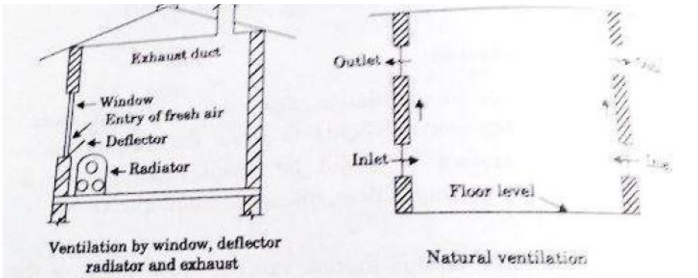


Fig. Ventilation by window, deflector radiator and exhaust

Fig. Natural ventilatio

Mechanical or Artificial ventilation

Mechanical arrangement is adopted to provide enough ventilation to the room. There are five methods of the mechanical ventilation

- Exhaust system
- Supply system
- Combination of exhaust and supply system
- Plenum process
- Air-conditioning

AIR CONDITIONING

It is defined as the process of simultaneously controlling and maintaining the properties of air like temperature, humidity, purity, direction of flow in a closed space.

Principle

An air-conditioner continuously draws an air from an indoor space to be cooled and cools it by the refrigeration principles and discharges it back into the same indoor space that needs to be cooled and recirculation of the cooled air keeps the indoor space at the required temperature.

Classification of air-conditioning system

- Comfort air- conditioning
    - Summer air – conditioning
    - Winter air – conditioning
    - Year-round air -conditioning
- Industrial air-conditioning
    - Unitary (Window) air-conditioning
    - Central air-conditioning

Comfort air- conditioning

It is to provide the environment with required temperature and humidity for comfort.

Summer air – conditioning

The temperature is high and hence the air conditioning system involves cooling & dehumidification.

Winter air – conditioning

Temperature is lower in the atmospheric hence air conditioning involves heating and dehumidification to provide comfort.

Year-round air –conditioning

System has both winter & summer air-conditioning.

Industrial air-conditioning

It is to provide the environment with the required temperature and humidity according to applications.

Unitary (window) air-conditioning

The unitary or window type air-conditioner is of small capacity. (0.5 tonnes to 2 tonnes)

Central air-conditioning

The central air-conditioning is of large capacity.(around 50 to 100 tonnes)

WINDOW AIR-CONDITIONER (ROOM AIR-CONDITIONER)

It is designed to condition the air in a single room and usually installed in a window.

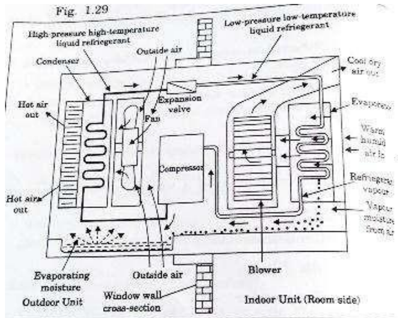
Construction

Main components are

- Compressor
- Condenser
- Air filter
- Evaporator
- Motor
- Fans
- Thermostat
- Capillary tube

  The while unit is divided into two units as
- Indoor unit (an evaporator, air filter, motor driven fan, control panel, trays)
- Outdoor unit (compressor, condenser, trays and motor driven fan)

Fig. 1.29



Layout of a window (or room) air-conditioner

Working

The evaporator fan sucks the air from the room to be conditioned through air filter and it passes the air over the cooling coil. It delivers cool and dehumidified air back to the room.

In the evaporator, the liquid refrigerant picks up heat from the room air. This cool air brings down the temperature and humidity levels in the room.

Compressor compresses the low-pressure vapour refrigerant coming from the evaporator or cooling coil and converts into high pressure vapour refrigerant. It is passed into the condenser where it is cooled.

Outside air is drawn in by the another fan and it cools the refrigerant then becomes liquid.

The high-pressure low-temperature liquid refrigerant from the condenser enters the capillary tube. It is passes to the evaporator coil.

In the evaporator, the liquid refrigerant picks up heat and gets vapourised. This cycle repeats again & again until required temperature is reached.

Advantages

- Individual temperature control device is provided
- For air distribution, ducts are not required.

Disadvantages

- Unit is installed outside the wall
- Unit has a fixed air quantity

PACKAGED AIR CONDITIONER

It is a self contained unit primarily for floor mounting, designed to provide conditioned air to the space.

Unit comprises a compressor, condenser and evaporator which are inter connected with copper refrigerant piping and refrigerant controls. It also includes fan for circulation of air and filter. The unit is provided with compressor and fan motor starter and factory wired safety controls.

Compressor is a device which compresses low pressure and low temperature refrigerant gas to high pressure high temperature super heated refrigerant gas.

Condenser condenses high pressure and high temperature refrigerant gas to liquid refrigerant at approximately the same temperature and pressure by removal of sensible heat of refrigerant by external means of water cooling or air cooling.

The packaged units available with microprocessor based controller installed in the unit for digits display of faults.

The packaged unit can also be provided with winter heating package or humidification package. It may be provided with either water-cooled condenser or a remote air cooled condenser with inter connected copper refrigerant piping.

The units are available with reciprocating compressor as also scroll the false ceiling to attend to the indoor unit including periodic cleaning of air filter.

Outdoor unit is mounted at the nearest open area where unobstructed flow of outside air is available for air cooled condenser.

CHILLED WATER PLANT

Chilled water is extensively used as a secondary refrigerant in larger commercial, institutional and industrial premises to make cooling available over a large area.

The refrigeration machine that produces chilled water(chiller).

It consists of the compressors, evaporator and condenser packaged as a single unit. The condensing medium may be water or outdoor air. Air cooled chillers are designed for outdoor installation and have large fans to force outdoor air oven the condenser coil for heat rejection.

The evaporator consists of a shell and tube heat exchanger with refrigerant in the shell and water in the tubes.

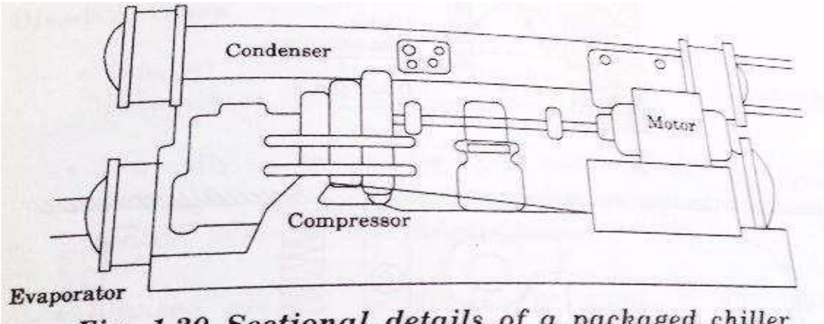


Fig. 1.30 Sectional details of a packaged chiller

FAN COIL UNITS

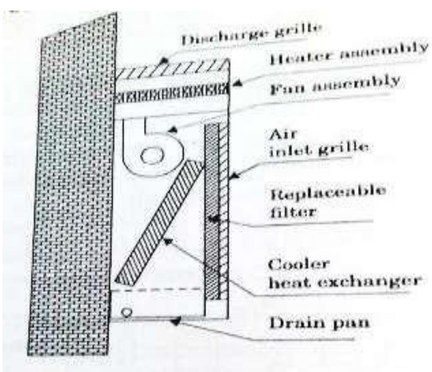
A fan coil unit consists of a heat exchanger in which water is circulated and a fan assembly, incorporating a filter and controls, designed for wall perimeter units.

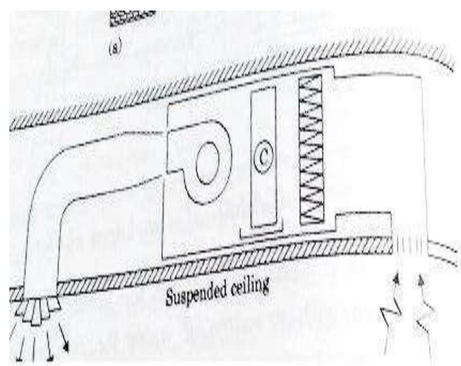
The ceiling units mounted within ceiling voids. The ceiling units can be configured as a cassette, drawing air into the centre and discharging at the periphery. Heating elements, electric, hot water or steam can be included.

The chilled water is fed to a number of air-handling unit each sized for a suitable zone, where the conditions throughout the zone can be satisfied by the outlet air from the unit.

This offers a range of comfort conditions within the space, with units serving rooms, or part of a room.

The coil is normally operated with a fin temperature below room dew point, so that some latent heat is removed by the coil which requires a condensate drain. Multi speed fans are usual, so that the noise level can be reduced at times of light load.





Advantages

- Individual control for zone or office, including heating in some zones and cooling in others
- Relativity low cost of standard units
- Simple control system
- Built in standby capacity where several units are located in one zone

Disadvantage

- Limited flexibility with standard units, all operating parameters fixed by manufacturer
- Limited control of fresh air input, if any, so that advantage of free cooling cannot be taken
- Limited ability to control air distribution

WATER PIPING

Water pipes are pipes or tubes frequently made of polyvinyl chloride, steel, cast iron or copper that carry pressurized and treated fresh water to buildings as well as inside the building.

Hydronics is the use of a liquid heat transfer medium in heating & cooling systems. A hydronic system may include both a chilled & a heated water loop, to provide for both heating & air conditioning.

When the hot air hits the cold coil of the air conditioner, it not only cools the air it squeezes the moisture out of the air. If the buildings is full of hot humid air, the air conditioner will condense the excess of water vapour into liquid water that can be drained outside.

The water drips from the cooling coil into channels that should be angled toward the back of the unit. If an air conditioner is not dripping it may not properly be doing its job of dehumidifying the room.

COOLING LOAD

It is defined as the total heat required to be removed from the space in order to bring it to the desired temperature by air conditioning and refrigeration equipment.

The purpose of a load estimation is to determine the size of the air conditioning and refrigeration equipment that is required to maintain inside conditions during periods of maximum outside temperatures.

The design load is based on inside & outside design conditions and it is air conditioning & refrigeration equipment to produce satisfactory inside conditions.

It is the rate at which sensible and latent heat must be removed from the space to maintain a constant space dry bulb air temperature and humidity. Sensible heat into the space causes its air temperature to rise while latent heat is associated with the rise of the moisture content in the space.

DIFFERENT TYPES OF AIR CONDITIONER SYSTEMS

Central air conditioner

- Split air conditioner
- Window air conditioner
- Portable air conditioner

Protection against fire to be caused by A.C systems

Failing to keep the not cleaned properly

- Storing flammable materials near the A.C systems
- Faulty parts & equipment

Regulated fire protection systems

Alarm system

- Sprinkler system
- Stand pipe system
- Smoke detector

CLIMATE AND DESIGN OF SOLAR RADIATION

Radiation is the intensity of sun rays falling per unit time per unit area. Its has unit of W/m^2.

The amount of solar radiation that reaches on the earth's surface varies according to

* Geographic location
* Time of day
* Season
* local landscape
* local weather.

The sun strikes the earth's surface at different angles. When the sun's rays are vertical, the earth's surface gets all the energy possible. The slanted the sun's rays are the longer they travel through the atomsphere, becoming scattered and diffuse. In polar regions sun's rays are not received at all during part of the year.

When the earth is nearer to the Sun, the earth's surface receives a little more solar energy and it is summer in the southarn hemisphere and winter in the northern hemisphere.

Direct solar radiation

Sun rays reaches the earth's surface without being diffused is called direct beam solar radiation.

diffuse solar radiation

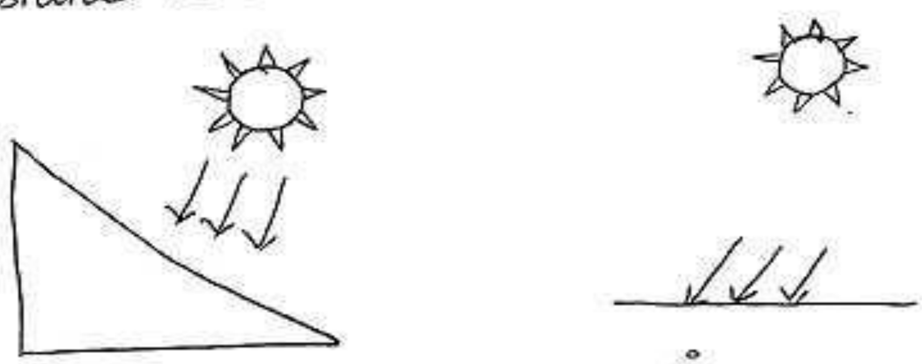
As sunlight (passes) passes through the atomsphere, it is absorbed, scattered and reflected by

* air molecules
* water vapor
* clouds
* dust
* pollutants
* Forest fires
* volcanoes.

This is called diffuse solar radiation.

The sum of the diffuse and direct solar radiation is called global solar radiation.

The instruments used for measuring of solar radiation are the pyranometer and the pyrheliometer. The duration of sunshine is measured by sunshine recorder.



Effect of orientation

Building on a south facing slope will receive more radiation compared to other orientations.

CENTRAL HEATING

Central heating System provides warmth to the whole interior of a buildings (or) portions of a building. It is based on the principle of convection The heat is distributed throughout the building, by forced-air through duckwork, water Circulating through pipes or steam fed through pipes.

Central heating system

Heat generation involves the combustion of fossil fuel in a furnace or boiler. The circulating hot water can be used for central heating. It includes

A gas supply lines, oil tanks and supply lines (or) distinct heating supply lines.

A boiler heats water in the system.

pump to circulate the water in the closed system.

Radiators which are wall-mounted panels through which the heated water passes in order to release heat into rooms.

Hot water from the boiler rises up passes through the radiators of different rooms. Radiators get heated and radiate heat to the room.

Hot water also reaches the cold water tank at the top of the building. Convection currents are set up and the building is kept warm continuously at a constant temperature.

The circulating water systems use a closed loop, the same water is heated and then reheated.

VENTILATION MEASUREMENTS

Natural ventilation occurs because of wind and thermal forces which produce a flow of outdoor air through the various openings in a building

The arrangement, location and control of Ventilation opening can be designed to take into consideration the driving forces of wind and temperature.

The types of openings include

Windows, doors, skylights, roof ventilators and specially designed inlet or outlet openings.

The ventilation flow needed to remove a given amount of heat from a building can be calculated as,

$$V = \frac{Q}{C_p(T_o - T_i)}$$

where V - Ventilation rate

Q - total heat gain in a space

C_p - average specific heat

$(T_o - T_i)$ - temperature rise of incoming air

Infiltration

Infiltration is the random flow of air through unintentional opening driven by wind and difference in pressures.

Air leakage is the sum of all parallel air flows through cracks and other openings into or out of a building without regard to flow directions coefficient of effectiveness K depends on the direction of the wind relative to the opening and on the ratio between the areas of two openings.

Stack effect

Ventilation due to convection effects arising from temperature difference between inside & outside is given by

$$Q = 7.0\, A \sqrt{h(t_r - t_o)}$$

Q - the rate of air flow (m^3/hr)
A - free area of inlet openings (m^2)
h - vertical distance between inlets & outlets (m)
t_r - average temperature of indoor air at height h (°c)
t_o - temperature of outdoor air (°c)

V - wind speed (in m/hr)

UNIT II ACOUSTICS

Sound waves are classified into three categories on the basis of frequency.

1. Infrasonics (below 20 Hz)
2. Audible sound (between 20 Hz to 20.000 Hz)
3. Ultra sound (above 20,000 Hz)

Audible sound is further classified as

a) **Musical sound** which produces pleasing effect on the ear.
b) **Noises** which produces unpleasant effect on the ear.

Characteristics of musical sound

a) Pitch – Pitch is the characteristic of sound that distinguishes between a shrill sound and a grave sound.
b) Quality – The quality of sound is that characteristic which enables us to distinguish between two notes of the same pitch and loudness produced by two different voices.
c) Intensity of sound – It is the energy of sound wave crossing per unit time through unit area at right angles to the direction of propagation.
d) Loudness – It is the degree of sensation produced in the ear.

Weber-Fechner law

Loudness of sound is defined as the degree of sensation produced on the ear. This cannot be measured directly. So that it is measured in terms of intensity. Loudness is proportional to logarithmic value of intensity.

$$L \propto \log I; \quad L = k \log I$$

Sound Intensity Level

It is the ratio of intensity of a sound (I) to the standard intensity of sound (I_o) .

$$\beta = \log_{10} (I/I_o)$$

Bel – 1 bel is defined as the relative intensity between two sound notes if one is 10 times more intense than the other.

Decibel – It is the smallest unit compared to Bel. It is the standard unit used to measure the loudness. One decibel is equal to one tenth of bel. An increase of sound intensity level by 1 dB would increase the intensity by 26 %.

Absorption coefficient

The absorption coefficient of a material is defined as the ratio of the sound energy absorbed by the surface to that of the total sound energy incident on the surface.

$$a = \frac{\text{Sound energy absorbed by the surface}}{\text{Total sound energy incident on the surface}}$$

The absorption coefficient can also be defined as the rate of sound energy absorbed by a certain area of surface to that of an open window of same area.

a = Sound energy absorbed by 1m^2 of surface

Reverberation time

The persistence of audible sound, even after the source has stopped to emit the sound is called reverberation. The time during which the sound persists in the hall is called as reverberation time.

Reverberation time is also defined as the time taken by the sound to fall to one millionth of its original intensity, after the source of sound is stopped.

$$I = Im/10^{-6}$$

When the reverberation time is lower than the critical value, sound becomes inaudible by the observer and the sound is said to be dead and if the reverberation time is too large, echoes are produced. Therefore, the reverberation time should have some optimum value.

Sabine's law

If *V* is the volume of the hall, *a* is the average absorption coefficient and *S* is the total surface area, the reverberation time can be related as

$$T = (0.167 V)/(\sum as)$$

Derivation of Sabine's law

Let us consider small element *ds* on a plane wall AB as shown in fig.

Assume that this element *ds* receives sound energy. Taking O as a mid-point on ds, two semicircles are drawn with radii r and r+dr. Consider a small shaded portion between the circles lying between two radii drawn at angles θ and $\theta+d\theta$.

Radial length of the shaded portion = dr
Arc length of the shaded portion = $r\, d\theta$
Area of the shaded portion = $r\, d\theta\, dr$

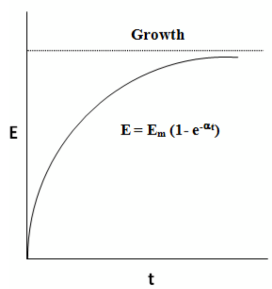
Imagine the whole figure is rotated about the normal through an angle $d\phi$ and shaded portion travels through a small distance dx and thus traces a elemental volume dV.

Distance travelled by this shaded portion, $dx = r \sin\theta\, d\phi$
Volume traced by the shaded portion, $dV = r\, d\theta\, dr\, .r \sin\theta\, d\phi$

If E is the sound energy density, then sound energy present within the volume element dV,

$$= E\, .\, dV$$

$$= E.\, r^2 \sin\theta\, d\theta\, dr\, d\phi$$



This equation expresses the growth of sound energy density 'E' with time 't'. This indicated that E increases with t, and when $t \rightarrow \infty$, $E = E_m$.

Decay of sound energy

Assume that, when sound energy has reached its steady (maximum value) state Em, sound energy is cut off. Then the rate of emission of sound energy, P = 0.

Therefore, equation (2) can be written as $Ee^{\alpha t} = K$

Substituting the boundary conditions $E = E_m$ at $t = 0$ and $P = 0$, we get $E_m e^0 = 0 + K$

$K = E_m$

Therefore, we get
$Ee^{\alpha t} = E_m$

$E = E_m / e^{\alpha t}$

Therefore, $\mathbf{E = E_m . e^{-\alpha t}}$

This equation represents the decay of sound energy density with time after the source is cut off.

Expression for reverberation time

The standard reverberation time is the time taken by the

sound to fall of its intensity to one-millionth of its initial value after the source is cut off. Now, the value of sound energy density before cut off is E_m, at standard reverberation time, it reduces to

$$E = E_m/10^6$$

To calculate T, we put $E = E_m.10^{-6}$ and $t = T$,

$E_m.10^{-6} = E_m.\ e^{-\alpha T}$

$e^{-\alpha T} = 10^{-6}$

$e^{\alpha T} = 10^6$

Taking log on both sides, we have

$\alpha T = 6\log_e 10$

$T = (6x2.3026x1)/\alpha$

$T = (6x2.3026x1) / (vA/4V)$

By using velocity of sound, v = 340 m/s

$\mathbf{T = 0.165\ V / A}$

or

$\mathbf{T = 0.165\ V / \Sigma as}$

This equation is in agreement with the experimental values obtained by Sabine.

<u>Factors affecting acoustics of buildings and their remedies</u>

i) Heavy curtains with folds are used to reduce reverberation time sound
ii) Floor is covered with carpets to absorb sound.
iii) Windows and openings are provided in the hall which can be opened or closed to control the reverberation time.
iv) Walls and ceilings are covered with sound absorbing materials.
v) If the hall is filled to its maximum capacity of audience, reverberation time is less.

2. **Loudness:** There should be adequate loudness in all parts of the hall. Remedies:

i) Large sounding boards are used behind the speaker facing the audience.
ii) Loudspeakers are used to increase the loudness.
iii) Low ceilings help to reflect the sound towards the audience.
iv) Sound absorbing materials are used in those parts of the hall where sound intensity is large.

3. **Echo:** The reflection of sound from a distant reflecting surface is known as echo. If the echo reaches the listener about $1/17^{th}$ of a second after the direct sound, the listener hears two sounds instead of one which causes confusion. Such echoes mush be eliminated in halls.
Remedy: High ceilings and distant walls are covered with second absorbing materials.

4. **Echelon effect:** Succession of echoes produced by a set of regularly spaced reflecting surfaces like staircase causes confusion in original sound. This effect is known as echelon effect. Remedy: The regularly spaced reflecting surfaces like stairs are covered with sound absorbing materials like carpets.

5. **Focusing:** Concave and parabolic surfaces in the hall focus sound. This causes concentration of sound in certain regions of the hall which is not desirable.
Remedies: Curved surfaces are avoided, If there are curved surfaces, they are covered with sound absorbing materials.

6. Resonance: Loose fitting window panels and some other objects resonate at some audible frequencies creating more sound of these frequencies. This distorts the original sound. Remedies: Window panels are fixed properly, Vibrating objects are placed on sound absorbing materials.

7. **Noise:** Noise from different sources adversely affects the quality of sound in a hall. The noise can be air borne, structure borne or inside noise.
   a) ***Air borne noise:*** the external noise, for example of traffic, which enters the halls through doors, windows and ventilators is known as external noise.
   Remedies:
      i) Openings for ventilators inside the hall are avoided.
      ii) Doors and windows are provided with rubber covering on frames so that they shut without any gaps.
      iii) Double doors and windows having separate frames enclosing sound absorbing materials are used.
   b) ***Structure borne noise:*** Noise produced by activities like drilling and hammering or the vibrations of heavy machinery is transmitted through the structure of the building. This is known as structure borne noise.
   Remedies:

i) Heavy machinery is mounted on sound absorbing materials like wood or rubber.
ii) Double walls are used with space between them.

c) ***Inside noise:*** It is the noise produced inside the hall by machinery, fans, air conditioners etc. Remedies:
i) Sound absorbing materials and curtains are provided near the sources of noise.
ii) The sources of noise are mounted on sound absorbing materials.

Methods of sound absorption

When a sound wave strikes one of the surfaces of a room, a part of the sound energy is reflected back into the room and others are penetrating through the surface. The parts of the sound energy are absorbed by the conversion to heat energy in the material, while the rest is transmitted through it. The level of energy conversion to heat energy depends upon sound absorbing properties of the material.

The listener and the sound source are in the same room, if the room has no sound absorbing surfaces, the sound energy is bounced back between the surfaces and it takes long time before dies out.

The listener will have a problem registering the speaker because listener hears both direct and repeated reflected sound waves. If the surfaces are covered with absorbing material, the reflected sound will decrease, also sound level of the room is decreased.

Noise measurement

The logarithms scale provides comparing the sound pressure of one sound with another. To avoid a scale which is too compressed a factor 10 is introduced, giving rise to the decibel unit.

1 decibel = 10 $\log_{10}$(intensity measured/reference intensity)

Where reference intensity 2 x 10^{-5} Newtons per sq.meter or 10^{-12} watts per sq. meter.

Sound pressure level(L_P or SPL) = 10 $\log_{10}(P^2 - P^2_{ref})$ (unit-db)

= 20 $\log_{10} P - 20 \log_{10} P_{ref}$ (unit-db)

Sound insulation and its measurements

It is a measure used to reduce the level of sound when it passes through the insulating building component. It is also called sound proofing.

Methods of sound insulation

By avoiding opening of pipes and ventilators.

By allotting proper places for doors and windows.

iii) When noise is structured-borne

Using double walls with air space between them. Insulating of machinery.

Impact of noise in multi-storeyed buildings

It is defined as the structure whose usage levels are regular in distribution and which correspond roughly to the required for human habitation. There are four main actions which causes impact of noise in multistoried buildings.

i) Speech privacy

It is an issue within office buildings, including individual work space, inside conference halls and between offices. It mainly affects the quality of work in the adjacent buildings.

ii) Back ground noise

It can adversely impact the work space too little background noise and speech privacy is reduced.

iii) Sound masking

It can blend the building systems noise levels within electronic noise systems in the middle. Traditional sound masking systems are located in loud speakers above the ceiling.

iv) Orientation of buildings

The noise impact may also be great for rooms perpendicular to road ways because, a noise pattern can be more annoying in perpendicular rooms. Windows on perpendicular walls do not reduce noise as effectively as those on parallel walls became at the angle of sound.

Sound absorbing materials

Materials used to increase the absorption of sound waves or to reduce the reflection of sound waves in a room or hall are known as sound absorbing materials.

An ideal absorbing materials should be economical in construction and maintenance, water-proof, fire-proof, sufficiently strong and good in appearance.

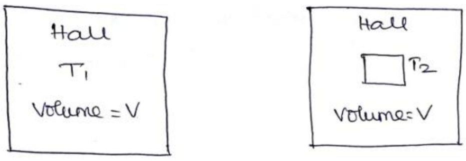
In the hall treated with absorbing materials, the speech can be heard clearly and music can be fully enjoyed.

They work on the principle that the sound waves penetrate into the pores and in this process, the sound waves are converted into other form by friction.

Absorbing materials depends on the thickness of the material, its density and frequency of sound.

Improper covering destroys the absorbing properties of the material.

Absorption Coefficient



$$T_1 = \frac{0.167V}{\Sigma as} \qquad T_2 = \frac{0.167V}{\Sigma as + a_1 s_1}$$

$$\frac{1}{T_1} = \frac{\Sigma as}{0.167V} \rightarrow (1) \qquad \frac{1}{T_2} = \frac{\Sigma as + a_1 s_1}{0.167V} \rightarrow (2)$$

$$(2) - (1) \Rightarrow \frac{1}{T_2} - \frac{1}{T_1} = \frac{\Sigma as + a_1 s_1}{0.167V} - \frac{\Sigma as}{0.167V}$$

$$= \frac{\Sigma as + a_1 s_1 - \Sigma as}{0.167V}$$

$$\frac{1}{T_2} - \frac{1}{T_1} = \frac{a_1 s_1}{0.167V}$$

$$a_1 = \frac{0.167V}{s_1} \left\{ \frac{1}{T_2} - \frac{1}{T_1} \right\}$$

$$a_1 = \frac{0.167V}{s_1} \left\{ \frac{T_1 - T_2}{T_1 T_2} \right\}$$

UNIT II ACOUSTICS

Characteristics of sound and Classification of Sound

Characteristics of sound and Classification of Sound. Sound is a form of energy. Sound is produced by the vibration of the body.
The sound requires a material medium for its propagation and can be transmitted through solids, liquids and gases.

CHARACTERISTICS OF SOUND

- Sound is a form of energy.
- The Sound is produced by the vibration of the body.
- Sound requires a material medium for its propagation and can be transmitted through solids, liquids and gases.
- When sound is conveyed from one medium to another medium there is no bodily motion of the medium.
- Sound requires a definite interval of time to travel from one point to another point in a medium and its velocity is smaller than the velocity of the light.
- Velocity of sound is maximum is solids, which have higher bulk modules and least in gases.
- Sound may be reflected, refracted, or scattered. It exhibits diffraction and interference.In transverse mode it exhibits polarization also.

CLASSIFICATION OF SOUND BASED ON CHARACTERISTICS OF SOUND

- Sound waves of frequencies below 20 Hz are termed as Infrasonic (inaudible)
- The Sound waves of frequencies above 20000 Hz are termed as Ultrasonic (inaudible)
- Sound waves of frequencies 20 Hz to 20,000 Hz are termed as audible sound

Further the audible sound is classified as Musical Sounds and Noise.
The sounds which products effect on the ear are called musical sound and that which produces jarring and unpleasing effect are called noises.
sound is classified into

1. Infrasonics
2. Audible
   1. Music
   2. Noise
3. Ultrasonics

CHARACTERISTICS OF SOUND – CHARACTERISTICS OF MUSICAL SOUND

There are three characteristics of Musical Sound in Characteristics of Sound

- Pitch or Frequency
- Quality or Timbre
- Intensity or Loudness

o PITCH OR FREQUENCY:

Pitch is the characteristic of sound which is the sensation conveyed to our brain by thesound waves falling in our ears.

It depends directly on the frequency of the incident soundwaves.

Though the pitch is directly related to frequency, they are not the same; in generalthe frequency is a physical quantity whereas the pitch is a physiological quantity.

Example: sound of mosquito produces high pitch than the sound of lion which is a lowpitch.

- QUALITY OR TIMBRE

The quality of the sound is the one which helps us to distinguish between the musical notes emitted by the different instruments or voices, even though they have the same pitch and loudness.

- INTENSITY OR LOUDNESS

The intensity of sound at a point is defined as the average rate of flow of acoustic energy(Q) per unit area situated normally to the direction of und wave. The intensity depends upon the following factors

Where n=Frequency of the sound wave

a=amplitude of the wave

p=density of the medium v=velocity of sound in that medium

x=distance from the source of sound to the receiving end or Intensity per unit area per unit time

CHARACTERISTICS OF SOUND – LOUDNESS – WEBER FECHNER LAW

Loudness of the sound is defined as the degree of sensation produced on the ear. The loudness varies from one observer to another.

It is a physiological quantity and therefore it is difficult to measure loudness. But, it can be measured a logarithmic value of intensity

Equation 1 is known as WEBER – FECHNER law. Differentiating equation 1, we have is called Sensitiveness of ear.

Therefore the sensitiveness decreases with the increase in Intensity. For example more sound in an auditorium will not be hard properly.

INTENSITY

1. It refers to the external measurement
2. And it is common to hear
3. it can be measureddirectly

LOUDNESS

1. It is just a sensation produced on the ear.
2. And It depends upon individual listener
3. It is measured only with respect to intensity.

CHARACTERISTICS OF SOUND – UNIT OF LOUDNESS

If L, is the Loudness of sound of intensity I and L is the loudness corresponding to thestandard reference intensity 1 = 10 watts/m, then according to Weber- Fechner law, we have

Now, the intensity level (I) which is equal to the difference in Loudness,
If k is taken as 1, the intensity level or difference in loudness is expressed in bels, a unit named after Alexander Graham Bell, the inventor of Telephone

DECIBEL

The unit of Bel is however quite large and hence I is expressed by another standard unitcalled decibel 1 bel = 10 decibels.

CASE 1:

If I=0dB, then equation 1 becomes

CASE 2:

If I = 1dB, then equation 1 becomes
Subtracting equation 2 from 3, we get 1.26-1=0.26
For a change in intensity level of 1 dB, the intensity changes to about 26%. When I_1 = 100 I_o ;I_L=20dB
When I_1 = 1000 I_o ; I_L=30dB
To build up a scale of business, zero on the scale is taken as the threshold of hearing, which corresponds to $I_o = 10^{12}$ W/m^2. The maximum intensity with which an earcan tolerate is I = 1W/m^2

S.NO	SOURCE	INTENSITY LEVEL IN dB
1.	Threshold of hearing	0
2.	Rustle of leaves	10
3.	Whisper	15-20
4.	Average house	40
5.	Ordinary conversation	60-65
6.	Motors or heavy traffic trucks	70-80
7.	Roaring of lion at 20 feet	90
8.	Thunder	100-110
9.	Painful sound	120 and above

Characteristics of Sound and Classification of Sound

PHON

we have expressed the loudness in dB, on the assumption that the threshold of audibilityis constant for all frequencies.
But it is found that threshold of audibility varies withfrequency. Sounds of same intensity but of different frequency differ in loudness.

Hence adifferent unit called PHON is used to measure loudness level or equivalent loudness.

DEFINITION:

The meausre of loudness in Phons of any sound is equal to loudness in decibels of an equally loud pure tone of frequency 1000Hz.

EXPLANATION:

Let us consider two sources ‘S’ the standard source and S, the source ofsound for which loudness is to be measured.
The two sounds are heard alternatively andthe intensity of S is adjusted to be equal to the loudness of the S as shown in the figure.
Now the intensity level of S is measured, If it say ‘n’ decibels above the standard intensity,then the equivalent loudness is ‘n’ Phons
The expression for loudness in Phon (L) is given by Where I is the intensity of sound in dB

SONE

Sone is another unit to measure the loudness in terms of Phon or dB.

It is used to measurevery high loudness, especially between the ranges of 40 Phons to 100 Phons. i.SONE in terms of PHON

DEFINITION:

The measure of loudness in some of any sound in equal to the loudness of that particular sound having a loudness level of 40 PHons.

EXPLANATION:

Suppose a source of sound is having the loudness or 40 Phons then it can be assumed to have a loudness of 1 Sone.
Expression for Loudness in Sone is empirically given by

EXAMPLE:

Suppose if the loudness in Phon is 40 Phons, then the loudness in Sone in given by

ii. Sone in terms of Decibel

DEFINITION:

In terms of decibels the Sone is defined as the loudness of an equally loud pure tone of frequency 1000Hz with 40dB if intensity level.

EXPLANATION:

It is similar to that of the measurement of loudness in Phon in terms of dB, but the increase in intensity level should be 40dB above the standard intensity, then the equivalent loudness is 1 Sone.

ACOUSTICS OF BUILDINGS

So a new field of science is developed which deals with the planning of a building or a hall with a view to provide best audible sound to the audience and is called Acoustics of building.

Therefore to provide a best audible sound in a building or hall a prime factor called Reverberation.

REVERBERATION

When a sound pulse is generated in a hall, the sound wave travels towards all directionand are reflected back by the walls, floors, doors, windows ceiling etc as shown.

So a sound wave has two to three hundred repeated reflections, before it becomes inaudible.

Therefore, the observer in the hall does not be able to hear a singlesharp sound instead a "role of sound" of diminishing intensity (since part of energy is lostat each reflection)

REVERBERATION TIME

The duration for which the sound persist is termed as reverberation time and is measured as the time interval between the sound produced by the source produced by the source and to the sound wave until it dies.

DEFINITION:

It is defined as the time taken for the sound to fall below the minimum audibility measured from the instant when the source sound gets stopped.

In designing the auditorium, theatre, conference halls etc, the reverberation time is the key factor.

If the reverberation time is too large, echoes are produced and if the reverberation time is too short it becomes inaudible by the observer and the sound is said to be dead.

Therefore the reverberation time should not be too large or too short rather it should havean optimum value.

In order to fix this optimum value standard forumla is dervied by W.C.Sabine, who defined the standard reverberation time as the time taken for the sound to fall to one millionth of its original intensity just before the source is cut off.

SABINES FORMULA FOR REVERBERRATION

The relation connecting the reverberation time with the volume of the hall, the area and the absorption coefficient is known a s Sabine's Formula.

Sabine's developed the formula to express the rise and fall of sound intensity by the following assumptions.

1. Distribution of sound energy is uniform throughout the hall
2. There is Interference between the sound waves.
3. The Absorption coefficient is independent of sound intensity.
4. The Rate of emission of sound energy from the source is constant.

Let us consider a small element 'ds' on a plane wall AB. Assume that the element ds receive the sound energy 'E'.

Let us draw two concentric circles of radii 'r' and r + dr from the center point 'O' of

Consider a small shaded portion lying in between the two semi circles drawn at an angle θ and θ+dθ, with the normal to ds as shown.

Let 'dr' be th radial length and rdθ be the arc length Area of

shaded portion rdθdr —- (1)

If the whole figure is rotated about the normal through an angle 'dϕ' as shown in the figure, then it is evident that the area of the shaped portion travels through a small distance dx.

To find total energy received by the element 'ds' per second, we have to integrate the equation 3 for the whole volume lying within a distance 'v' is the Velocity of sound.

It is obvious from the geometry of the figure that,

GROWTH AND DECAY OF SOUND ENERGY

If 'P' is the Power Output (i.e., the rate of emission of sound energy from the source) then we can write.

Here E_m is the maximum energy from the source (which has been emitted) that is maximum energy which is incident on the wall.
Where k is the constant of integration

GROWTH OF SOUND ENERGY

Let us evaluate for growth

Initially during the growth the boundary conditions Are at

t=0 E=0

Thereore equation 8 becomes

Where E_m is the maximum sound energy.
This expression gives the growth of sound energy density 'E' with time 't'. The growth

is along an exponential curve as shown.

DECAY OF SOUND ENERGY

Let us irst evaluate k or decay.

Here the boundary conditions are at t=0; E=Em

Initially the sound increases from E to E_m and now it is going to decay from Em. Therefore time is considered as '0' for E=Em. At $E=E_{mv}$ the sound energy from the source is cut off. Therefore rate of emission of sound energy from the source=0 i.e., P=0 Therefore

from equation 8 we can write

Equation 10 gives the decay of sound energy density with time 't' even after the source is cut off. It is exponentially depressing function from maximum energy(Em) as shown.

The growth and decay of sound energy together is represented in the figure.

PROOF OF REVERBERATION TIME(T)

According to Sabine, the reverberation time is defined as the time taken by a sound to fall to one millionth of its initial value, when the source of sound is cut off.

Equation 13 represents the Reverberation time, which depends on the three factors viz,

1. Volume of the hall(V)
2. Surface area(S)
3. Absorption coefficient(a) of the materials kept inside the hall. Among these three actors volume is fixed.

Therefore, the reverberation time can be optimized by either varying the surface area of the reflecting surfaces or the absorption coefficient of the materials used inside the hall.

ABSORPTION COEFFICIENT

Thus, we can say that the open window behaves as a perfect absorber of sound and hence the absorption coefficient can be defined as the rate of sound energy absorbed by a certain area of the surface to that o an open window of same area.

DEFINITION:

The absorption coefficient of a surface is defined as the reciprocal of its area which absorbs the same amount of sound energy as absorbed by a unit o an open window.

For example if $2m^2$ of a carpet absorbs the same amount of sound energy as absorbed by $1\ m^2$ of an open window, then the absorption coefficient of the carpet is 1.2=0.5.
The absorption coefficient is measured in open window unit (O.W.U) or Sabines.

AVERAGE ABSORPTION COEFFICIENT

The average absorption coefficient is defined as the ratio between the total absorption in the hall to the total surface area of the hall.

MEASUREMENT OF SOUND ABSORPTION COEFFICIENT

Let us consider a smaple for which the absorption coefficient (a_m) is to be measured.
Initially without this material the reverberation time in a room and again the reverberation time is measured and let it be T_2.

Then rom Sabine's ormula

For Case (1) i.e. without the sample

Here, by knowing the terms on the right hand side the absorption coefficient of the given sample can be determined.

FACTORS AFFECTING THE ACOUSTICS OF BUILDING

We know, when sound waves are produced in a hall, it reaches the observer directly as well as after reflections from walls, floors, ceilings, etc.

Thus there is a possibility for causing interference between these waves, which in turn affects the originality of the sound produced.

The actors affecting the acoustics (sound) of building are as follows.

1. Unoptimised reverberation time
2. Very low or very high loudness
3. Improper focusing of sound to a particular area, which may cause interference
4. Echoes or echelon effects produced inside the buildings
5. Resonance caused due to matching of sound waves.
6. Unwanted sound rom outside or inside the building, so called noise may also affect the acoustics o buildings.

OPTIMUM REVERBERATION TIME AND ITS REMEDY

We know Reverberation time is the taken for the sound to fall to one millionth o its original sound intensity, when the source of sound is switched off.

This reverberation time is high then it produces, echoes in the hall and if the reverberation time is very low, the sound will not be cleary heard by the audience.

Therefore, for clear audibility, we should maintain optimum reverberation. The optimum

reverberation time can be achieved by the following steps

1. By having the full capacity o audience in the auditorium.
2. By choosing absorbents like felt, fiber, board, glass etc inside the auditorium and even at the back of chairs.
3. Reverberation time can be optimized by providing windows and ventilators at the places wherever necessary and using curtains with folds or the windows.
4. The reverberation time can also be optimized by decorating the walls with beautiful pictures.

The optimum reverberation time will not be constant for all types of building; it varies from one building to another as follows.

- For concert halls, the speech should have the optimum reverberation time of 0.5 seconds and music should have the optimum values o 1 or 2 seconds
- For auditorium, or theatres, the optimum reverberation time should be between 1.1 to 1.5 seconds for smaller area and between 1.5 to 3 seconds for larger area.

LOUDNESS AND ITS REMEDY:

We know loudness is the degree of sensation produced on the ear; it varies from observer to observer.

But, it is found that for a single observer the loudness varies from one place to another in the same auditorium.

This defect is caused due to the bad acoustical construction of buildings.

The loaudness will be very low in some area and will be very high in some areas. It can be optimized by the following remedies.

REMEDIES

1. Loudspeakers should be placed at the places where we have low loudness.
2. The loudness can also be increased by making reflecting surfaces, wherever necessary
3. Loudness can be increased by constructing low ceilings
4. Absorbents are placed at the places where we have high loudness.

Thus, the loudness should be made even, all over the auditorium, so that the observer can hear the sound at a constant loudness at all the places.

FOCUSING AND INTERFERENCE EFFECTS

In some places of a hall, the sound will not be heard properly and that place is said to be a dead space, which is due to presence of convex or concave surfaces in the hall as shown in the figure.

Sometimes the sound waves will have interference pattern because of ceiling surfaces which will create maximum intensity of sound(due to constructive interference) in some places and minimum intensity of sound(due to destructive interference) at some places and hence causing uneven distribution of sound intensity in the hall and hence causing uneven distribution of sound intensity in the hall.

REMEDIES

1. By avoiding curved surfaces (or) covering the curved surfaces by suitable absorbents the focusing can be avoided.
2. By evenly polishing and decorating with absorbents the interference effects can be avoided.

ECHOES AND ECHELON EFFECT

In some halls, the walls o the halls will scatter the sound waves rather than reflecting it, thus way create nuisance effect due to echoes.

The echoes are formed when the time interval between the direct and reflected sound waves are about $1/15^{th}$ of a second.
This effect occurs due to the reason that the reflected sound waves reaches the observer later than the direct sound.

If there is a greater repetition of echoes of the original sound to the observer then the effect is called as Echelon effect.

REMEDIES

The echo can be avoided by lining the surfaces with suitable sound absorbing materials and by providing enough number of doors and windows.

RESONANCE

Resonance occurs when a new sound note of frequency matches with standard audio frequency.

Sometimes, the window panel, sections of the wooden portion is thrown into vibrations to produce new sounds, which results in interference between original sound and created sound.

This will create disturbance to the audience.

REMEDIES

1. The resonance effect can be avoided by providing proper ventilation and by adjusting the reverberation time to the optimum level.
2. Nowadays the resonance is completely eliminated by air conditioning the halls.

NOISE

Noise is an unwanted sound produced due to heavy traffic outside the hall which leads to displeasing effect on the ear. There are three types of noises.

1. Air Borne noise
2. Structure Born Noise
3. Inside Noise

All these three noises pollute the area at which it has been produced and create harmful effects to the human beings.

Fortunately human beings have the capability to reject the sound within certain limits with conscious efforts and to carry on his normal work.

But sometimes the noises are strong which results in the following effects.

EFFECTS PRODUCED DUE TO NOISE POLLUTION

- It produces mental fatigue and irritation.
- Diverts the concentration on work and hence reduces the efficiency of the work.
- It sometimes affects the nervous system and lowers the restorative quality of sleep.
- Some strong noises leads to damage the eardrum and make the worker hearing impaired.
- The noises which are produced regularly will even retard the normal growth of infants and young children.

- AIR BORNE NOISE

The noise which reaches the hall through open windows, doors, and ventilations are called as air borne noise.

This type of noise is produced both in rural areas natural sound of wind and animals and in urban areas noise that arises from factories, aircrafts, automobile, trains, Flights etc.

REMEDIES

1. By making the hall air conditioned, this noise may be eliminated

2. By allotting proper places or doors and windows, this noise can be reduced.
3. It can be further by using double doors and windows with separate rames and by pacing the absorbents in-between them

- STRUCTURE BORNE NOISE

The noise that reaches the hall through the structure of the building is termed as Structure Borne noise.

Those types of noise produced inside the building, which may be due to the machinery operation, movement of furniture's footsteps etc and these sounds will produce structural vibration giving rise to the Structure Borne Noise.

REMEDIES

1. By properly breaking the continuity of the interposing layers by some acoustical insulators this type of noise can be avoided.
2. By providing carpets, resilent, antivibration mounts etc., this type of noise can be reduced.

- INSIDE NOISE

The noises that are produced inside the halls is known as inside noise.

Or example in some offices the sound produced by machinery, type writers ect produces this type of noise.

REMEDIES

1. By placing the machineries and type writers over the absorbing materials or pads this type of noise can be reduced.
2. It can be reduced by covering the floors with carpet.
3. By fitting the engine on the floor with a layer of wood or elt between them this type of noise can be avoided.

FACTORS TO BE FOLLOWED FOR GOOD ACOUSTICS OF BUILDING

To have a clear audibility of sound have an optimum level

1. The reverberation time should have an optimum level
2. The sound must be evenly distributed to each and every part of the building.
3. There should not be any focusing of sound to any particular area.
4. Each and every syllable of sound must be herd clearly and distinctly, without any interference.
5. There should not be any echoes, echelon effects and resonance inside the buildings.
6. The building should be made as sound proof building, so that external noises may be avoided.
7. Generally to say the total quality o sound should be maintained all over the building to all the audience.

Properties of Ultrasonic waves

The human ear is sensitive to sound waves in the frequency range from 20-20, 000 Hz.

This range is called Auduble range. Sound waves of frequency more than 20,000Hz are called Ultrasonics. These frequencies are beyond the audible limit.

These waves also travel with the speed of sound(330m/s) Their

wavelength are small.

Production of Ultrasonic waves

Production of Ultrasonic waves

Principle:

When a rod of ferromagnetic material like nickel is magnetized. Longitudinally, it undergoes a very small change in length.

This is called Magnetostriction effect.

Construction:

The circuit diagram of magnetostriction ultrasonic generator is as shown in the figure1.3.2.

A short permanently magnetized nickel rod is clamped in the middle between two knife edges.

A coil L_1 is wound on the right hand portion of the rod.
C is a variable capacitor. L_1 and C_1 form the resonant circuit of the collector- tuned oscillator.
Coil L_2 wound on the LHS of the rod is connected in the base circuit. The coil L_2 is used as a feed back loop.

Working:

When the battery is switched on, the resonant circuit L_1C_1 sets up an alternating current o frequency.
This current lowing round the coil L1 produces an alternating magnetic iels of frequency f along the length of the nickel rod.

The rod starts vibrating due to magnetostrictive effect. The

vibrations of the rod create ultrasonic waves.

The longitudinal expansion and contraction of the rod produces an E.M. in the coil L_2.

This e.m.f is applied to the base of the transistor.

Hence the amplitude of high frequency of high oscillations in coil L1 is increased due to positive feedback.

The developed alternating current frequency can be turned with the natural frequency of the rod by adjusting the capacitor.

CONDITION FOR RESONANCE:

Frequency of the oscillator circuit = Frequency of the vibrating rod

Where ‘l’ is the length o the rod

‘E’ is the Young’s modulus o the rod

‘ρ’ is the density of the material of the rod.

The resonance condition is indicated by the rise in the collector current shown in the milliammeter.

ADVANTAGES:

Magnetostriction Oscillators are mechanically rugged. The

construction cost is low.

They are capable of producing large acoustical power with fairly good efficiency.

LIMITATIONS

It can produce frequencies up to 3MHz only.

They frequency o oscillation depends upon the temperature.

Breadth o the resonance curve is large. It is due to vibrations of elastic constants of ferromagnetic material with the degree of magnetization.

So we cannot get a constant single frequency.

PIEZO ELECTRIC CRYSTALS

The crystals which produce piezo-electric effect and converse Piezo electric effect are termed as Piezo electric crystal.

Example: Quartz, Tourmaline, Rochelle Salts etc.

At typical example or a piezo electric crystal (Quartz) is as shown

It has an hexagonal shape with pyramids attached at both ends. It consists of 3 axes. Viz.,

(i) Optic Z axis, which joins the edges of the pyramid

(ii) Electrical axis(X axis), which joins the corners of the hexagon and

(iii) Mechanical axis, which joins the center or sides of the hexagon as shown

X-CUT AND Y CUT CRYSTALS

X-CUT CRYSTAL:

When the crystal is cut perpendicular to the X-axis, as shown in the figure 1.4.2, then it is called X-crystals.

Generally X-cut crystals are used to produce longitudinal ultrasonic waves.

Y-CUT CRYSTAL:

When the crystal is cut perpendicular to the Y-axis, as shown in the figure 1.4.3, then it is called Y-cut crystal.

Generally, Y-Cut crystal produces transverse ultrasonic waves.

PIEZOELECTRIC EFFECT

Definition: When a mechanical stress is applied to the mechanical axis with respect to optical axis, a potential difference is developed across the electrical axis with respect to optic axis

INVERSE PIEZOELECTRIC EFFECT:

Definition: When an alternating electric field is applied to electrical axis with respect to optical axis, expansion or contraction takes place in the mechanical axis with respect to optical axis.

PRODUCTION OF ULTRA SONIC WAVES – PIEZO ELECTRIC EFFECT

PRINCIPLE:

This is based on the **Inverse piezoelectric effect.**

When a quartz crystal is subjected to an alternating potential difference along the electric axis, the crystal is set into elastic vibrations along its mechanical axis.

If the frequency of electric oscillations coincides with the natural frequency of the crytal, the vibrations will be of large amplitude.

If the frequency of the electric field is in the ultrasonic frequency range, the crystal produces ultrasonic waves.

CONSTRUCTION:

The circuit diagram is shown in the figure 1.5 It is

base turned oscillator circuit.

A slice of Quartz crystal is placed between the metal plates A and B so as to form a parallel plate capacitor with the crystal as the dielectric.

This is coupled to the electronic oscillator through the primary coil L_3 of the transformer. Coils L_2 and L_1 of oscillator circuit are taken for the primary of the transformer. The collector coil L_2 is inductively coupled to base coil L_1.
The coil L_1 and variable capacitor C form the tank circuit of the oscillator.

WORKING:

When the battery is switched on, the oscillator produces high frequency oscillations.

An oscillatory e.m.f is induced in the coil L3 due to transformer action. So the

crystal is now under high frequency alternating voltage.

The capacitance of C1 is varied so that the frequency of oscillations produced is in resonance with the natural frequency of the crystal.

Now the crystal vibrates with larger amplitude due to resonance. Thus high

power ultrasonic waves are produced.

CONDITION FOR RESONANCE:

Frequency of the oscillator circuit = Frequency of the vibrating crystal Where ‘l’ is

the length o the rod

‘E’ is the Young’s modulus o the rod

‘ρ’ is the density of the material of the rod.

‘P’ = 1,2,3 …. Etc for fundamental, first overtone, second overtone etc respectively

ADVANTAGES:

1. Ultrasonic frequencies as high as 500MHz can be generated.
2. The output power is very high. It is not affected by temperature humidity.
3. It is more efficient than the Magnetostriction oscillator.
4. The breadth of the resonance curve is very small. So we can get a stable and constant frequency of ultrasonic waves.

DISADVANTAGES:

1. The cost of the quartz crystal is very high.
2. Cutting and shaping the crystal is quite complex.

SONAR – Sound Navigation and Ranging Principle:

It is based on the principle of Echo – Sounding.

When the Ultrasonic waves are transmitted through water, it is reflected by the objects in the water and will produce an echo signal.

The change in frequency of the echo signal, due to Doppler Effect helps us in determining the velocity and direction of the object.

DESCRIPTION:

It consists of timimg section which triggers the electric pulse from the pulse generator.

This pulse generator is connected to the transducer so that ultra sonic can be produced.

The transducer is further connected with the CRO for display.

The timing section is also connected to the CRO display or reference of the timing at which the pulse is transmitted as shown in the block diagram.

WORKING:

The transducer is mounted on the ship's hull without any air gap between them as shown.

The timing at which the pulse generated is recorded at the CRO or reference and this electrical pulse triggers the transducer which is kept in hull of the ship to produce ultrasonic waves due to the principle of inverse piezo electric effect.

These ultrasonic waves are transmitted through the water in sea.

On stricking the object the ultrasonic waves (echo pulses) are reflected in all directions as shown

CAVITATION:

Definition:

The Ultrasonic sound waves that propagate into the liquid media result in alternating high pressure (compression) and low-pressure (rarefaction) cycles, with rates depending on the frequency.

During the low pressure cycle, high intensity ultrasonic waves create small vcuum bubbles or voids in the liquid.

When the bubbles attain a volume at which they can no longer absorb energy, they collapse violently during a high pressure cycle.

This phenomenon is termed cavitation.

During the low pressure cycle, high intensity ultrasonic waves create small vacuum bubbles or voids in the liquid.

When the bubbles attain a volume at which they can no longer absorb energy, they collapse violently during a high pressure cycle.

This phenomenon is termed cavitation.

During the implosion very high temperature(approx 5,000K) and pressures (approx 2,000atm) are reached locally,

The implosion of the cavitation bubble also results in liquid jets of up to 280m/s velocity.

ACOUSTIC GRATING

The ultrasonic waves generated with the help o a quartz crystal inside the liquid in a container sets up standing wave pattern consisting of nodes and anti-nodes.

The nodes are transparent and anti-nodes are opaque to the incident light.

In effect the nodes and anti-nodes acts like grating(a setup of large number of slits of equal distance) similar to that of ruling in diffraction grating. It is called as acoustic grating or aqua grating.

At nodes the density of the liquid is maximum and at antinodes density is minimum.

This arrangement is very much similar to the diffraction grating and is called acoustic grating.

Hence, by using the condition for direction, we can ind the wavelength of ultrasound and thereby the velocity of sound in the liquid medium.
When ultrasonic waves are generated in a liquid kept in rectangular vessel, the wave can be reflected from the walls of the vessel.

The direct and reflected waves get superimposed, which causes a standing wave to be formed.

The density o the liquid at the node will be more than the density at an antinode.

Under these conditions, if a beam of light is passed through the liquid at right angles to the wave the liquid acts as a diffraction grating. Such a grating is known as an acoustical grating.

Here, the antinode acts as the transmitting slit and the node acts as the opaque part. Thus resembling a normal ruled diffraction grating.

This is obvious because the nodes have points o minimum density and hence allow more amount o light to pass through them than those at antinodes.

Thus, the nodes act like slits.

DIFFRACTION GRATING

A Diffraction grating is an extremely useful device.

It consists of large number of narrow slits side by side. The slits

are separated by opaque surfaces.

When a wavefront is incident on the grating surface, light is transmitted through the slits and obstructed by the opaque spaces.

Such a grating is called transmission grating.

ACOUSTICAL GRATING METHOD PRINCIPLE:

When ultrasonic waves travel through a transparent liquid, due to alternate compression and rare action, longitudinal stationery waves are produced.

If monochromatic light is passed through the liquid perpendicular to these waves, the liquid behaves as diffraction grating.

Such a grating is known as Acoustic Grating.

Here the lines of compression and rareaction act as transparent light waves.

It is used to find wavelength and velocity(v) of ultrasonic waves in the liquid.

ACOUSTICAL GRATING METHOD – CONSTRUCTION;

It is consists of a glass tank, filled with the liquid.

A piezo-electric (Quartz) is fixed at the bottom of the glass tank and is connected with piezo-electric oscillatory circuit as shown in the figure 1.7.

An incandescent lamp is used as a monochromatic source (S) and a telescope arrangement is used to view the diffraction pattern.

A collimator consisting of two lenses L1 and L2 is used to ocus the light effectively in the glass tank.

ACOUSTICAL GRATING METHOD – WORKING:

(i) When the piezo-electric crystal is kept at rest:

Initially the piezo-electric crystal is kept at rest and the monochromatic at light is switched ON.

When the light is focused in the glass tank filled with the liquid, a single image, a vertical peak is observed in telescope.

i.e., there is no diffraction.

(ii) WHEN THE PIEZO-ELECTRIC CRYSTAL IS SET INTO VIBRATIONS:

Now the crystal is put into vibrations using piezo-electric oscillatory circuit.

At Resonance, Ultrasonic waves are produced and are passed through the liquid.

These Ultrasonic waves are reflected by the walls of the glass tank and form a stationery wave pattern with nodes and antinodes in the liquid.

At nodes the density of the liquid becomes more and at antinodes the density o the liquid becomes less.

Thus, the liquid behaves as a directing element called acoustical grating element.

Now when the monochromatic light is passed the light gets directed and a diffraction pattern consisting of central maxima and principle maxima on either side is viewed through the telescope as shown in figure 1.7.2 as well as in 1.7.3.

CALCULATION OF ULTRASONIC VELOCITY

The velocity of Ultrasonic waves can be determined using the condition.

Thus, this method is useul in measuring the wavelength and velocity of ultrasonic waves in liquids and gases at various temperatures.

INDUSTRIAL APPLICATIONS

Ultrasonic waves find application in two major fields:

1. Engineering filed
2. Medical field

Application of ultrasonic waves in engineering and industry Ultrasonic waves in the wide applications in engineering and industry as follows.

1. Non destructive testing (detection of flaws in metals)
2. Ultrasonic drilling
3. The ultrasonic welding
4. Ultrasonic drilling
5. A ultrasonic soldering
6. ultrasonic cutting and machinery
7. A ultrasonic cleaning
8. Sonar

ULTRASONIC NON DESTRUCTIVE TESTING – INDUSTRIAL APPLICATIONS OF ULTRASONIC WAVES

Principle:

The basic principle behind the ultrasonic inspection is the transmission of the Ultrasound with the medium and the reflection or scattering at any surface or internal discontinuity in the medium due to the change in the acoustic impedance.

The Discontinuity means the existence of the flaw or detect or cracks or hole in the material.

The reflected or scattered sound waves are received and amplified and hence, the defects in the specimen are suitably characterized.

BLOCK DIAGRAM OF THE ULTRASONIC FLAW DETECTOR

PRINCIPLE:

Whenever there is a change in the medium, then the Ultrasonic waves will be reflected.

This is the principle used in Ultrasonic flaw detector.

Thus, from the intensity of the reflected echoes, the flaws are detected without destroying the material and hence this method is known as a Non Destructive method.

WORKING:

1. The pulse generator generates high frequency waves and is applied to the Piezo-electric transducer and the same is recorded in the CRO.
2. The piezo electric crystals are resonated to produce Ultrasonic waves.
3. These Ultrasonic waves are transmitted through the given specimen.
4. These waves travel through the specimen and is reflected back by the other end.
5. The reflected Ultrasonic are received by the transducer and is converted into electric signals. These reflected signals are amplified and is recorded in the CRO.
6. If the reflected pulse is same as that o the transmitted pulse, then it indictes that there is no defect in the specimen.
7. On the other hand, if there is any defect on the specimen like a small hole or pores, then the Ultrasonic will be relected bby the holes(i.e.) defects due to change in the medium.
8. From the time delay between the transmitted and received pulses, the position of the hole can be found.
9. From the height o the pulse received the depth of the hole can also be determined.

ULTRASONIC SCANNING METHODS – A,B AND C SCAN DISPLAYS

– Industrial Applications of Ultrasonic waves

In the Ultrasonic scanning methods, the principle, construction and working is the same as that of the Ultrasonic law detector.

Here, it is based on the position o the transducer and the output displayed in the CRO screen, we can classiy the scanning methods into three types

1. A-scan
2. B-scan
3. T-M scan or C-scan

All these three modes of scanning are obtained with respect to the pulses of Ultrasound transmitted into and received from the specimen.

The three modes are explained below.

A-SCAN OR AMPLITUDE MODE DISPLAY

Amplitude mode display gives only one-dimensional information about the given specimen.

In this, a single transducer is used to transmit and receive the pulses from the specimen.

The received or the reflected echo signals from the specimen is given to the Y- Plate and time base is connected to the X-Plate of the CRO, so that they are displayed as vertical spikes along horizontal base line as shown in the figure 1.10.1.

The height of the vertical spikes corresponds to the strength of the echo from the specimen.

The position of the vertical spike from left to right along the X-axis corresponds to the depth of penetration.

i.e, it gives the total time taken by the Ultrasonic sound to travel from transmitter to the specimen and from the specimen to the receiver.

Thus by passing Ultrasonic waves o known velocity and by noting the time delay, we can find the distance at which the detect or flaws are present, by using the formula.

Distance = Velocity x time

In ultrasonic flaw detector, A-scan method is used to detect the position and size of the flaws.

B-Scan or Brightness Mode Scan

B-scan or Brightness mode display gives a two dimensional image.

The principle of the B-Scan is same as that of A-Scan except with a small difference.

Here in the B-Scan the transducer can be moved rather than keeping in a fixed position.

As a result each echo's are displayed as dots on the screen as shown in the figure 1.10.2.

T.M Scan or Time –Motion Mode or C-Scan display

This method is used to obtain the information about the moving object.

This combines the features of both A-Scan as well as B-Scan. In this the transducer is held stationary as in A-scan and echoes appear as dots in the B- scan.

Here, the X-axis indicates the dots at the relevant location and Y-axis indicates the movement of the object.

Therefore when the object moves, the dot also moves at a low speed.

Thus an object with the oscillatory movement will appear as a trace as shown in the figure 1.10.3.

SONOGRAM RECORDING OF MOVEMENT OF HEART

FETAL HEART MOVEMENT

Principle:

It works under the principle of Doppler Effect

i.e., there is an apparent change in the frequency between the incident sound waves on the fetus and the reflected sound waves from the fetus.

DESCRIPTION:

It consists of a Radio Frequency Oscillator(RFO), for producing 2 MHz of frequency and RFA (Radio Frequency Amplifier) to amplify the receiver signal as shown in the figure.

WORKING:

The transducer is fixed over the mother's absominal wall, with the help of a gel or oil.

RFO is switched on to drive the pulses and hence the transducer produces Ultrasonic waves of 2 MHz.

These Ultrasonic waves are made to be incident on the fetus.

The reflected Ultrasonic waves from the etch are received by the transducer and are amplified by RFA.

Both the incident and the received signals are mixed by the mixer and is filtered to distinguish the various types of sound and finally the Doppler shift or change in frequency is measured.

The movement o the heart can be viewed visually by CRO or can be heard by the Loud Speaker, after necessary amplification by AF.

ULTRASONIC IMAGING SYSTEM – INDUSTRIAL APPLICATIONS OF ULTRASONIC WAVES

PRINCIPLE OF WORKING

During the scanning of the body surface by Ultrasonic transducer, the Ultrasonic waves are transmitted into the patient's body.

The echoes from the body are collected by the receiver circuit.

Since some echoes come from the depth, they are weak; therefore, proper depth gain compensation is given by DGC circuit.

Then these signals are converted into digital signals by an analog to digital converter and are stored in the memory of the Control Processing Unit (CPU) o a computer.

Meanwhile, the control unit in the CPU receives the signals of transducer position and TV synchronous pulses.

These signals generates X plate and Y plate address information's or the T.V monitor and is also stored in the memory of the CPU.

The stored signals are processed and colour coded and is given to the digital to analog(D/A converter), which converts the digital into analog signal.

Finally the mixing circuit mixes the analog signals and TV synchronous signals properly.

The mixed signals are finally fed to the video section of the television monitor as shown in the igure 1.12.

The TV monitor produces the coloured Ultrasonic image of the internal part o the Body.

Unit III
LIGHTING DESIGN

Optical measurement techniques can be divided into two types, they are

i) Photometry – determination of optical quantities which is related to the sensitivity of the human eye.

ii) Radiometry – it is measurement of energy per unit time emitted by light sources imping on a particular surface.

Solid angle

Solid angle is defined as ratio between area of the sphere and its square of its radius. It has unit of steradian (sr).

= 4 = 12.57 (sr)

Radiant power or radiant flux $_e$

It is defined by the total power or radiation emitted by a source transmitted through a surface or impinging upon a surface. It has unit of watts (W).

If a light source emits uniformly in all directions, it is called an isotropic light surface.

Radiant intensity I_e

The source's radiant power de emitted in the direction of the solid angle element dΩ is given by

$$\int$$

It has unit of W/sr

Radiance L_e

Radiance L_e describes the intensity of optical radiation emitted or reflected from a location on an emitting or reflecting surface in a particular direction. The radiant power emitted by a surface element dA in the direction of the solid angle element is given by

where is the angle between the direction between the direction of the solid angle element and the normal of the emitting or reflecting surface element dA.

The radiant intensity emitted by the area element dA in a particular direction is given by

and $\int$ (W/m^2 sr)

Irradiance E_e

It describes the amount of radiant power impinging upon a surface per unit area.

Irradiance is maximized when the surface element is perpendicular to the beam.

Corresponding area element is oriented perpendicular to the incident beam, is given by

With denoting the angle between the beam and the normal of , we get

Unit is W/m^2

Radiant exitance M_e

It quantifies the radiant power per unit area, emitted or reflected from a certain location on a surface.

Amount radiant exitance dM_e emitted or reflected by a certain location on a surface in the direction of the solid angle element is given by

and $\int$

Spectral Quantities

The source's radiant power emitted in the wavelength interval between λ and λ+d λ is given by

( )

It is defined as a source's radiant power per wavelength interval as a function of wavelength.

Area describes the contribution of the wavelength interval to the total value of radiant power
This is expressed by the integral

$\int$ ( )

Photometry

It deals with the measurements of the intensity of light emitted by a source, its illuminating power or intensity of illumination of a surface is called photometry.

Luminous flux ( )

Light energy emitted per second from a light source. Unit is lumen (lm).

Lumen

It is the luminous flux emitted from a standard candle.

Luminous intensity or illuminating power (I)

Illuminating power of a source in any direction is defined as the luminous flux emitted per unit solid angle in that direction.

–

Candela

A light has a luminous intensity of 1 candela if it emits 1 lumen (1 lm per steradian.)

Illumination or intensity of illumination (E)

The luminous flux incident normally per unit area of the surface is called illumination or intensity of illumination.

Lambert's cosine law

Intensity of illumination is directly proportional to cosine of the angle of incidence of light radiation on the surface and inversely proportional to the square of distance between the surface and source.

If dF is elemental light flux incident on an elementary area dA then illuminance E is defined as

Consider an elementary surface AB of area of dA illuminated by the source S which subtend solid angle Ω at the point source S. Then intensity of illumination

If L is the illuminating power of the source is defined as luminous flux per unit solid angle.

Therefore intensity of illumination

If r is the distance of surface of dA from the source

Illuminance =

If ,

Inverse square law

It states that the intensity per unit area is inversely proportional to the square of the distance.

Consider a point source S of light. It is radiating equally in all directions. Two concentric spheres of radii r_1 and r_2 around the source and drawn. Let the energy radiating from the source per second is Q. Energy incident per second on unit area of sphere having radius r_1

similarly

Therefore

Consider two surfaces AB=dA_1 and CD=dA_2 on the two spheres, then energy incident

And

If $E_1 = E_2$

Spectral luminous efficiency

It is ratio between spectral density of the luminous flux and the spectral emissive power P_λ

( )

Relative spectral luminous efficiency is defined as ( ) ( ) ( )

Total emissive power P is expresses as

$\int$

Luminous flus is given by

$\int$ ( ) ( ) ( )

Hemispherical reflectance ρ_λ

It is defined as the ratio of the radiant flux reflected from a surface to the radiant flux incident to it.

Hemispherical transmittance τ_λ

It is defined as the ratio of the radiant flux transmitted through the surface to the radiant flux incident to it.

Photopic, Mesopic, Scotopic

Photopic vision: Vision under well-lit conditions, which provides for color perception, and which functions primarily due to cone cells in the eye.

Mesopic vision: A combination of photopic vision and scotopic vision in low lighting, which functions due to a combination of rod and cone cells in the eye.

Scotopic vision: Monochromatic vision in very low light, which functions primarily due to rod cells in the eye.

Colour-Luminous efficiency function

It is the characteristics of human visual perception described through colour categories such as red, blue, yellow, green, orange and purple.

Luminous efficiency =

$$—\int ( ) ( )$$

Luminous efficiency = —— ————————

$$\int \qquad ( )$$

Day light calculations

Daylight

Daylight is the combination of direct and indirect sunlight during the day time. This includes direct sunlight, diffuse sky radiation and both of these reflected by the earth and terrestrial objects.

Daylight factor (DF)

It is the ratio between the measured internal and external light levels. It represents the amount of daylight received into an indoor space or room. DF is given by

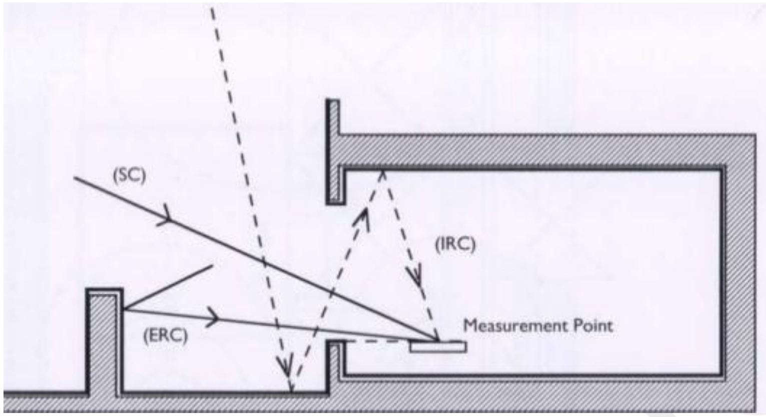
$$( )$$

where, is illuminance due to daylight at a point on the indoors & is illuminance at a point on the outdoors.

a) Daylight can be handled quantitatively by using relative values (daylight factor) which compare indoor to outdoor illuminance.
b) Illuminance level (LUX) at a point is given by

where, - light from the patch of sky visible at the point considered as sky component
- light reaching the point after reflected from exterior surfaces, and

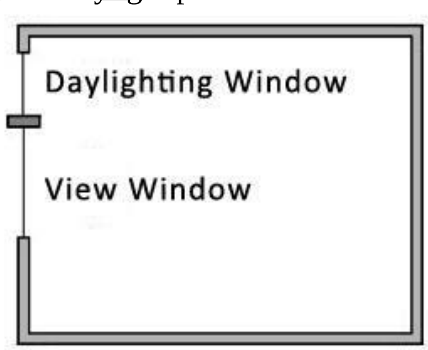
- light reaching the point only after reflected from internal surfaces



Daylight design of windows

Daylighting refers to the practice of placing windows or other openings & reflective surfaces to achieve effective internal lighting through natural daylight. The particular attention is given to daylighting while designing a building. The aim is to maximize visual comfort or to reduce energy use.

a) **Windows** is used for allowing light, heat and sound. Windows on multiple orientations must usually be combined to produce the right mix of light for the building depending on climate and latitude.
b) **Window-Wall ratio (WWR)** - Minimum 20 percent to 30 percent of window area should be provided in total wall area to achieve better daylighting.
c) **High windows** are more effective than individual or vertical windows, to distribute light deeper into the space.
d) Consider separating windows into two horizontal stripes, one at eye level for view and one above to maximize daylight penetration.

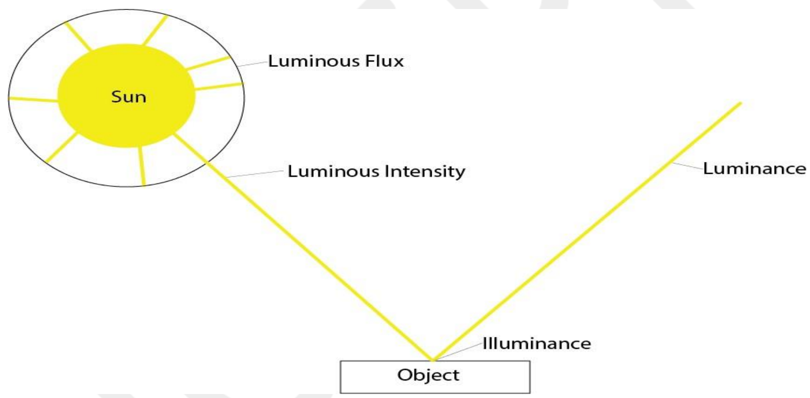


e) **High ceilings** - More daylight savings will be realized if ceiling heights are 10 feet or higher.
f) **Light shelves** - Using interior and exterior light shelves between the daylight window and the view window.

g) Daylighting is more effective if open plan workstations are located on the north and south side of the building. Open configuration absorbs less light and inter-reflections provide a more uniform distribution of light deep into the space.
h) **Interior sun control** - Horizontal blinds on the sound windows and vertical blinds on the east and west windows are most effective.

Measure of Daylight

a) **Luminous flux** – The amount of light given off by a particular source in all directions is called luminous flux (or luminous power). It is measured in lumens.
b) **Radiant flux** – It is a measure of total power of the electromagnetic radiation from a source and not just visible light but also infrared and ultraviolet light, and is measured in watts.
c) **Illuminance** – It is the total luminous flux incident on a surface per unit area. It is a measure of how much amount of incident light illuminates the surface. It is used by most common performance indicators to determine daylight availability in the interior. It is measured in lux.

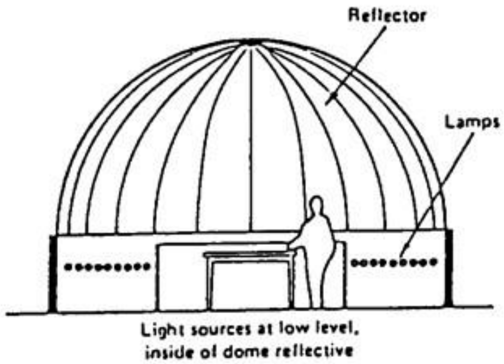


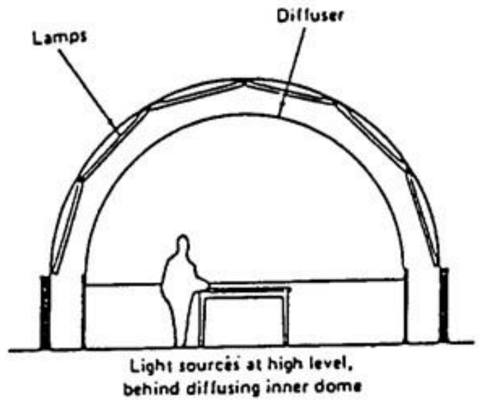
d) **Luminance** – It is a measure of the luminous intensity per unit area of light travellingin a given direction. It describes the amount of light that get reflected from a particular area. The unit of luminance is candela per square metre.
e) Luminance levels can be measured with a luminance meter or through the use of high dynamic range imaging technique coupled with a digital camera and luminance mapping software.

Models of artificial skies

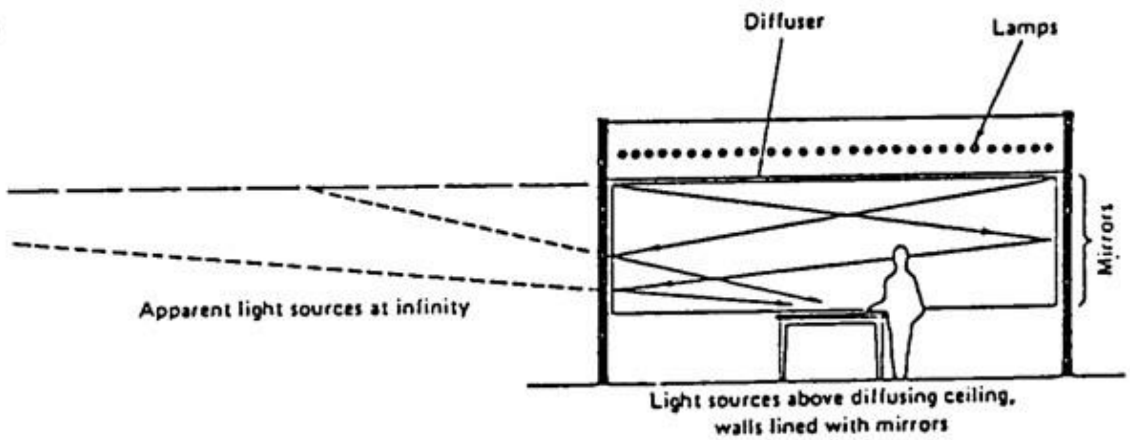
a) Model studies can be used to predict daylight penetration into any building. This is the only reliable prediction method in the case of unusual situations, complex geometries or heavily obstructed windows.
b) The artificial sky simulates the standard overcast sky conditions by giving uniform luminance.

c) There are two basic forms of artificial sky: the hemispherical and the rectangular.
d) Hemispherical artificial sky is mostly constructed as a diffusely reflective opaque dome surface, illuminated from below, or a translucent dome with lighting mounted behind.





e) The rectangular sky has a luminous ceiling and four strictly vertical walls lined with mirrors. The multiple reflections between accurately parallel opposing mirrors give an infinite horizon effect. The mirror glass absorption through multiple reflections ensures a luminance distribution.



Principles of artificial lighting

- Artificial lighting is the lighting which is man-made such as fluorescent, tungsten, sodium and mercury vapor lamp etc.
- Artificial lights are the other sources of light which is developed to compensate for or assist the natural light. It will have different frequencies and wavelengths that determine the light color.
- Artificial lighting can be done in three ways: **Direct**, **Semi-direct** (or) Reflected and ***Indirect***
  a) **Direct light** is the undiffused & unfiltered light traveling directly from the light source to the subject. Direct light is like full sun on a clear day.

b) **Semi-direct light** is the light proceeding from a light source and bouncing off a remote surface and reflecting onto an object. Light reflected into an umbrella with a black backing is an example of semi-direct light. It is visible but brightness will be less.

c) **Indirect light** is invisible but it falls on working area. The combination of all these 3 types of lighting can be used on any systems.

- The most common artificial light sources are as follows:

    a) **Incandescent lamp** – Light is produced by passing current through a filament (Tungsten). This method is considered wasteful as most of the energy entering the lamp leaves it as heat instead of visible light.

    b) **Compact fluorescent lamp (CFL)** - It was designed as a more efficient replacement for incandescent lamp. It is supplied with the fixing system (screw or bayonet).

    c) **Fluorescent tubes** - It is the main form of lighting for offices and commercial buildings. They are a form of gas discharge lamp. They are covered in a thin glass cylinder.

    d) **Discharge lamps** - They work by striking an electrical arc between two electrodes, causing a filter gas to give off light.

    e) **Light Emitting Diode (LED) -** LEDs use semi-conductors to convert electrical energy directly into light. They are only recently becoming available as a light source for lighting purposes. LED torches are becoming very popular, as they provide a far longer battery life than other types of light.

Supplementary artificial lighting

There are two forms of artificial lighting as follows: Indoor lighting & Outdoor lighting

Indoor lighting

Indoor lighting is usually accomplished using light fixtures (also called Luminaire) and it is a key part of interior design. Luminaire is a lighting unit consisting of one or more electric lamps with all of the necessary parts and wiring. Light fixtures are classified according to the light function, lamp type and installation method.

Let's discuss light fixtures based on light function which are further classified according to the function of aim of using it.

a) **Ambient lighting (general lighting)** – This lighting provides an area with overall illumination. It radiates a comfortable level of brightness without glare, and allows us to see and walk safely. It is often provided by traditional pendant type fixtures, down lights, ceiling mounted fixtures. Having a central source of ambient light in all rooms is fundamental to a good lighting plan.

b) **Task lighting** – It is aimed at a specific task. It is a way to provide more light on a specific area to perform a task that requires more light than the ambient fixtures can give.

It can be provided by recessed and tack lighting, pendant lighting and under cabinet lighting, as well as portable floor and desk lamps.

c) **Accent lighting** – It is also a sort of a directional lighting that adds drama to a place by creating visual interest. It is used to draw the eye to houseplants, paintings, sculptures and other prized possessions. It is usually provided by recessed and track lighting or wall-mounted picture lights.

d) **Guidance lighting** – It is designed to help us see our way safely. The light in your closet, light near door bell, night lights, path lighting and motion lights are good examples of informational lighting.

e) **Decorative lighting** – It is used to decorate the interior of a room or auditorium. Light strips, pendants, chandeliers are examples of light fixtures that draw attention and add beauty to the place.

UNIT IV

NEW ENGINEERING MATERIALS

Composites

Composites are combination of two or more materials that results in better properties than those of the individual components used alone.

Types

Based on the shape of the reinforcement used, composites are classified as (i) Particulate reinforced composite (ii) Discontinuous fiber reinforced composite (iii) Continuous fiber reinforced composites.

Fibre reinforced plastics

It is a composite material. We know that the composite materials have been developed to get improved or desired properties in them. Nowadays fiber reinforced plastics (FRP) plays an important role in the machine parts where we require high strength, high modulus, heat resistance and light weight.

The fibrous glass is used in reinforced plastics in the form of ravings, chopped strands, milled fibers, yarns, non woven mats and woven fabrics.

Most commonly used reinforcements are

(i) Random chopped strand mat, bonded together with a resinous binder (polyster).

(ii) Mat from continuos strands, deposited in a swirl pattern and loosely bonded together with a resinous binder.

(iii) Filament type thin mats.

(iv) Performs

(v) Woven fibrous glass clothes.

(vi) Parallel stranded glass fibers

(vii) Short stranded

The glass fibers having a vinyl silence-epoxy surface treatment on the fibers are used. This treatment gives best dry and wet strength. E type glass is one of the important glass fiber materials which use boric acid rather than soda ash as one of the component of the melt. Mostly polyester resin is used as plastic. Epoxy and phenolic resins are also used.

The fibers are made from synthetic textile fibers treated in such a way that the side groups are entirely removed. The carbon fiber reinforced plastics are used in aeroengines, high pressure rotor and stator blades since they can withstand higher thrusts. Silica and boron fiber reinforced plastics have high strength and low density. But these are all costlier than glass or carbon fiber reinforced plastics.

Advantages

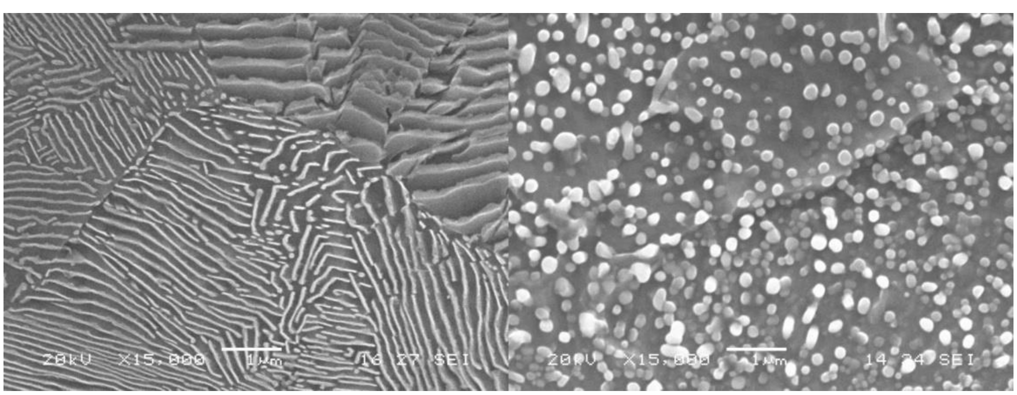
1. It has high strength to weight ratio
2. It has low cost tooling.
3. Intricate and large shapes are possible in one piece. Since it can be fashioned more easily than a metal it is used in making complicated machine parts.
4. Excellent environment exposure resistance can be obtainable.
5. It has excellent electrical properties.
6. It has higher heat resistance.

Disadvantages

1. The material cost is so high.
2. The strengths perpendicular to fiber orientations are low.
3. It has low rate of heat transfer and dissipation.
4. It has lower flexural modulus than steel and requires higher thickness for equlistiffness.

Fiber reinforced metal

Fiber reinforced metals (FRM) are composites, which are made up of inorganic fibers fabricate with metal.
FRM are composed of fibers (reinforcement phase) and metals (matrix phase). The following diagram exhibits the FRMs (silicon fiber reinforced in metals).

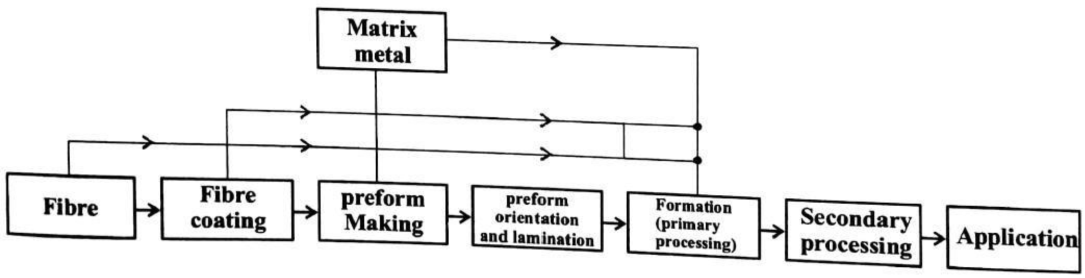


Fabrication of FRM

The fabrication of FRM consists of joining the interfaces of both phases. Before doing the fabrication of FRM, the reinforcement fibers and thematrix materials should be choosen carefully with light weight and high strength materials.

The reinforcement fibers and the corresponding matrix metals used for fabricating FRM are given below.

S. No	Reinforcement Fibers	Matrix metals	Composite System
1.	Boron	Al and Mg	Boron System
2.	Carborundum	Al and Ti	Corborundum System
3.	Carbon	Al, Mg and Cu	Carbon System
4.	Alumina	Al and Mg	Alumina System



1. Depending upon requirements, fibers are given pre-treatment such as fibre coating to improve wetting and joining ability with matrix metals and to prevent failure caused by reaction between different surfaces.
2. Then, performs are made, which are cut to the required dimensions.
3. These performs are oriented and laminated according to the design specifications of the components.
4. The next process is called forming (primary processing) in which composition and shaping is carried out.
5. At this stage the matrix metal and the reinforcement fibers are primarily processed together to form the FRM composite.
6. After forming the FRM, the secondary processing such as cutting, trimming and joining is done.

   Thus the fabrication is complete and shall be used for further applications.

Properties of FRM

i) FRM is light weight
ii) FRM has a high stiffness
iii) FRM possess high strength at high temperatures [i.e. 200 to 400 ˚C].
iv) FRM are high in inter-lamina strength and stress transmissibility between filaments and highly resistant to polyaxial and complex stress.
v) FRM are resistant to impact and superior in extreme low temperature characteristics.
vi) FRM are infiltrated by water and are not corroded by rain.
vii) They do not require any measures against lightning strike or static, nor any coating for electromagnetic shielding

Applications of FRM

i) FRM are used in constructing space machines and satellite body structures. The material system used for this are B/Al, B/Mg, C/Al, C/Mg.
ii) FRM are to make pylons, frames, beams, fans, compressor blades, fairings, wing boxes, access-doors in air crafts. The material systems used here are B/ Al, SiC/ Al.
iii) FRM are used to make truss structures in helicopters. The promising material systems used are B/ Al, SiC/ Al, Al_2O_3/ Al.
iv) FRM are used to make engine electric components such as motor brushes, cables, etc., C/Cu is the material systems used for these products.
v) FRM are used to make sports goods such as tennis rackets, Golf clubs, etc., the materials systems used for these are B/ Al, SiC/ Al, C/Al, Al_2O_3/ Al.

Metallic glasses

Definition: ***Metallic glasses*** are the amorphous metallic solids which have high strength, good magnetic properties and better corrosion resistance and will possess both the properties of metals and glasses.

Examples: Alloys of Fe, Ni, Al, Mn, Cu, Cr and Co mixed with metalloids such as Si, Ge, As, B, C, P and N.

CONCEPT BEHIND THE FORMATION OF METALLIC GLASSES

Generally liquids can be made into glassy state by increasing the rate of cooling. In a similar manner the metals can also be made into glassy state by increasing the rate to cooling to a very high level [2 x 10^6 °C per second]. At that state the atoms will not be able to arrange orderly because of its rapid cooling rate.

Thus, the atoms will not be allowed to go to crystalline state, rather it goes to amorphous state and it will form a new type of material. These new type of materials which are made by rapid cooling technique (i.e., the temperature decreases suddenly with respect to time) are called ***metallic glasses.***

The cooling rate for the formation of metallic glasses varies from material to material.

Glass Transition Temperature

The temperature at which the metals [alloys] in the molten form transforms into glasses i.e., liquids to solids is known as ***glass transition temperature (T_g).***

It was found that the glass transition temperature for metallic alloys varies from 20°C to 300°C.

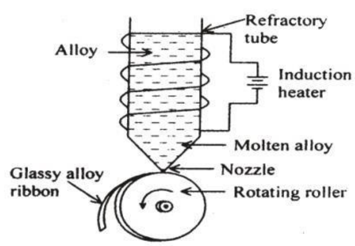
PREPERATION OF METALLIC GLASSES

Principle

"Quenching" *is* a technique used to form metallic glasses,*quenching* means rapid cooling. Actually atoms of any materials move freely in a liquid state. Atoms can be arranged *regularly* when a liquid is cooled *slowly.* Instead, when a liquid is *quenched*, there will be an *irregular pattern, which results in the formation of metallic glasses.*

Technique

The process involved in the formation of metallic glasses is melt spinning technique. This technique is illustrated in Fig.5.1



Experimental Setup

Fig.5.1

The setup consists of a refractory tube with fine nozzle at the bottom. The refractory tube is placed over the rotating roller made up of copper. An induction heater is wounded over the refractory tube in order to heat the alloy inside the refractory tube as shown in fig 5.1.

Preparation

The alloy is put into the refractory tube and the induction heater is switched ON. This heats the alloy and hence the super heated molten alloy is ejected through the nozzle of the refractory tube onto the rotating roller and is made to cool suddenly. The ejection rate may be increased by increasing the gas pressure inside the refractory tube. Thus due to rapid quenching a glassy alloy ribbon called metallic glass is formed over the rotating roller.

Metallic glasses of various thicknesses can be formed by increasing (or) decreasing the diameter and speed of the roller.

TYPES OF METALLIC GLASSES

Metallic glasses are of two types viz,

(i) Metal-metalloid glasses

Examples: Metals : Metalloids

Fe, Co, Ni: Ge, Si, B, C

(ii) Metal – Metal glasses

Examples: Metals : Metals

Ni : Niobium

Mg : Zn

Cu : Zr

PROPERTIES OF METALLIC GLASSES

Since the atoms in the metallic glasses are disordered, they have some peculiar properties as follows:

(i) Structural Properties

a.Metallic glasses have tetrahedral closely packed (TCP) structure rather than hexagonal closely packed (HCP) structure.

b.They do not have any crystal l defects such as grain boundaries, dislocations etc.

(ii) Mechanical Properties

a.The metallic glasses are very strong in nature.

b.They have high corrosion resistance.

c.They possess malleability, ductility etc.

(iii) Magnetic Properties

a.Metallic glasses can be easily magnetized and demagnetized.

b.They have very narrow hysterisis loop as shown in fig 5.2 . In Fig 5.2 the hysterisis loop of the metal alloy in crystalline phase is also given for reference.

c.They exhibit very low hysterisis loss and hence transformer core loss is very less.

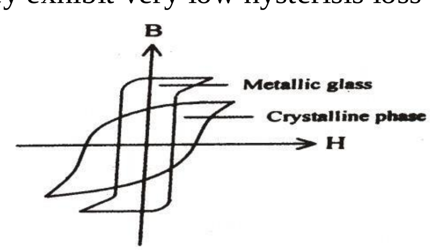


Fig.5.2

(iv) Electrical Properties

a.Metallic glasses have high electrical resistance (100 μΩ - cm).

b.The electrical resistance for metglasses will not vary with temperature.

hey possess very low eddy current losses.

APPLICATIONS OF METALLIC GLASSES

*Since the metallic glasses possess low magnetic loss, high permeability, saturation magnetization and low coercivity, ***these materials are used in cores of high power transformers.*** *Examples:* $Fe_{75}P_{15}C_{10}$, $Fe_{24}Zr_{76}$ *etc.*

*As the metallic glasses are malleable and ductile, it can be used in simple filament winding to reinforce pressure vessels.
*Since the metallic glasses are very strong/hard they are used to make different kinds of springs.
*As the metglasses are similar to the soft magnetic alloys, they are used in leads of tape recorder, cores of transformers and magnetic shields.
*Because of their high resistivity, they are used to make computer memories, magneto-resistance sensors etc.
*Since they have high corrosion resistance, they are used in reactor vessels, surgical clips, marine cables etc.

*Since some metallic glasses can behave as super conductors, they are used in the production of high magnetic fields.
*Since the metglasses are not affected by irradiation, they are used in nuclear reactors.

Shape memory alloys

Shape memory alloys (SMA) *are the alloys which change its shape from its original shape to new shape and while heating /cooling it will return to its original shape.*

Transformation temperature

In SMA, the shape recovery process occurs not at a single temperature rather it occurs over a range of temperature [may be few degrees].

Thus, the range of temperature at which the SMA switches from new shape to its original shape is called **transformation temperature (or) memory transfer temperature.**

Below the transformation temperature the SMA can be bent into various shapes. Above the transformation temperature the SMA returns to its original shape. This change in shape was mainly caused due to the change in crystal structure (phase) within the materials, due to the rearrangement of atoms within itself.

PHASES (STRUCTURES) OF SMA

In general the SMA has two phases (crystal structures) viz.,

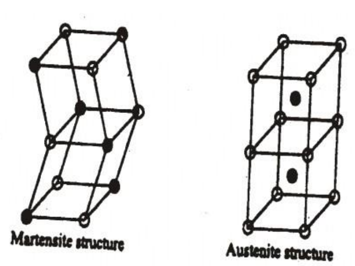


fig 5.3

(i) Martensite

*Martensite is an interstitial supersolution of carbon in γ-iron and it crystallizes into **twinned structure**as shown in fig. 5.3. The SMA will have this structure generally at lower temperatures and it is softin this phase.*

(ii) Austenite

*Austenite is the solid solution of carbon and other alloying elements in γ-iron and it crystallizes into **cubic structure** as shown in fig5.3. The SMA will attain this structure at higher temperatures and it is hard in this phase*

PROCESSING OF SMA

Shape memory effect

*It is very clear that at lower temperature the SMA will be in martensite structure and when it is heated then it will change its shape to austenite structure and while cooling it will again return to martensite form. This effect is called **shape memory effect.***

Let us consider a shape memory alloy, for which the temperature decreased. Due to decrease in temperature, phase transformation take place from austenite to twinned martensite as shown in fig 5.4 [Process 1] i.e., a micro constituent transformation takes place from the platelet structure (Austenite) to needle like structure (martensite).

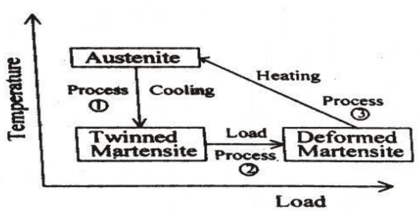


Fig 5.4

During this state the twinned martensite phase will have same size as that of austenite phase as shown in fig 5.5(Macroscopic view). Hence macroscopically if we see, no change in size (or) shape is visible between the Austenite phase and twinned Martensite phase of the SMA.It is found that the transformation from austenite to martensite takes place not only at a single temperature, but over a range of temperatures.

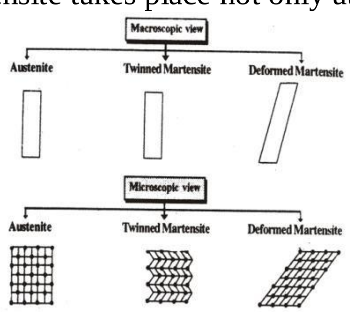


Fig 5.5

Both austenite and twinned martensite is suitable in a particular range of temperature. Now when the twinned martensite is applied a load, it goes to deformed martensite phase as indicated in fig 5.4 (Process 2). During the transformation from twinned martensite to deformed martensite the change in shape and size occur both microscopically and macroscopically as shown in fig 5.5.

Now when the material is further heated it will go from deformed martensite to austenite form (Process 3) and the cycle continues as shown in fig 5.4.

CHARACTERISTICS OF SMA

(i) The transformation occurs not only at a single temperature rather they occur over a range of temperatures.

(ii) **Pseudo – elasticity:** *Pseudo-elasticity occur in some type of SMA in which the change in its shapewill occur even without change in its temperature*

(iii) **Super – elasticity:** *The shape memory alloys which have change in its shape at constanttemperature are called* ***super-elastic SMAs*** *and that effect is known as super-elasticity.*

Here, at a single temperature, when the load is applied the SMA will have a new shape(deformed Martensite) and if the load is removed it will regain its original shape (TwinnedMartensite), similar to pressing a **rubber** (or) **a spring.**

(iv) **Hysterisis:** For an SMA, during cooling process, a martensite starts (m_s) and ends (m_e) and during heating process, austenite starts (A_s) and ends (A_e).

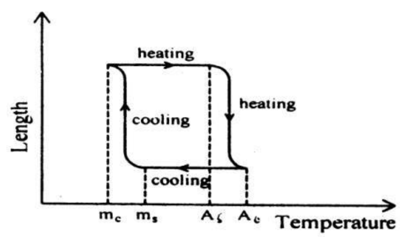


fig.5.6

It is found that they do not overlap with each other and the transformation process exhibits the form of hysterisis curve as shown in fig.(5.6)

iii. Crystallographically the thermo-elastic martensites are reversible.

APPLICATIONS OF SMA

Shape memory alloys have vast applications in our day-to-day life, as follows:

1.We know that the recently manufactured eye glass frames can be bent back and forth, and can retain its original shape within fraction of time. All these materials are made up of Ni-Ti alloys, which can withstand to maximum deformation.

2.We might have seen toys such as butterflies, snakes etc. which are movable and flexible. These materials are made using SMAs.

3. The life time of Helicopter blades depends on vibrations and their return to its original shape. Hence shape memory alloys are used in helicopter blades.

4. The SMA is cooled and sent into vein, due to body temperature it changes its shape and acts as a blood clot filter, by which it controls the blood flow rate.

5. The SMA is mainly used to control and prevent the fire and toxic gases (or) liquids to a large extent. For example, if an SMA is placed in a fire safety valve, when fire occurs, then due to change in temperature the SMA changes its shape and shuts off the fire. Similar principle has been used in the area of leakage in toxic gases (or) liquids.

6. The Ni-Ti spring is used to release the hot milk and the ingredients at certain temperature and to close it after particular time, thereby we can get coffee automatically [coffee makers].

7. SMA is used for cryofit hydraulic couplings i.e., to join the ends of tubes. Here, the SMA material is pasted in between the two tubes to be joint at a particular temperature when the temperature change the SMA expands and thus the two ends are joined.

8. Using SMA the circuit can be connected and disconnected, depending on the variation in temperature. Hence SMA is used as a circuit edge connector.
9. They are used in controlling and preventing cracks.
10. They are used in relays and activators.
11. They are used for steering the small tubes inserted into the human body.
12. They are used to correct the irregularities in teeth.
13. Ni-Ti SMA is also used in artificial hip-joints, bone-plates, pins for healing bones-fractures and also in connecting broken bones.

Advantages

i. SMA is very compact in nature.
ii. It is safe and smart.
iii. They are flexible.
iv. They are Non-Corrosive.

Disadvantages

i. Cost is high.
ii. Efficiency is low.
iii. Transformation occurs over a range of temperatures.
iv. Structural arrangements may sometime get deformed.

Ceramic materials

"Ceramic materials" are defined as those containing phases that are compounds of metallic and nonmetallic elements.

Classification of Ceramics

1. Functional Classification

(i) Abrasives	: Alumina, carborundum
(ii) Pure oxide ceramics	: MgO, Al_2O_3, SiO_2
(iii) Fire-clay products	: Bricks, tiles, porcelain etc.
(iv) Inorganic glasses	: Window glass, lead glass etc.
(v) Cementing materials	: Portland cement, lime etc.
(vi) Rocks	: Granites, sandstone etc.
(vii) Minerals	: Quartz, calcite, etc.
(viii) Refractories	: Silica bricks, magnesite, etc.

2. *Structural Classification*

(i) Crstalline ceramics: Single-phase like MgO or multi-phase form the MgO and Al_2O_3binary system.
(ii) Non-crystalline ceramics: Natural and synthetic inorganic glasses.
(iii) "Glass-bonded" ceramics: Fire clay products-crystalline phases are held in glassy matrix.
(iv) Cements: Crystalline and non-Crystalline

Properties of ceramic materials

Mechanical properties

(i) The compressive strength is several items more than the tensile strength.
(ii) Non-ductile/brittle. Stress concentration has little or no effect on compressive strength
(iii) The ceramic materials possess high modulus of elasticity due to ionic and covalentbonds.
(iv) At high temperature, rigidity is high.

Electrical properties

(i) Ceramic exhibits low dielectric constant contributes to low power loss and low loss factor.
(ii) Porcelain has large positive temperature coefficient.
(iii) Rutile bodies have large negative coefficients,

- The specific values of dielectric strength vary from 100 V per mil for low -tension electrical porcelain to 500 V per mil for some special ceramics.
- Rutile bodies show higher breakdown strength at higher frequencies.

Thermal properties

Since the ceramic materials contain relatively few electrons, and ceramic phases are transparent to radiant type energy, their thermal properties differ from that of metals. The following are the most important thermal properties of ceramic materials.

1. Thermal capacity

- The specific heats of fine clay bricks are 0.25 and 0.297 at 1000˚C and 1400˚C respectively.
- Carbon bricks possess specific heats of about 0.812 at 200˚C and 0.412 at 1000˚C

2. Thermal conductivity

- The ceramic material possesses a very low thermal conductivity since they do not have enough free electrons.
- The impurity content, porosity and temperature decrease the thermal conductivity.
- In order to have maximum thermal conductivity, it is imperative to have maximum density which most of the ceramic materials do not possess.

3. Thermal shock

- "Thermal shock resistance" is the ability of a material to resist cracking or disintegration of the material under abrupt or sudden changes in temperature.
- Lithium compounds are used in many ceramic compounds to reduce thermal expansion and to provide excellent thermal shock resistance.
- Common ceramic materials graded in order of deceasing thermal shock resistance or given below:
  1. Silicon nitrite2. Fused silica3.Cordierite4.Zircon5.Silicon carbide6.Beryllia 7.Alumina8.Porcelain9. Steatite

Chemical properties

1. Several ceramic products are highly resistant to all chemicals except hydrofluoric acid and to some extent, hot caustic solutions. They are not affected by the organic solvents.
2. Oxidic ceramics are completely resistant to oxidation, even at very high

temperatures.

3. Zirconia, magnesia, alumina, graphite etc., are resistant to certain molten metal and are thus employed for making crucibles and furnace linings.

4. Where resistant to attack from acids, bases and salt solutions is required, ceramics like glass are employed.

Optical properties

1. Several types of glasses have been employed for the production of windows, subjected to high temperatures and opticals lenses.

2. Special glasses used for selective transmission or absorption of particular wavelength such as infrared and ultra violet.

Nuclear properties

As ceramics are refractory, chemically resistant and its different compositions offer a wide range of neutron capture and scattering characteristics. They are finding nuclear applications such as fuel elements, moderators, and controls and shielding.

Classification of Ceramic Products

A general classification of 'ceramic products' is difficult to make because of the great versatility of these materials, but the follwing list includes the major groups.

1. Whitewares2. Bricks and tiles3.Chemical stoneswares4. Cements and concretes
5. Abrasives6. Glass7.Insulators8. Porcelain enamel9. Refractories
10. Electrical porcelain11. Mineral ores12. Slags and fluxes

Advantages of Ceramic Materials

The ceramic materials have the following advantages

1. The ceramic are hard, strong and dense.
2. They have high resistance to the reaction of chemicals and to the weathering.
3. Possess a high compression strength compared with tension.
4. They have high fusion points.
5. They offer excellent dielectric properties.
6. They are good thermal insulators.
7. They are resistant to high temperature creep.
8. Cheaply available.

Applications of Ceramics

The applications of ceramics are listed below

1. Whitewares (older ceramics): are largely used as:
    - Tiles
    - Sanitary wares
    - Low and high voltage insulators
    - High frequency applications
    - Chemical industry - as crusibles, jars and components of chemical reactors;
    - Heat resistant applications as pyrometers, burners, burner tips, and radiant heater supports.
2. Newer ceramics: (e.g., borides, carbides, nitrides, single oxides, mixed oxides, silicates, metalloid and intermetallic compounds) which have the high hardness values

and heat and oxidation values are largely used in the following applications

- Refractories for industrial furnaces
- Electrical and electronic industries as industors, semiconductors, dielectrics, ferro-electric crystals, piezo-electric crystals, glass, porcelain alumina, quartz and mica etc.
- Nuclear applications - as fuel elements, fuel containers, moderators, control rods and structural parts. Ceramics such as UO_2, UC, UC_2 are employed for all these purposes.
- Ceramic metal cutting tools-made from glass free Al_2O_3
- Optical applications-ytralox is a ceramic material which is useful as window glass and can resists very high temperature

3. Advanced ceramics: (e.g., ZrO_2, B_4C, SiC, TiB_2etc)

   The advanced ceramics are used in the following areas.

   - Internal combustion engines and turbines, as armor plate
   - Electronic packaging
   - Cutting tools
   - Energy conversion, storage and generation

Structure of crystalline ceramics

Most ceramic phases, like metals, have crstalline structure. Ceramic crystals are formed by the pure ionic bond, a pure covalent bond or both the ionic and covalent bonds.

- Ionic bonds give ceramic materials of relatively high stability. They are also harder and more resistant to chemical reactions.
- Covalent bond usually gives high hardness, high melting point and low electrical conductivity at room temperature.
- The ceramic crystals structures are, however, invariably more complex as compared to those of metals, since atoms of different sizes and electronic configurations are assembled together

Common crystal structure found in crystalline ceramics particularly those of oxide type are:

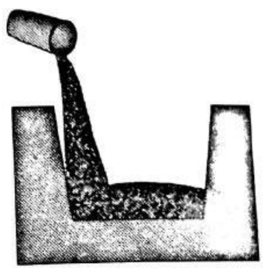
1. Rock salt structure 2. Cerium chloride structure 3.Zinc blend structure 4.Wurzite structure5. Spinal structure6. Fluorite structure7. Ilmenite structure

SLIP CASTING

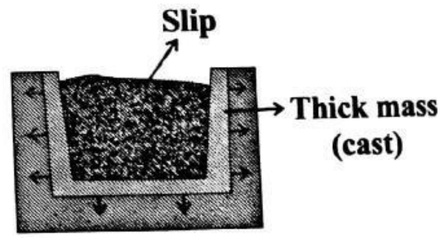
Forming a hallow ceramic part by introducing a pourable slurry into a mould is known as slip casting.

Formation

Slip casting is the most conventional method of producing different pieces that can have complex shapes such as refractory, sanitary and technical ceramics, without the use of heat.



4.17 (a)
Fill mold with slip



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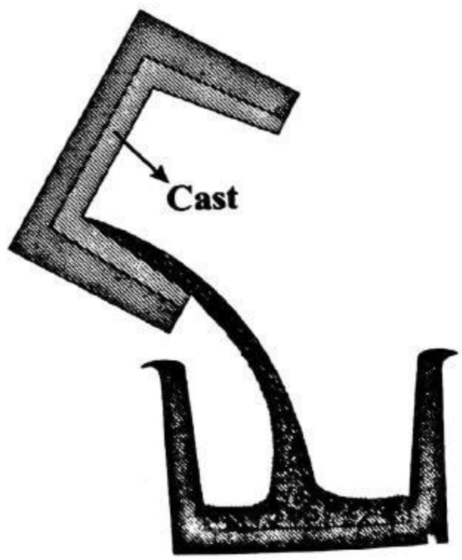
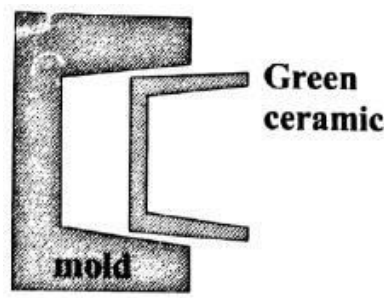


4.17 (c)



4.17 (d)

The following steps were involved in slip casting.

1. Slip casting technique normally uses aqueous slurry of ceramic powder. The slurry, known as slip, is poured into a mould [usually made of plaster of paris].
2. The fineness of the powder and the consequent high surface area ensure that electrostatic forces dominate gravity so that settling does not occur.
3. Now, sodium silicate is added to the slip to deflocculate the particles.
4. When the water from the slurry begins to move out by capillary action, a thick mass builds along the mould wall.
5. When sufficient product thickness is built, so called cast is formed and the rest of the slurry is poured out.
6. Now, the mould and cast are allowed to cry. After drying, casting is removed.
7. The green ceramic is then dried and fired or sintered at high temperature to obtain a dense ceramic material.

Uses of slip casting

1. Slip casting is a low cost way to produce complex shapes.
2. In traditional pottery industry, slip casting method is used for the production of teapots, jugs, statues and other ceramic sanitaryware.
3. Slip casting method is the standard method to make alumina crucibles which is used to make complex structural ceramic components such as gas turbine rotors.

Isostatic pressing

Isostatic pressing involves the application of hydrostatic pressure to a powder in a flexible container. The advantage of applying pressure in all directions is that there is more uniform compaction of the powder and more complex shapes can be produced

There are two types of isostatic pressing (i) Cold isostatic pressing (ii) hot isostatic pressing

(i) Cold isostatic pressing

A powder-shaping technique in which hydrostatic pressure is applied during compaction is known as cold isostatic pressing. This is used for achieving higher green ceramic density or compaction of more complex shapes.

There are two types (i) Wet-bag cold isostatic pressing (ii) Dry-bag cold isostatic pressing

(i) Wet-bag cold isostatic pressing

The following steps are involved in the processing.

1. The powder is weighed into a sealed rubber mould
2. The rubber bag is sealed by using a metal mandrel over which mould seal plate is fixed.
3. Now the sealed bag is placed inside a high pressure chamber that is filled with a fluid and is hydrostatically pressed.
4. The pressure used can vary from about 20 MPa upto 1 GPa depending upon press and the application
5. Once the pressing is complete, the pressure is released slowly
6. After releasing the pressure, the mould is removed from the pressure chamber.
7. Finally the pressed component is removed from the mould.

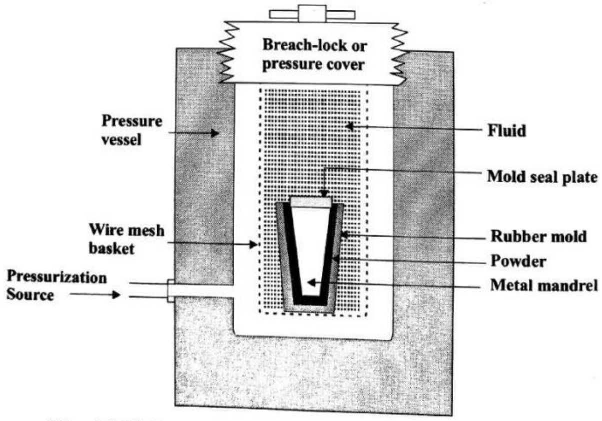


Fig. 4.18 Schematic of a wet-bag isostatic pressing system

Advantages

1. We can produce wide range of shapes and sizes.
2. Uniform density of the pressed product shall be obtained
3. Tooling costs is very low

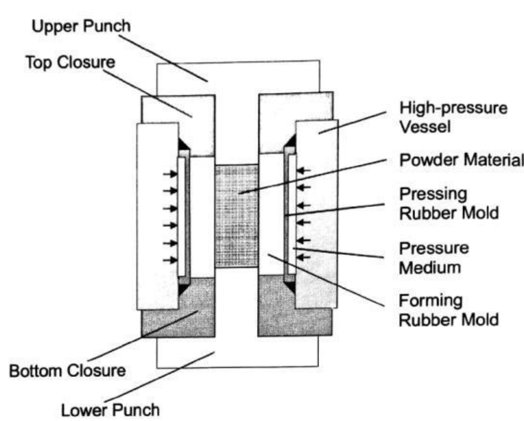
Disadvantages

1. Some time it forms poor shape and may not have dimensional control
2. Product often require green machining after pressing
3. It take long cycle time and give low product rates

(ii) Dry-bag cold isostatic pressing

The following steps are involved in the processing.

1. In dry bag process, the rubber mould is an integral part of the press, in which the powder material is taken.
2. The high pressure fluid is applied using pressure vessel.
3. The top closure, the bottom closure, the upper punch and the lower punch helps to hold the material tightly while pressing.
4. After pressing, the pressed part is removed without disturbing the mould.
5. Hence the dry bag press can be readily automated.
6. Production rates are as high as 1 part per second is being achieved industrially.



Uses

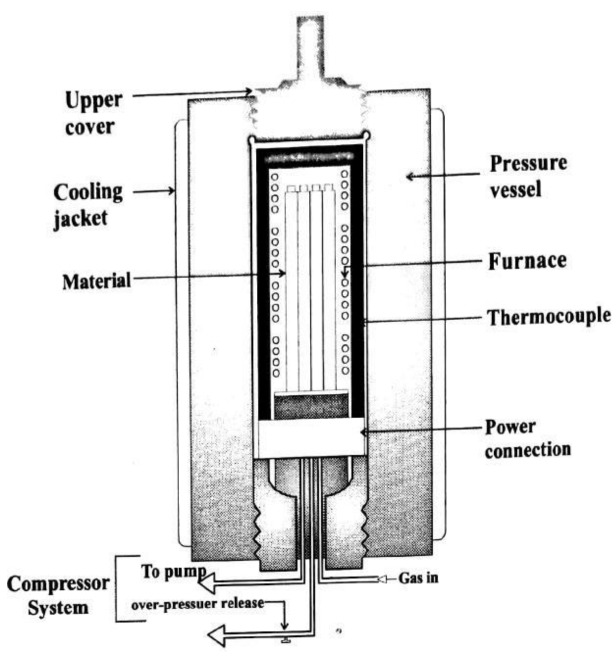
1. The dry-bag has been used for many years to press spark plug insulators.
2. The world's largest producers of spark plugs produced by this method are champion and AC spark plug

(ii) Hot isostatic pressing (or) Gas pressure bonding

Hot isostatic pressing (or) gas pressure bonding is a method used to densify a material, where in heat and pressure are imposed simultaneously and the pressure is applied from all directions via a pressurized gas such as argon or helium.

Construction

1. A basic HIP unit consists of a water-cooled pressure vessel within which a furnace, thermally insulated from the pressure vessel is kept. The pressure vessel is usually made with low alloy steel.
2. Heating elements are arranged in multiple banks to obtain uniform temperature and each bank can be controlled independently. Temperature control is obtained using sensitive thermocouples while the gas pressure is controlled using a compressor system. The gas can be recycled for reuse.
3. It also consists of auxillary systems like vacuum pumps and materials pumps to release the excess pressure.
4. Power connection enables to switch ON and OFF the heater, whenever required.
5. Furnaces used are radiation or convection type heating furnaces with graphite, molybdenum and nichrome heating elements, and hence it is covered by the upper cover and is surrounded by the cooling jacket.



Working

1. The basic function of the HIP unit is to heat the material by applying uniform gas pressure on all the surfaces.
2. The material to be prepared is kept inside the furnace.
3. Normally, a metal container or glass is used as a flexible, a leak proof mould in hot isostatic pressing. The mould is degassed after filling with powder to remove volatile components then sealed, using upper cover.
4. The furnace heats the material to be pressed. At the same time, a pressurizing medium, usually a argon gas is used to apply a high pressure during the process for specific times.
5. The pressurizing gas is further compressed using a compressor so as to increase the pressure to the desired level
6. Thus, both temperature and pressure are raised to the required values.
7. The furnace is then allowed to cool, followed by depressurizing the chamber and removal of parts.
8. The process results in full density parts with isotropic properties, even in large and complex shaped parts. During HIP, the pores present not only get closed by flow of matter by diffusion and creep, but also bonded across the interface to form a continuous material.

Advantages

1. The process offers increase in design flexibility
2. The process is not shape or size dependent, which results in optimized usage.
3. HIP results in enhanced quality and improved mechanical properties.
4. Tooling is simple and scrap is minimized and machining is not required
5. HIP produces dense materials without growing the grains.

Disadvantages

1. The design of the equipment is very complex and critical as it has to withstand a combination of high pressure and high temperature
2. Cost is very high

Uses

1. HIP can be used for fabricating components of aluminum, magnesium, copper-base alloys, cemented tungsten carbides, magnetic materials.
2. HIP can also be used for bonding of dissimilar material, consolidation of plasma coatings, processing soft and hard magnetic materials.
3. HIP has also been applied to the formation of piezoelectric ceramics such as $BaTiO_3$, $SrTiO_3$, and lead zirconate titanate (PZT) for use in acoustic wave filters and oscillators.
4. HIP are mostly used in structural ceramics.

5.

Ferroelectric ceramics

- **Ferroelectric ceramics** exhibit *electric polarization even in the absence of electric field*
- **Fabrication** – Powders made by *traditional methods* – *Forming process* (like slip casting) is done – Followed by *densification* by hot isostatic pressing – Later, ceramics are *sliced, lapped and finally polished*
- **Micro-structure** – *Grain size in the range of 2-6 μm* – Uniform grain size is highly

desirable

- **Electrical / Electro-mechanical property** – *High dielectric constant* – Exhibit *hysteresis behavior* – PZT and PLZT possess *highest electromechanical coupling coefficient*
- **Thermal / Optical properties** – Better choices for thermal imaging applications because of their *high pyroelectric coefficients* – PLZT have *high optical translucency and transparency*
- **Electro-optic properties** – *Quadratic, Kerr and birefringence effects* are observed

Applications of ferroelectric ceramics

- Ferroelectric ceramics are used as **capacitors** because of their *high dielectric constant* – $BaTiO_3$
- Ferroelectric ceramics can *convert electrical signal into mechanical signal* (such as sound) and vice versa and hence used as **transducers**
- Ferroelectric ceramics are used as *medical ultrasonic composites*
- Ferroelectric ceramics can be used in **photostrictors** and **integrated circuit** (IC) applications
- Ferroelectric ceramics can be used in *medical diagnostics through transducers*

Ferromagnetic ceramics

- Ferromagnetic ceramics, also known as ferrites, are compounds of various oxides
- General formula $MO.Fe_2O_3$ where M stands for a bivalent metal ion such as Zn, Ni and others
- Ferrites are ceramic materials with a crystalline structure of *spinel type*
- *Mineral magnetite* ($FeO.Fe_2O_3$) is the only naturally occurring mineral of this type
- Properties – *High volume resistivity* and *high permeability* – Specific gravity is between 4 and 5, which is less than iron (8) – Can be made both into *soft and hard permanent magnetic* materials – Exhibit a *square hysteresis loop* of magnetization – Extremely low switching time between magnetic saturation and demagnetization
- Applications – *Cores of radio and television loop antennas*, high reception quality and selectivity in antennas – *Memory cores in electron computers* – Military airborne applications due to 35% lower density than metallic magnets

High aluminium ceramics

- These ceramics are composed with ***more than 92wt% of alumina***, along with additives such as silica, iron oxides and alkaline oxides
- High alumina ceramics are *readily coupled with metals and other ceramics* by metallising and brazing techniques
- Offers a combination of *good mechanical and electrical properties* leading to wide range of applications
- **Properties** – *Excellent wear characteristics*, white in colour with *high hardness, good chemical resistance, good electrical insulation, high mechanical strength, high compressive strength, high dielectric strength*, half the density of metals and hence half the weight of metals
- **Applications** – *Electric arc furnaces*, manufacturing gem stones and laser components,

manufacturing *insulators and capacitors*, bio-ceramic parts for *orthopedic and dental surgery, thermocouple protection tubes* and refractory parts

UNIT -5 HAZARDS

INTRODUCTION

A hazard can be defined as "the degree of loss to a given element or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude"

It is expressed on a scale from 0 (no damage) to 1 (total loss). When the risk becomes tangible and impeding, there is a distinct threat of disaster. Hence, the sequence of states permitting to disaster is as follows:

HAZARD → RISK → THREAT → DISASTER → AFTERMATH

Globally, it appears that the toll of death and damage in natural disasters is increasing. Recently the disaster is reduced to large extent by improvements in prediction, warning, mitigation and international aid.

FUNDAMENTAL CONCEPTS RELATED TO EARTHQUAKE

1. Earthquake

   Earthquake is term used to describe both sudden slip on a fault and the resulting ground shaking and radiated seismic energy caused due to the following reasons viz., (i) the slip (ii) by volcanic and magmatic activity and (iii) other sudden stress that changes in the earth.

2. Earthquake source

   Earthquake source is the released forces that generate acoustic or seismic waves. During an earthquake when the ground is shaking, it also experiences acceleration. The peak acceleration is the largest increase in velocity recorded by a particular station during an earthquake.

3. Hypocenter

   The hypocenter is the point within the earth where an earthquake rupture starts.

4. Epicenter

   The epicenter is the point on the earth's surface vertically above the hypocenter and the point in the cruct where a seismic rupture begins.

5. Ground motion

Ground motion is the movement of the earth's surface from earthquakes on explosion. Ground motion is produced by the waves that are generated by sudden slip on a fault or sudden pressure at the explosive source and travel through the earth and along its surface.

6. Fault

A fault is a fracture along which the blocks of the crust on either side have moved relative to one another parallel to the fracture. The plane at which the fault takes place is called fault plane.

Types of faults

There are three types of faults, viz,

(a) Dip-Slip faults are inclined fractures where the blocks have mostly shifted vertically.

(b) A thrust fault is a reverse fault with a dip of 45 degrees or less.

(c) Oblique-slip faults have significant components of different slip styles

7. Slip

It is the relative displacement of adjacent points on opposite sides of a fault measured on the fault surface.

8. Directivity

Directivity is an effect of a fault rupturing whereby earthquake ground motion in the direction of rupture propagation is more severe than that in other directions from the earthquake source.

9. Ritcher Scale

The Ritcher magnitude scale was developed by Charles F.Ritcher of the California institute of technology as a mathematical device to compare the size of earthquakes. The magnitude of an earthquake is determined from the logarithm of the amplitude of waves recorded by seismographs.

In Ritcher scale, magnitude is expressed in whole numbers and decimal fractions. Eg. For a moderate earthquake, the magnitude is 5.3 and a strong earthquake rated with 6.3.

SEISMOLOGY

Seismology is the scientific study of earthquakes and seismic waves that move through and around the earth, by both naturally and artificially generated seismic waves.

Seismograph

Seismograph or seismometer is an instrument used to detect and record earthquakes. Generally, it consists of a mass attached to a fixed base. During an earthquake, the base moves and the mass do not. The motion of the base with respect to the mass is commonly transformed into an electrical voltage. The electrical voltage is recorded on paper, magnetic tape, or another recording medium.

This record is proportional to the motion of the seismometer mass relative to the earth, which can be mathematically converted to a record of the absolute motion of the ground. Seismograph generally refers to the seismometer and its recording device as a single unit.

Seismic gap

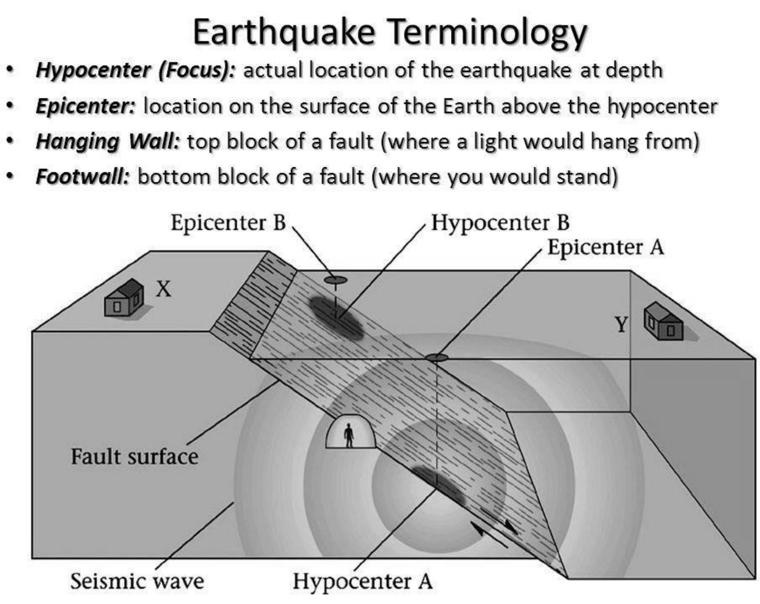
A seismic gap is a section of a fault that has produced earthquakes in the past but is now they are quiet. However the fault segment is capable of producing earthquakes on some other basis, such as plate-motion information or strain measurements.

Seismic moment

The seismic moment is a measure of the size of an earthquake based on the area of fault rupture, the average amount of slip, and the force that was required to overcome the friction sticking the rocks together that were offset by faulting. Seismic moment can also be calculated from the amplitude spectra of seismic waves.

The seismic moment can be measured using the following relation. Seismic moment $M_o = \mu AD$

Where, μ – Rigidity modulus, A – Fault rupture area, D – Average dislocation



Uses of Seismology

1. Seismology is useful to measure the speeds at which seismic waves travel through the earth
2. Seismology is used in prospecting for oil deposits. The first oil field to be discovered by this method was found in Texas in 1924.
3. Seismic methods are used to locate subsurface water and do detect the underlying structure of the oceanic and continental crust.
4. With the development of underground testing of nuclear devices, seismographic stations are used to collect seismic wave data during nuclear tests conducted under (or) below the earth.

Seismic waves

Seismic waves are low frequency waves that travel through the earth's interior generally caused by the following, viz. (i) tectonic earthquake (ii) volcanic eruptions (iii) Magma movement (iv) Large landslides (v) Large man-made explosions.

Types of seismic waves

Seismic waves can be classified into two basic types, viz. (i) Body waves (ii) Surface waves. Waves that are most destructive are surface waves which generally have the strongest vibration.

(i) Body waves

Waves which travel through the earth are called body waves.

(a) Compressional or primary (P) waves

1. Sound waves are usually called P – waves and are heard but not often felt.
2. Expect in the most powerful earthquakes they generally do not cause much damage.
3. P – Waves shake the ground in the direction they are propagating as shown.
4. The P wave, or compressional wave, ultimately compresses and expands material in the same direction it is travelling.
5. P – Waves travel very fast, at speeds between 4-8 km/ secin the earth's crust.
6. The P – Wave is the first to arrive at a location, as it is the fastest.

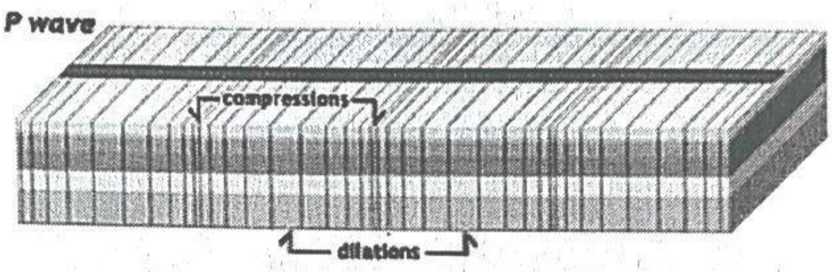


Fig. 5.4 P-waves

(b) Shear or Secondary (S) waves

1. S wave is shear wave which causes particles to oscillate.
2. S waves can travel through solid material but not through liquid or gas.
3. S – Waves shake perpendicularly or transverse to the direction of propagation.
4. They displace material at right angles to their path.
5. S – Waves travel more slowly, usually at 2.5-4 km/ sec.
6. S – Waves arrive slower than P – Waves

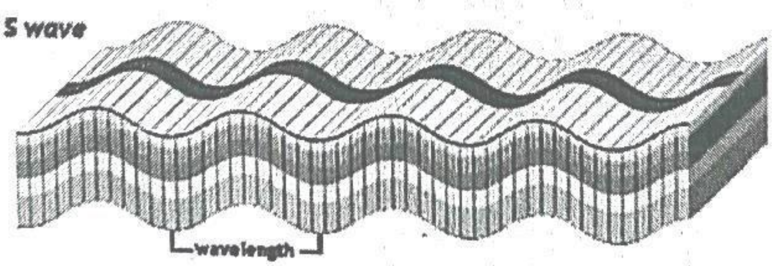


Fig. 5.5 S-Waves

(ii) Surface waves

Waves which travel along the earth's surface are called as surface waves. They arrive after the main P and S waves and are confined to the outer layers of the earth. They cause the most surface destruction.

Earthquake surface waves are divided into two categories,

(a) Love waves

1. Love waves are the fastest surface waves that move on the ground from side to side, which are confined to the surface of the crust.

2. Love waves have purely transverse motion in the horizontal plane. Hence love waves results most damage to structures.

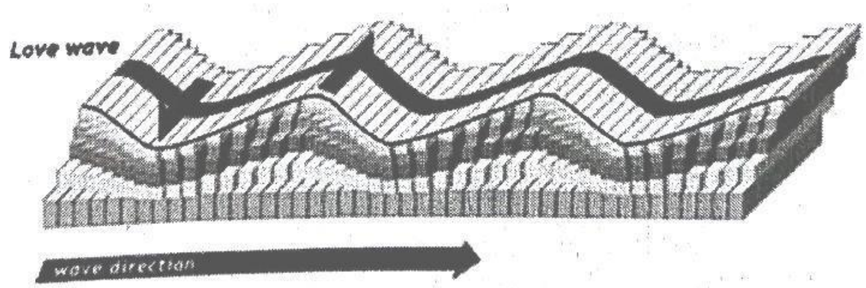


Fig. 5.6 Love waves

(b) Rayleigh waves

1. A Rayleigh wave rolls along the ground just like a wave rolls across a lake or an ocean.
2. Because it rolls, it moves the ground up and down, and side to side in the same direction similar to a wave motion.
3. Most of the shaking felt from an earthquake is due to the Rayleigh waves, which can be much larger than the other waves.
4. Rayleigh waves have retrograde particle motion confined to the vertical plane of motion.

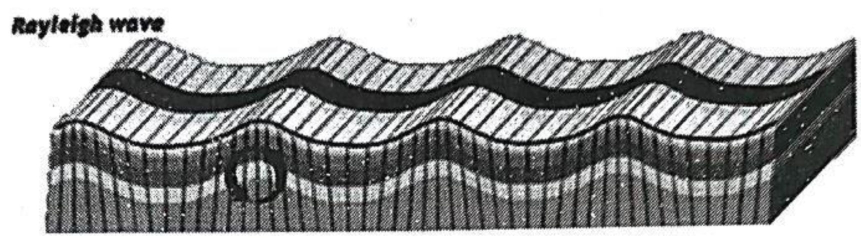


Fig. 5.7 Rayleigh waves

EARTHQUAKE GROUND MOTION

The terms earthquake motions, earthquake ground motion, or ground motion is the vibrational motion of the ground near the ground surface, which is caused by earthquake waves propagated away from the earthquake source. Earthquake ground motion is a complicated phenomenon which arises due to several factors such as (i) Dynamics of source breakage (ii) Details of the transmitting media. The ground motion varies from source to source, from path to path or from site to site and therefore introduce large scattering in numerical values of ground motion.

Earthquake ground motion – basic concepts

Ground motion at a particular site is influenced by four main elements; viz.

(i) Source, which describes how the size and nature of the earthquake source controls the generation of earthquake waves.

(ii) Directivity, which describes the direction at which the earthquake ground motion, is affected.

(iii) Travel path, which describes the effect of the earth on these waves as they travel from the source to a particular location.

(iv) Local site condition, which describes the effect of the uppermost several hundred meters of rock and soil and the surface topography at that location on the resultant ground motion produced by the emerging or passing earthquake waves.

Earthquake source

The earthquake source consists of a circular fault of radius ‘r’ that begins rupturing everywhere along the fault at the same time. After an earthquake begins, the accumulated strain resulting from tectonic stresses is too large for the rocks to bear.

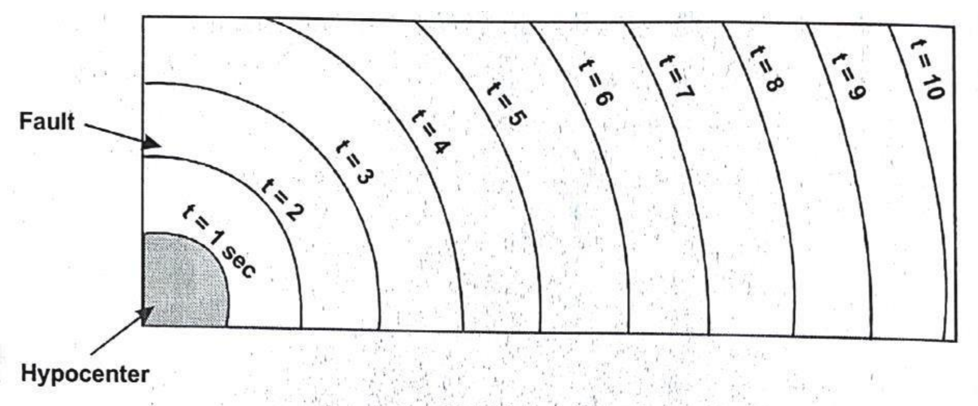


Fig. 5.8

The process of starting, propagation and ending of earthquake is as follows.

1. The hypocenter, is the point of rupture nucleation, where in which the earthquake starts and is shown near the lower left hand corner.

2. As the earthquake continues the rupture propagates away from the hypocenter to other parts of the fault.

3. The curved lines represent the locations of the rupture front, or boundary between the broken and unbroken parts of the fault, at different times after the initiation of rupture or origin time of the earthquake.

4. The rupture process stops at locations where it breaks the surface of the earth or where the rock is strong enough to bear the strain without breaking.

5. The rupture usually proceeds at a rupture velocity somewhat less than the velocity of S waves in the adjacent rock.

6. An increase in rupture velocity cab result in an increase in an increase in the amplitude of ground motion, particularly at high frequencies.

7. It is obvious that the rupture did not progress at the same velocity because of the heterogeneity in rock properties, fault geometry and stress release along the fault.

Faults consists of stronger parts [which are called barriers and asperities] and weaker parts, which rupture during an earthquake

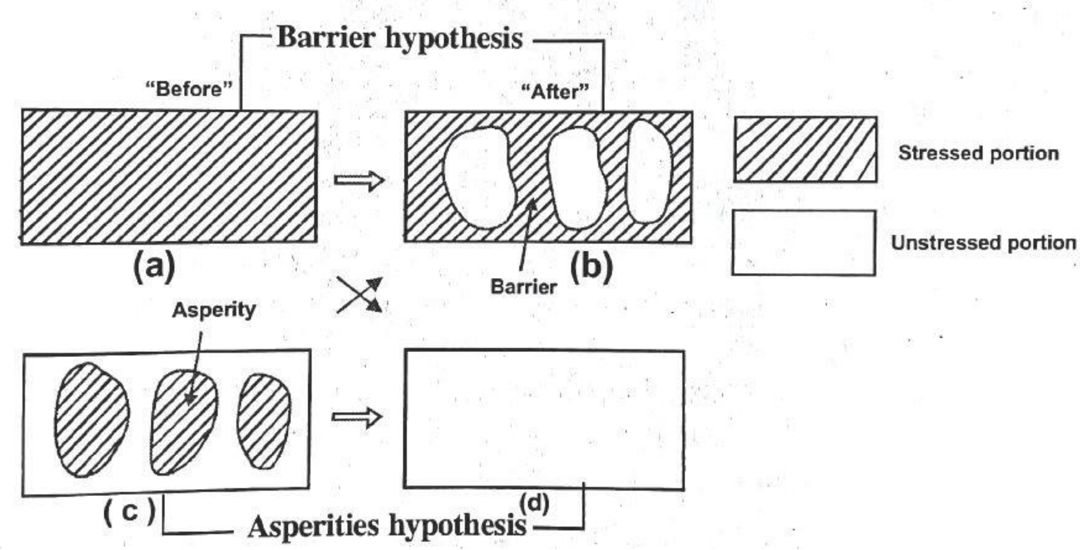
Barrier hypothesis

Before earthquake: The fault is in a state of uniform stress as shown Fig. (a).

During earthquake: The rupture propagates leaving unbroken stronger patches as shown in Fig. (b).

Asperities hypothesis

Before earthquake: The fault is not in a state of uniform stress as shown in Fig (c) and hence having strong patches by the release of extensive stress.
During earthquake: The patches or asperities are broken resulting in a smoothly slipped fault (bare land) as shown in Fig. (d).



Barriers and asperities are significant to earthquake ground motion because they represent locations of concentrated stress release and localized stopping.

(ii) *Directivity (or) focusing of Seismic energy*

Another source characteristic which can affect earthquake ground motion is called directivity, also referred to as focusing. Directivity occurs because the source of seismic waves. Directivity occurs because the source of seismic waves (fault rupture) is a moving source travelling along a fault at a finite rupture velocity.

1. The propagation of ‘seismic energy from the epicenter will have the following effects. The direction of fault rupture affects ground motion. Simply to say, if a fault rupture propagates towards a particular site the ground motion at that site will be greater than if a fault rupture propagates away from it as shown in Fig. 5.10 (a)
2. Here, when the fault ruptures, or earthquake source moves, from right to left from the epicenter, it generates ground motion from each part of the fault.
3. The pulse which began the earliest, near the epicenter, has spread the farthest, while the pulse that began the latest at the end of the fault rupture has spread the least.

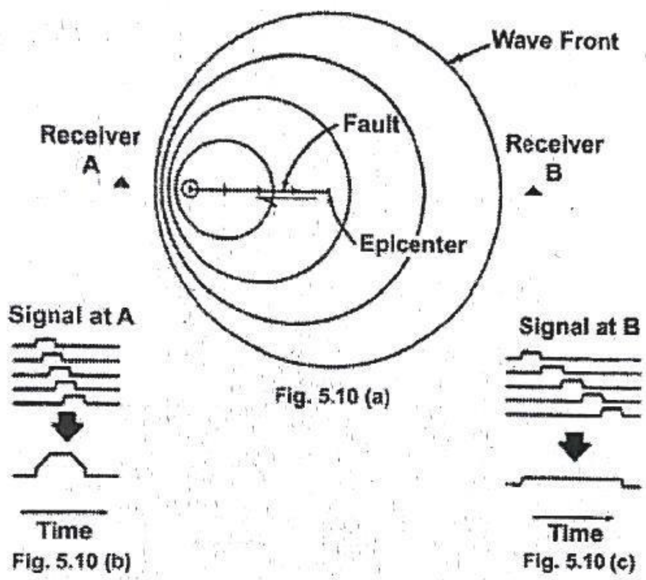


Fig. 5.10 Directivity or focusing of seismic energy

4. Although they originated at different times, the wave fronts, and therefore the pulses generated, tend to arrive close to the same time at receiver A (in the direction of rupture propagation) because the pulses that started the latest have the least distance to travel, as shown in Fig 5.10(b).
5. At receiver B (opposite to the direction of rupture propagation) the pulses that started last have the greatest distance to travel, so that pulses originating from different parts of the fault tend to arrive spread out over time, as shown in Fig 5.10(c).

6. The constructive interference of the ground motion at receiver A results in high amplitude motion. Thus the effect of directivity is to yield the highest ground motion (and shortest total duration) in t] direction of rupture propagation and the lowest ground motion (at longest total duration) opposite to the direction of rupture propagation.

7. This effect increases as the rupture velocity approaches the seismic wave velocity and as the angle between the point of observation an: the direction of rupture propagation becomes smaller.

(iii) Travel path effects

The effects of the travel path on earthquake ground motion are primarily related to the attenuation of the propagating seismic waves.

Seismic wave attenuation consisting of two major elements, viz., (a) Geometric spreading and (b) Absorption (sometimes called damping).

(a) Geometric spreading

Geometric spreading results from the conservation of energy as waves and wave fronts occupy more area as they spread out form the seismic source. If the earth were homogeneous and isotropic (the same properties in all directions) body waves would have spherical wave fronts and their amplitudes1 would decrease as E, where R is the distance to the earthquake source.

Similarly if the earth was both uniformly layered and flat, surface waves would have cylindrical wave fronts and their amplitudes would decrease as 1/ R The nonuniform, spherical nature of the earth modifies these factors.

(b) Absorption

Absorption is a net loss of energy as seismic waves propagate. Absorption is caused due to intrinsic physical loss mechanisms such as sliding friction across cracks, internal friction, and grain boundary effects which occur, as a seismic wave passes through the rock. The rate at which seismic wave amplitude attenuates (due to absorption) with increasing distance, is given by r.

$$\tau = \frac{\pi f}{QV}$$

Where, f → Frequency, V → Seismic wave velocity and Q → Quality factor which varies with wave type and is a function of material. Q increases with frequency and the relation between them is given by

$$Q = Q_0 f^n$$

EARTHQUAKE GROUND MOTION: ESTIMATION TECHNIQUES

Measuring Earthquake Ground Motion

Seismic waves and the resulting ground motion were divided into weak motion (from distant or small earthquakes) and strong motion (from nearby or large earthquakes).

In seismic hazard analysis estimates of ground motion are dealt with strong motion. Strong-motion instruments are designed to make usable records of earthquake ground motion which can destroy whole cities.

Instrumentation technique

Strong motion instruments are specially designed seismographs (accelerographs) configured to provide useful records of acceleration (accelerograms) from nearby earthquakes.

The heart of the accelerograph is a high frequency seismometer (accelerometer), the output of which is directly proportional to ground acceleration over a wide frequency range.

In Digital instruments, data can be stored electronically and easily processed. The earthquake ground motion can be estimated by the following techniques viz.,

1. Statistical regression techniques.
2. Theoretical ground motion modelling.
3. Semi-empirical techniques.
4. Semi-Theoritical techniques.

Statistical regression technique

Statistical regression techniques allow bringing together the available strong motion data, recorded under different source, travel path, and local site conditions, to define empirical correlations that permit the estimation of ground motion for many earthquake scenarios.

The basic functional form for ground motion regression equation is given by

$Y \alpha f_1 (M) f_2 (R) f_3 (M, R) f_4 (P_i) \varepsilon$ [or]

$Y = þ f_1 (M) f_2 (R) f_3 (M, R) f_4 (P_i) \varepsilon$

Where,

$Y \longrightarrow$ Strong motion parameter to be estimated (dependent variable).

B → Constant scaling factor.

f_1 (M) → Function of the independent variable M (magnitude or earthquake source size).
f_2 (R) → Function of the independent variable R (source to site distance).

f_3 (M, R) → Joint function of M and R.

f_4 (P_i) → A function, or functions, representing possible source, site, and building effects and
ε → An error term representing the uncertainty in Y.

Almost all ground motion regression analyses assume a relationship of this form. The different variable or parameters used in these regressions and their estimation technique is as follows.

Estimation of f_1 (M), f_2 (R) and f_3 (M, R)

For computing the strong motion parameter "Y", two parameters are very important viz,

1) The earthquake size which is, usually described by magnitude (M).

2) The second necessary parameter is source to site distance (R).

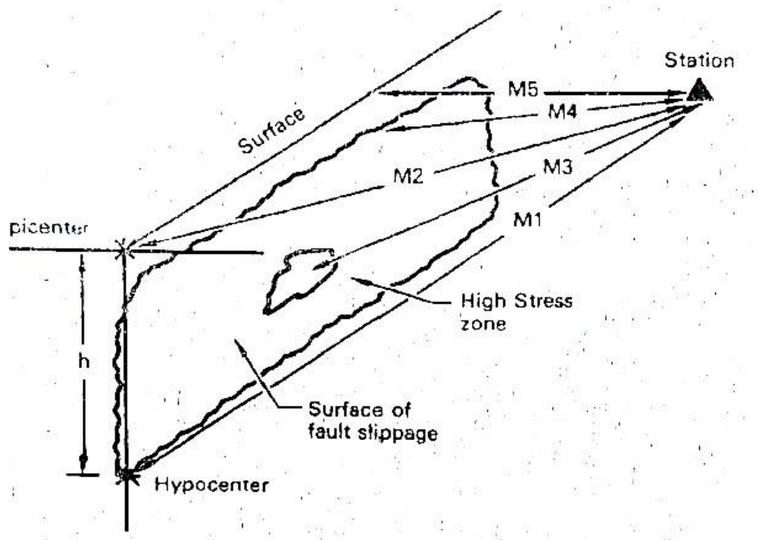


Fig. 5.11

Fig. 5.11' shows the schematic illustration of methods of distance measurement used in the determination of the distance value to be associated with a ground motion observation.

Here,

* M_1 is the hypocenter distance (focal depth is h).
* M_2 is the epicenter distance.
* M_3 is the distance to the center of high-energy release (or high localized stress drop).

* M_4 is the closest distance to the slipped fault; in this case, the fault rupture does not extend to the surface.
* M_5 is the closest distance to the surface projection of the fault rupture.

Measurement

1. The hypocentral distance (M_1) and epicentral distance (M_2) can be determined easily from knowledge of the recording station location and the earthquake catalog.
2. M_3 which is the distance to. the energetic zone, in turn represents the strongest source of ground motion can be measured by the distribution of strong-motion recordings with respect to the magnitude and distance used in regression analysis.
3. M_4 and M_5 which are the closest distance to the slipped fault or its surface projection will be widely measured using experimental methods.
4. The joint distance magnitude function f_3 (M, R) shown in equation (1) implies the relative change in ground motion due to change in magnitude and distance and are not independent of each other.
5. A function, or set of functions f_4 (P_i) which is shown in equation (1), has to be included in the regression to account for local site conditions, source characteristics other than size, and the effect of structures upon the motion. By calculating the above functional, parameter we can estimate the earthquake ground motion.

(2) Theoretical Ground Motion Modeling

Theoretically based numerical ground motion modeling techniques are used in applied seismic hazard analysis. Theoretical ground motion models may be classified into two main types viz., (i) Dynamic and (ii) Kinematic.

Kinematic model

This is a very Simple model in which simple uniform slip (dislocation), travels at a constant rupture velocity on a rectangular fault as shown in Fig. 5. 12. The following steps are adopted to determine the total ground motion by using kinematic ground motion modeling.

1. Initially the slip functions are measured at various points on the hypothetical fault surface (F) with respect to the Hypocenter.

2. Graph is drawn by taking time along X-axis and slip along Y axis for the various points as shown in Fig. 5.12.

3. For each plot (graph), depictions of Green's functions in an x,y,z Co-ordinate system was made as shown in Fig. 5.13.

4. From Fig. 5.13, we can see that the individual points on the fault surfaces at A,B,C,...F undergo instantaneous unit-amplitude slip resulting in ground motion (Green's functions) at observation point X_0.

5. The slip functions for each fault segment dF is convolved with the appropriate Green's function.

6. The resulting ground motions from each segment are summed to get the total ground motion at X_0 as shown in Fig. 5.14.

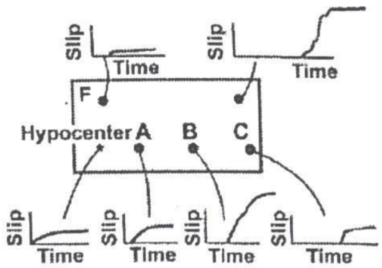


Fig. 5.12

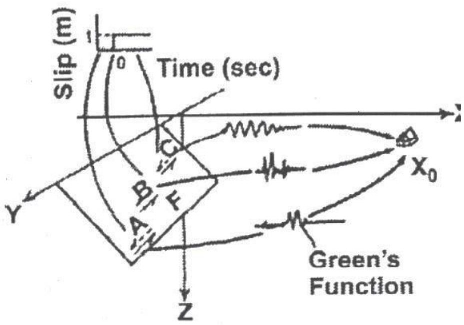


Fig. 5.13

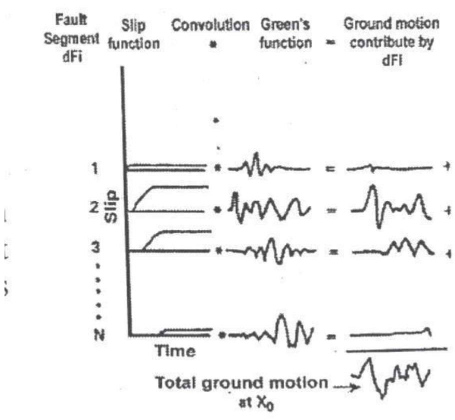


Fig. 5.14

Limitations

1. It is not possible to accurately estimate the ground motion in the near field.

2. Close to the earthquake source the contribution of high frequencies to the overall level of ground motion can be quite high.

3. It is limited only to low frequency ground motion.

4. The relative lack of close-in data results in large uncertainties at these distances.

EARTHQUAKE GROUND MOTION – SITE EFFECTS

Site effects play a very important role in characterizing seismic ground motions, because they may strongly amplify (or) deamplify seismic motions at the last moment just before reaching the surface of the ground or the basement of man-made Structures.

Because of the high level of amplification caused by site effects, which can be of almost two orders of magnitude, we cannot neglect them in engineering practice.

There are plenty of ways to estimate site effects. Some of the methods are,

1. Amplification Factor.
2. Nonlinearity of soil response.
3. Empirical Modeling of Site Effects.
4. Topographic Effects.

1. *Amplification Factor*

When there are sharp changes in rock properties below the earth's surface, several things happen. First, there is a change in amplitude (usually an increase) as the upwardly propagating seismic wave traverses then; there is a change in impedance (usually a decrease).

In the case of vertical incidence of body waves, either S waves or p waves, the amplification factor is given by

$$|\mathrm{U}(\omega)| = 2\{\gamma^2\}^{-1/2} = 2\gamma^{-1}$$

Here the amplification factor is twice the inverse of the impedance contrast (y). The amplification factors in the frequency domain for two thicknesses, [t= 100m & t = 15m] of alluvium is shown in Fig. 5.15.

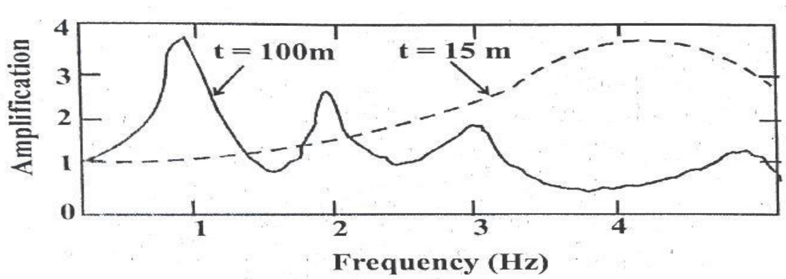


Fig. 5.15

From the curves obtained, we can find that the am'plication factor is higher at lower frequency & vice versa. Further, we can notice that the amplification factor is higher at lower thickness and vice versa.

2. *Nonlinearity of soil response*

Nonlinearity is the phenomenon which allows for changes in soil properties and therefore changes in soil response as the level of ground motion increases. Nonlinearity of soil response is also called strain dependence, because the strain in the soil during an earthquake increases with the level of stress or ground motion.

Therefore, the soil nonlinearity is characterized by the following factors viz., (i) Reduction of shear rigidity. (ii) Reduction of shear wave velocity. (iii) Increase of damping factor.

3. *Empirical Modeling of Site Effects*

If we obtain site effects directly from observed data; such an approach is called an empirical modeling approach.

In the empirical modeling of site effects, we must observe strong or weak ground motions due to one or more earthquakes and analyze data to extract site effects.

4. *Topographic Effects*

There are so many different observations on the strength of the topographic effect. The observations are

1. Even a rock site has strong site effects due to' the subsurface structure below.
2. Further it may be difficult to distinguish the effects of the subsurface structure and those of the topography from observed site effects, unless we know the subsurface velocity structure of the site in detail.
3. Surface waves, or body waves, is likely to happen but more than two arrivals with the same phase rarely meet at the same location.
4. Strong topography can be found only in the mountain area, where amplification itself is basically low compared to the basin surface.

Conclusions

1. The essential aspects of the site-effect studies are reviewed by focusing mainly on the physical modeling scheme to reproduce wave propagation phenomena in the shallower part of the Earth.
2. Physical properties of the actual complex structures of the Earth can be obtained by various geological, geophysical, and geotechnical methods, which can be used in the physical modeling scheme.
3. Once a physical model of the whole area of interest is calibrated to actual observation, then such a model of the ground will be a common property of people, on which we can depend forever.
4. To conclude, physical modeling of the ground is now a realistic and effective approach for practical evaluation/ prediction of site effects.
5. The advantage of the physical modeling approach is that it can predict site amplification for any hypothesized sources that have not yet happened but will happen in the near future.
6. Thus, we may need to develop a way to translate site effects evaluated by a physical modeling approach into simple but with effective engineering representations for better seismic design of structures.

SEISMIC HAZARD

Seismic hazard is defined as a natural phenomenon such as ground shaking, fault rupture, or soil liquefaction that is formed by an earthquake.

The term seismic hazard in engineering practice can refer specifically to strong ground motions produced by earthquakes that could affect engineered structures.

Seismic hazards are very severe and damaging, which depend on the magnitude of the earthquake, the distance a site from the earthquake, local site conditions and the response of the system of interest (For example, dams, buildings, powerplants).

Seismic hazard analysis

Seismic hazard analysis often refers to the estimation of earthquake induced ground motions having specific probabilities over a given time period.

In simple, Seismic hazard analysis refers to the estimation of some measure of the strong earthquake ground motions expected to occur at a selected site.

Importance of seismic hazard analysis

(i) The seismic hazard analysis is important for earthquake resistant design of a new structure such as dams, nuclear power plants, highrise buildings, long-span bridges, etc. at that site.

(ii) The seismic hazard analysis is also important in estimating the safety of existing structures also.

Types of seismic hazard analysis

There are two basic methods for seismic hazard analysis, viz., (a) Deterministic Seismic Hazard Analysis (DSHA) (b) Probabilistic Seismic Hazard Analysis (PSHA)

(a) Deterministic Seismic Harard Analysis (DSHA)

In Deterministic (Scenario earthquake) Seismic Hazard Analysis (DSHA) approach, the strong-motion parameters are estimated for the maximum credible earthquake, assumed to occur at the closest possible distance from the site of interest, without considering the likelihood of its occurrence during a specified exposure period.

Description

The deterrninistic seismic hazard analysis method uses geology and selsmlcity to identify earthquake sources and interpret the strongest each source is capable of producing regardless of time.

The main Objective is to identify the largest earthquake that appears along a recogmzed fault as a result of known (or) presumed tectonic activity.

Deterministic seismic hazard analysis usually requires four separate steps that are illustrated in Fig. 5.16.

Step 1 Identification of earthquake socures

Identify and characterize (geometry and maximum magnitude) all earthquake sources capable of generating significant shaking at the Slte.

Step 2 Calculation of source-to-site parameters

Calculate the appropriate source-to-site distance parameter such as R_1, R_2, and R_3 for each source identified in Step 1.

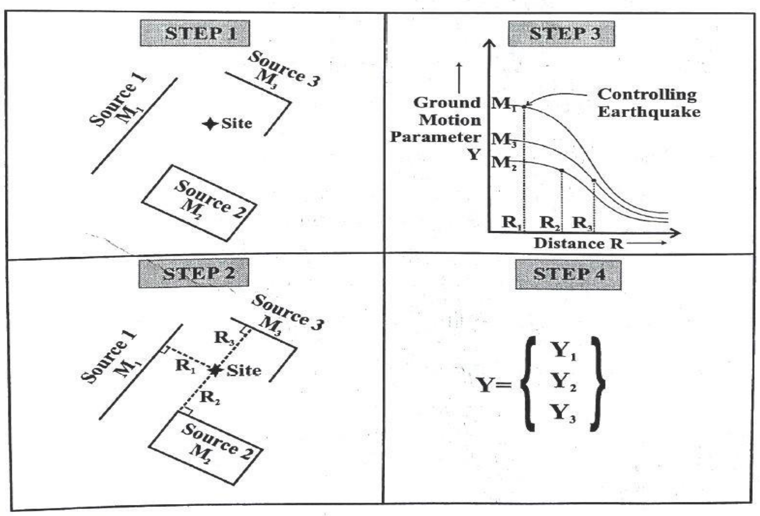


Figure 5.16

Step 3 Determination of ground motion parameters

Select the controlling earthquake. This is the earthquake that will generate the greatest shaking i.e, the ground motion parameter (Y) at the site with respect to R_1, R_2 and R_3, using and attenuation model appropriate for the region.

Step 4 Estimation of seismic hazard

Define the hazard at the site based on the controlling earthquake. The hazard at the site can be expressed in terms of maximum spectral ordinates, maximum ground displacement, and so on.

Advantages

The advantages of the deterministic seismic hazard analysis procedure are as follows.

1) It is simple to apply.

2) It yields conservative results for well-defined tectonic feature (e. g. line sources).

3) Largest Earthquake shall be easily analysed using this method.

Disadvantages

The disadvantages of this type of analysis are as follows

1) It is difficult to apply this analysis for distributed sources close to the site where the source-to site distance is difficult to establish.

2) It provides no information on the likehood of the controlling earthquake occurring at the site of interest.

3) It provides no information on the level of shaking a structure.

(b) *Probabilistic Seismic Hazard Analysis (PSHA)*

The Probabilistic (an ensemble of earthquakes) Seismic Hazard Analysis (PSHA) involves integrating the effects of all the earthquakes expected to occur at different locations during a specified life period, with the associated uncertainities and randomness.

Description

The application of the probabilistic seismic hazard analysis usually requires four steps, illustrated in Fig.5.l7.

Step 1 Identification of the seismogenic sources

For a given site, geographic zones representing seismotectonic sources are drawn. For each zone, it is assumed that the probability of earthquake occurrence IS the same for the entire surface area (a seismogenic source). Thus, we have to identify the earthquake sources.

Step 2 Determination of seismicity

For each source, a magnitude-recurrence relation of the type log N = A – bM is defined for various distances say R_1, R_2 and R_3. Historical seismicity is used to establish the parameters of this relation. A maximum (cut-off) magnitude M_{max} is also defined for each source.

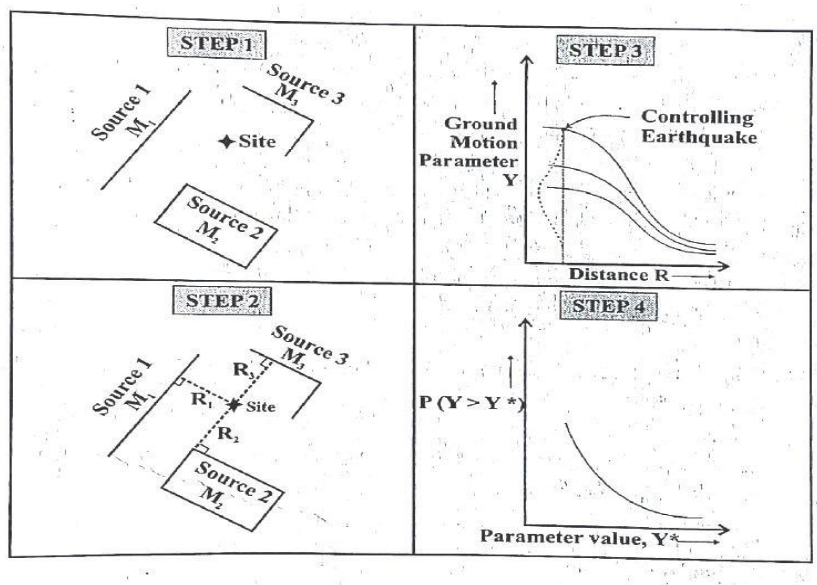


Figure 5.17 Step in probabilistic seismic hazard analysis

Step 3 Determination of attenuation

An attenuation relation is determined between each source and a given site. Often the same attenuation relation is used for the entire region.

Step 4 Calculation of the hazard curve for the site

The attenuation relations are combined with the magnitude-recurrence relations to calculate the annual number of earthquakes exceeding a chosen ground motion level at any given site (i.e. the recurrence rate). The total recurrence rate at the site from all sources is obtained by adding up the recurrence rates from each source.

The four steps above are then repeated on a grid for each given site in a region. Contour lines are then plotted for the chosen seismic parameter. These contour lines, based on the same annual probability of exceedance, creating a seismic hazard map for the region.

1) The probabilistic seismic hazard analysis procedure (PSHA) provides a systematic frame work for the treatment of uncertainty.

2) Two types of uncertainties need to be considered in the development of seismic hazard maps viz.,
(i) Aleatory uncertainty due to the randomness of the model parameters and

(ii) Epistemic uncertainty due to uncertainty in the knowledge of the model parameters.

CYCLONE HAZARDS

Cyclones

Cyclones are huge revolving or intense vortex storms in the atmosphere with very strong winds circulating around it in anti-clockwise direction in the Northern Hemisphere and in clockwise direction in the Southern Hemisphere.

The word “Cyclone” is derived from the Greek, word “Cyclos” meaning the coils of a snake.

Different names used for cyclones

Cyclones are called by different names based on its origin. Some of them are as follows.

1. Hurricane: When cyclone is formed in the North Atlantic Ocean, Caribbean Sea, Gulf of Mexico, Eastern north pacific and western coast of Mexico.

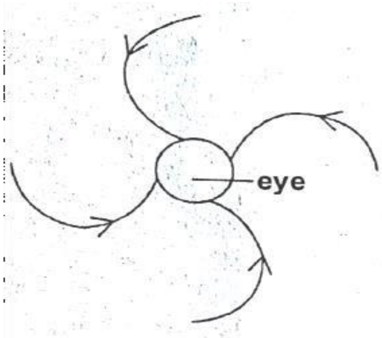
2. Typhoon: When cyclone is formed in the western Pacific Ocean.

3. Cyclone: When cyclone is formed in southern ocean and Indian ocean.

4. Willy-Willy: When cyclone is formed in Australia.

Formation of a cyclone

Formation of cyclones is due to intense low pressure areas which originate from the centre eye, the pressure increases outwards from eye centre. The amount pressure drop in the centre and the rate at which it increases outwards gives the intensity of the cyclones and the strength of winds. Cyclones develop over water and tend to lose their force over land, by the following steps.



at sea level

Fig. 5.18 (a)

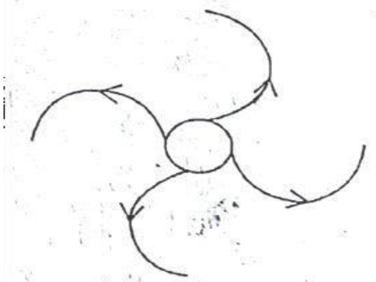

at high altitudes

Fig. 5.18 (b)

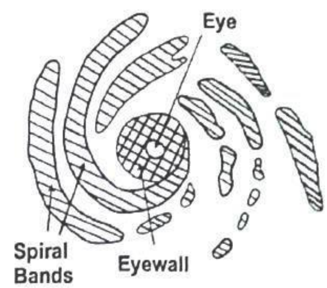


Fig. 5.18 (c)

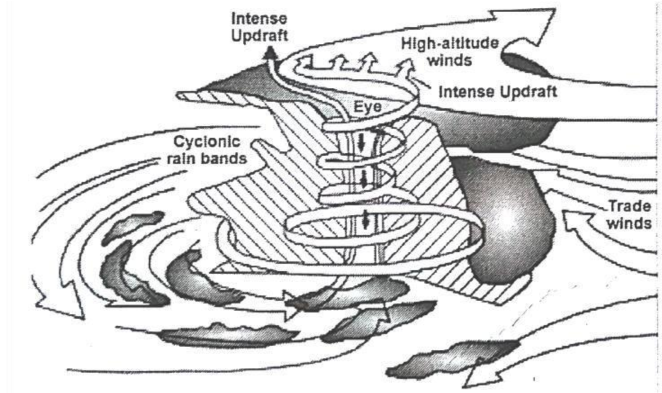


Fig. 5.18 (d)

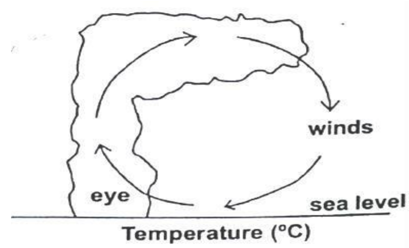


Fig. 5.18 (e)

Step 1 The central calm region of the storm is called the "Eye" at sea level is shown in Fig. 5.18 (a) and at higher altitudes it is shown in Fig.5.18(b).

Step 2 Around this calm and clear eye, there is the "Wall Cloud Region" of the storm about 50 km in extent, where the gale winds, thick clouds with torrential rain thunder and lightning prevail.

Step 3 Away from the "Wall Cloud Region", the wind speed gradually decreases. However, in cyclonic storms, wind speeds of 50 to 60 kmph can occur even at a distance of 600 km from the storm centre.

Step 4 Air converges at sea level and raises 1n spiralling motion around the eye, producing a heavy mass of cumulo-nimbus cloud of great depth as shown in Fig. 5.18(c).

Step 5 The gales give rise to a confused sea with waves as high as 20 metres, swells that travel a thousand miles.

Step 6 Torrential rains; occasional thunder and lightning flashes join these under an overcast black canopy, as shown in Fig.5.18 (d).

Step 7 Through these churned chaotic sea and atmosphere, the cyclone moves 300 to 500 km, in a day to hit or skirt along a coast, [Fig.5.18 (e)] bringing with it storm surges as high as 3 to 12 metres, as if splashing a part of the sea sometimes up to 30 km inland leaving behind death and destructions so called cyclone hazard.

Causes of Cyclones Hazards

There are three elements associated with a cyclone, which cause destruction, viz.

1. Cyclones are associated with high-pressure gradients and consequent strong winds. These, in turn, generate storm surges. A storm surge is an abnormal rise of sea level near the coast caused by a severe tropical cyclone; as a result, sea water overflows low lying areas of coastal regions drowning human beings and livestock, eroding beaches and embankments, destroying vegetation and reducing soil fertility.

2. Very strong winds may damage installations, dwellings, communication systems, trees, etc., resulting in loss of life and property.

3. Heavy and prolonged rains due to cyclones may cause river floods and submergence of low lying areas by rain causing loss of life and property. Floods and coastal overflows due to storm surges pollute drinking water sources causing outbreak of epidemics.

Here, all the three factors mentioned above occur simultaneously and, therefore, relief operations for distress mitigation become difficult.

So it is imperative that advance action is taken for relief measures before the commencement of adverse weather conditions due to cyclones.

CYCLONE PREDICTION Weather Satellites are probably the most important instruments for detecting and monitoring hurricanes. These include polar orbiting and geostationary satellites, such as those of the GOES and NCAA families. For instance, a geostationary satellite positioned 35,900 km above the Equator can provide storm surveillance images once every 11 minutes. Most cyclones move according to well-defined paths, in which future motion is predictable on the basis of momentum derived from previous tracking as shown in Fig 5.19.

Hence, in 70 percent of cases hurricane paths can be forecasted 24 hours in advance on the basis of directions and speeds over the previous 24-36 hours.
The most probable track is predicted up to 72 hours in advance (depending on the speed of forward movement) and the likely position of the hurricane at any point during this time interval is specified with respect to a 50 percent probability ellipse.
The width of the ellipse is indicative of the sensitivity of the forecast, and it tends to dilate as the time interval of prediction is increased. At landfall, digital simulation models can also give a clear picture of the expected maximum wind speed with distance inland, and this will probably be proportional to the damage which the storm causes. Based on these predictions, we can take precautionary measures to reduce the damages caused due to cyclones.

Safety Precautions and Timely Actions to Reduce Damage

Effective Cyclone Disaster Prevention and Mitigation Plan requires the following

- A cyclone forecast and warning service.
- Rapid dissemination of warnings to the government agencies, marine interests like the ports, fisheries and shipping and to general public.
- Organizations to construct cyclone shelters in the cyclone-prone areas and ready machinery for evacuation of people to safer areas.
- Community preparedness at all levels to meet the exigencies.

Safety precaution

Some of the safety precaution and the timely action (Hour by Hour) that we should take in order to reduce the damages caused due to Cyclone/Hurricane are detailed below.

Cyclone is 24 hours away

(i) Fill water buckets and cover them.

(ii) Top up your car's fuel tank.

(iii) Ensure you have fresh batteries for your radio.

(iv) Make sure you have adequate supplies of prescribed medicines.

(v) Stock up on non perishable food items if required.

(vi) Ensure your neighbors are aware of the issued warning.

Cyclone is 16 hours away

(i) Listen to the media for regular updates.

(ii) Ensure your children are home.

(iii) Gather tools that will be needed for emergency repairs, e.g. hammer, nails, rope, and tarpaulins.

(iv) If you live in a caravan, identify a solid structure to which you can move if required.

Cyclone is 9 hours away

(i) Prepare the safest part of your house (usually the bathroom) and place emergency stores there.

(ii) Account for and lock up your pets.

(iii) Gather protective gear and place in shelter.

Cyclone is 6 hours away

Listen to the media for regular updates.

(i) Stay in a safe place, don't move.

(ii) Beware of the calm "eye" of the cyclone and do not go outside until you are advised to do so.

When The Cyclone has passed

(i) Listen to the media for regular updates.

(ii) Do not make unnecessary demands on the emergency services.

(iii) Do not touch wet switches, and beware of fallen power lines, treat them as if they are live.

(iv) Stay at home and resist the urge to go sightseeing. The water surge caused by your vehicle can send flood water into people's homes.

FLOOD HAZARDS

A flood is an overflow of Water that submerges land which is usually dry. Floods are the most common natural disaster (or) Hazard in India. The heavy south west monsoon rain causes the Himalayan river basin distend their banks, often flooding surrounding areas. It results heavy losses for both economic and lives.

TYPES OF FLOOD HAZARDS

The types of flood hazards are given below

(1) Riverine floods or Fluvial (2) Estuarine floods (3) Coastal floods (4) Various catastrophic causes.

1. *Riverine floods. or Fluvial*

Fluvial, or riverine flooding, occurs .when excessive rainfall over an extended period of time causes a river to exceed its capacity. It can also be caused by heavy snow melt and ice jams.

There are two main types of riverine flooding

- Overbank flooding occurs when water overflows over the edges of a river or stream. This is the most common and can occur in any size channel from small streams to huge rivers.

- Flash flooding is characterized by an intense, high velocity torrent of water that occurs in an existing river channel. Flash floods are very dangerous and destructive not only because of the force of the water, but also the hurtling debris that is often swept up in the flow.

2. *Estuarine floods*

Estuarine floods usually result from the combination of a tidal surge at sea, caused by storm-forced winds and river flooding caused by rainstorms in inland.

3. *Coastal floods*

Coastal floods can be caused by hurricanes and other severe sea storms or by tsunami waves.

4. *Various catastrophic causes*

Various catastrophic causes can be identified, such as dam-burst or th effects of earth quake or volcanic eruption, can also lead to flood hazard.

EFFECTS CAUSED DUE TO FLOOD HAZARDS

There are 3 major effects that are caused due to flood hazard. They are

1. Primary effects that occur due to contact with water.

2. Secondary effects that occur because of the flooding, such as disruption of services, health impacts such as famine and disease.

3. Tertiary effects such as changes in the position of river channels.

1. *Primary Effects*

The primary effects of floods are those due to direct contact with the flood waters. Here, water velocities tend to be high in floods.

- Water entering human built structures cause water damage. Even with minor flooding of homes, furniture, floors and walls are damaged.

- Anything that comes in contact with the water is likely to be damaged or lost. Flooding of automobiles usually results in damage that cannot easily be repaired.

- Massive amounts of erosion can be accomplished by flood waters. Such erosion can damage bridge structures, and buildings.

- The high velocity of flood allows the water to carry more sediment as suspended load. When the flood waters retreat, velocity is generally much lower and sediment is deposited. After retreat of the floodwaters everything is usually covered with a thick layer of stream deposited mud, including the interior of buildings.

- Flooding of farmland usually results in crop loss. Pets and other animals are often carried away and drown by the flood.

- Humans that get caught in the high velocity flood waters are often drowned by the water.
- Floodwaters can concentrate garbage, debris, and toxic pollutants that can cause the secondary effects of health hazards.

2. *Secondary Effects*

Secondary effects are those that occur because of the primary effects and tertiary effects which are the long term changes that take place. Some of the secondary effects of a flood are as follows: Drinking water supplies may become polluted. This may result in disease and other health effects, especially in under developed countries.

- Gas and electrical service may be disrupted.
- Transportation systems may be disrupted, resulting in shortages of food and clean-up supplies. In under developed countries food shortages often lead to starvation.

3. *Tertiary effects (long term effects)*

- As the result of flooding, new channels may develop, leaving the old channels dry.
- Sediment deposited by flooding may destroy farm land.
- Jobs may be lost due to the disruption of services, destruction of business, etc.
- Insurance rates may increase.
- Corruption may result from misuse of relief funds.
- Destruction of wildlife habitat may occur.

Preventive & Protection measures to the taken during and after flood hazards

1. We should keep calm and do not panic.
2. We should always keep an emergency kit, enough supply of food and drink for the family to last the estimated length of the emergency situation.
3. We should listen to the radio but does not use the cell phone without reason.
4. Switch off electricity, gas and central heating. If there is enough time, move valuable or delicate objects and pollutant products to the higher levels of the strongest parts of the building.
5. Take the essential items like emergency baggage, identity and personal papers, medicines etc.
6. Do not cross flooded areas on foot or in a vehicle. If necessary secure yourself by holding onto ropes or cables.

7. Collaborate with public safety bodies and the services helping the homeless.
8. Check and see if there are any injured people in the vicinity and, if possible, help them.
9. Make yourself available to help with rehabilitation work.
10. Collaborate in the identification of bodies.

FIRE HAZARDS

A material, substance, or action that increases the likelihood of an accidental fire occurring is called fire hazard. In other words, an object, building etc that could easily catch fire or cause a fire and thereby endanger life is called fire hazard.

Examples
(i) The large number of dead trees poses a fire hazard.

(ii) Smoking in toilets is a fire hazard.

Fire hazards pose threats to life and property. It is, therefore, the prime object of safety systems to detect, remove or reduce the risk of tire threatened by those potential hazards. A fire can happen at any time at any place irrespective of its occupancy status. You can expect a fire at any structure, may be at your home or at your workplace or m a hospital or in public places like theatres, malls, etc.

Causes for Fire Hazards

The fire hazards are caused due to the following reasons, viz.,

1. All types of flames used for any work like cooking, smoking, etc causes fire.

2. Electric wires, higher loads, loose connections and old electrical equipments also cause fire.

3. All works and situations where fire is essential such as welding, cutting, metal casting etc. causes fire.

4. Improper storage of tools, equipment and items may cause fire.

5. Improper and unauthorized storage of flammable and hazardous materials and chemicals especially the flammable ones like fireworks, ammunitions and explosives will lead to fire.
6. Insufficient capacity and number of emergency exits and stairs and absence of fire detection and alarm system will also be a root cause for fire.

7. Insufficient numbers and types of fire extinguishers and hindrance to sight or reach firefighting equipment, markings and alarm systems will also cause fire.
8. Violation of building and fire codes are also the main reason for the occurrence of fire.

Classification of Fire Hazards

Fire hazards are classified by the types of fuel they burn.

Class A: Class A Fires consist of ordinary combustibles such as wood, paper, trash or anything else that leaves an ash.

Remedy: Pouring water is the best method to extinguish a Class A fire.

Class B: Class B Fires are fueled by flammable or combustible liquids, which include oil, gasoline, and other similar materials.

Remedy: Smothering effects which deplete the oxygen supply is best to extinguish Class B fires.

Class C: Energized electrical fires are known as Class C fires.

Remedy: Always de-energize the circuit then use a non-conductive extinguishing agent such as Carbondioxide.

Class D: Class D Fires are combustible metal fires. Magnesium and Titanium are the most common types of metal fires. Once a metal ignites, do not use water in an attempt to extinguish it. Only use a Dry Powder extinguishing agent.

Remedy: Dry powder agents work by smothering and heat absorption and hence reduces tire.
Class K: Class K Fires are fires that involve cooking oils, grease, animal fat etc.

Remedy: It can be extinguished using Purple K, the typical agent found in kitchen or galleys extinguishers.

Fire protection

Fire protection is the study and practice of mitigating the unwanted effects of potentially destructive fires. In other words, the measures and practices for preventing or reducing injury and loss of life or property by fire is called fire protection.

Fire protection maintains safety and reduces hazards associated with fires. Fire protection studies the behavior, suppression, and investigation of tire and related emergencies, as well as the research and development activities. There are three basic essentials of fire protection,

- **Study of Fire:** We should learn the causes of tire, lire extinguishing techniques, detection and extinguishing equipment and their uses, and the rules and regulations related to building construction.

- **Active Fire Protection:** Includes manual or automatic detection of fire, the use of tire and smoke alarms, firefighting and first aid.

- **Passive Fire Protection:** It includes design of building and infrastructures, use of fire resistance material in construction, provision of isolating fire, fire walls and doors, smoke doors, training of firefighting, signage, markings and evacuation of building in case of fire.

Fire-proofing materials and their applications Fire Proofing

Fire Proofing is a type of fire protection measure. It refers to the act of allowing materials to be more resistant to fire outbreaks.

Properties of fire-proofing materials

1. The strength of the material should, be more even at high temperature.

2. The material should not break down and disintegrate under the impact of high temperature.

3. The material should not be exorbitant.

4. The material should be non flammable as much as possible.

5. It should be non-ignitable (fire-proof).

6. Fire proof materials that are used in constructiOn are all designed to maintain their durability, strength and structural integrity as the temperature rises during a fire outbreak.

Applications

Fire proofing materials are used to make clothes, construction materials and many other items. Some of the items and their application are listed below

1. A material may be fire proof due to an infused chemical whereas others are fire proof by nature.

Applications: Refinery workers, maintenance workers, foundry workers, power and electric utility workers typically wears fire proof clothing in the course of their day to day duties.

2. Natural fibers like wools and cotton can also be treated with fire proof chemicals or even fire inhibitors to provide effective fire resistance.

Applications: Some fire blankets are also made with fiberglass and are most appropriate for smaller household kitchen fires or a small fire that starts from clothing.

3. Some phosphate free, environmentally friendly fire proof wood products are also available for those who want to use a green product.

Applications: Fire proof building materials such as dry wall, paint, roofing materials and exterior siding and many other types of fire proof building materials used on interiors, exteriors, roofs of house such as cast iron, steel, brick, stone, concrete and fire proof wood products.

4. Fire proof materials used for buildings also include a dry wall whereby non-combustile material and glass fibers have been fused into the core of the gypsum.

Application: This prevents the wall board from disintegration and slows down the spread of a tire.

FIRE SAFETY

Fire safety refers to planning and infrastructure in an organization that's designed to reduce fires and their effects. Simply, Fire Safety is the science of fire and the means of protection against it.

Fire safety regulations

1. Fire Safety in Home and Other Places

- Strike matches away from the body.
- Keep a lighted match ready before turning the knob of a gas burner.
- Stoves should be placed on a raised platform and not on the ground.
- Connect only one electric plug in a socket.
- Storage shelves should be away from the burner so that you do not have to lean over the flame to fetch the items.
- Never play with children or allow children to play in the kitchen.
- Do not keep a lighted stove or burner near a gas cylinder.
- Always close the regulator when the gas is not used.
- Replace the rubber tubes regularly so that it does not leak.
- Never place the cylinder in a horizontal position. Keep it vertical.
- Good housekeeping with proper arrangement of furniture, vessels and kitchen arrangements itself is a good fire safety measure.

2. In case of a gas leak from the LPG Cylinder

- Do not take any naked flame or allow a spark if you smell a gas leak.
- Do not operate any electrical switch as the spark.
- Open the door and windows and allow the gas to escape (LPG is heavier than air and so it tends to settle down on the ground or floor level)
- If possible, try to remove the leaking cylinder to a safe and open place so that the gas goes out and escapes.

3. In case of a fire in Cinema Hall

- When you enter the auditorium check the place at which normal exits and where the emergency exits.
- Rush out as soon as possible, through the exits and reach a place of safety.

- Do not panic.
- If there is smoke, lie on the floor as a smoke is usually lighter than air and tends to float.
- Use the stairs while running down.
- Do not smoke in the auditorium, toilet, refreshment halls etc.
- Locate the place of fire extinguishers and use them to put out the fire.

Safely tips against fire in Hotels

- Ask the porter / room boy about the ordinary as well as emergency passages, particularly the escape routes in the event of a fire.
- Find out the nearest escape route from your room.
- Electrical equipment must not be adjusted or altered without the permission of the management.
- Do not smoke in the bed. In case you smell smoke, raise an alarm.
- On the outbreak of fire, do not panic. You may sometimes be safer in your room.
- Leave the hotel by the staircase.
- Do not walk through smoke but crawl with your hands and knees on the ground and keep moving along the wall on the exit side.
- Read fire safety instructions/ fire plan, if available.

FIRE FIGHTING EQUIPMENT

Technical equipment designed to rescue people and protect valuable goods and natural resources from fire is called fire lighting equipment.

Examples

The basic apparatus are fire trucks, tire-fighting trains, fireboats, and lire-lighting airplanes and helicopters.

Types of fire fighting equipments and its uses

It is important to have fire safety equipment at hand both at home and at work. You never know when a fire is going to start, and so having a fire bucket, lire blanket, or fire extinguisher could save your life.

Here is an overview of the different types of fire lighting equipment that are currently available.

1. *Fire Extinguishers*

A fire extinguisher is on firefighting equipment, which is used to extinguish fire. The different types of fire extinguishers are given below

- Carbon dioxide extinguishers (CO_2)
- Foam extinguishers.
- Powder extinguishers.
- ABC fire extinguishers
- Wet chemical extinguishers.
- Fire blankets.

CO_2 Fire extinguisher

Principle

Carbon dioxide is extracted from the atmosphere and stored at high pressure in the liquid state within a fire extinguisher. When the extinguisher is let off, the liquid is released into the air neutralizing the oxygen that the fire is feeding on and disable the fires ability to spread.

Construction

CO_2 fire extinguisher cylinders are red. They range in size from 5 lbs to 100 lbs or larger (1bs=pound; 11bs=0.454 Kg).

(i) It consists of a steel cylinder in which the liquefied CO_2 gas is filled as shown in Fig.5.20.
(ii) A control valve is provided to allow a clear passage for CO_2.

(iii) In addition to this it is also provided with a discharge horn, which is designed to stop the entrainment of air with CO_2 and to reduce the velocity.

(iv) The function of dip tube is to deliver liquid carbon dioxide outside the bottle. It protects CO_2 from evaporation and freezing.

Working

(i) Take the extinguisher as close as possible to the fire.

(ii) Hold the horn with left hand.

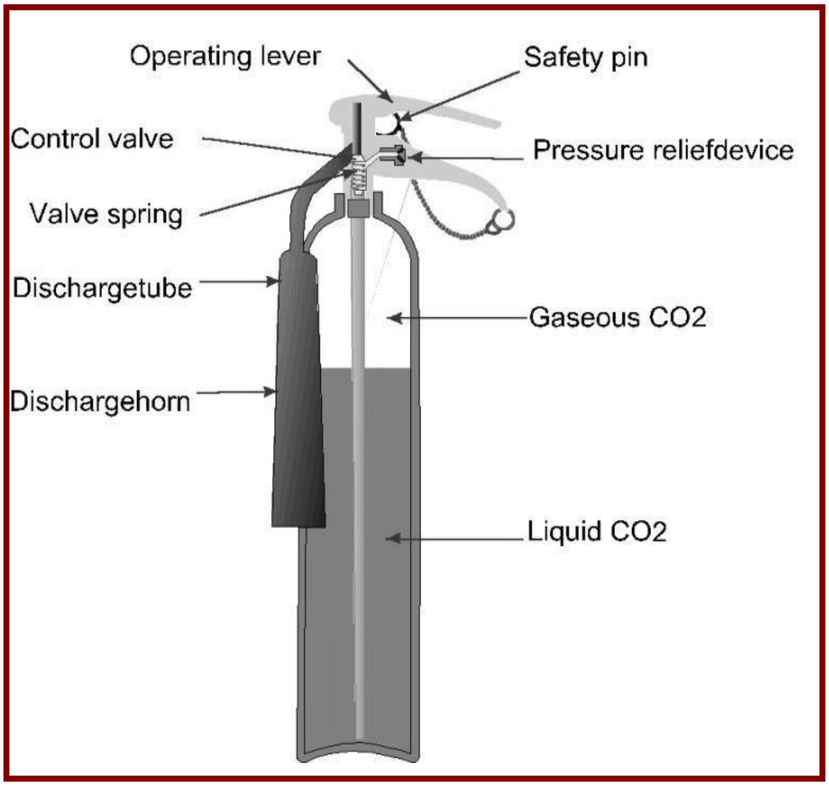
(iii) Open the control valve.

(iv) Direct the jet at the base of the fire with sweeping action from as close as possible to the fire.

(v) If flammable liquids aim the horn at the base of the fire and move across the area, be careful not to splash the burning liquid with the powerful jet of the CO_2 extinguisher.

(vi) If electrical equipment, switch off the power (if safe to do so) and then direct the hose straight at the fire.

(vii) CO_2 is very cold as it comes out of the extinguisher, so it cools the fuel as well.



Advantages

(i) CO_2 gas is electrically non conductive and therefore safe for fighting fires in electrically powered equipment.

(ii) CO_2 does not contaminate food, valuable materials and leaves no residue.

(iii) CO_2 is non-corrosive and nonconductor of electricity.

(iv) No residues left after application and no deterioration will happen with age of the appliance.

Disadvantages

(i) CO_2 is highly suffocating. 9% concentration causes unconsciousness within minutes.

(ii) Very little cooling effect. So there is danger of re-ignition.

(iii) When discharged, solid CO_2 particles present and generate sufficient static electricity to produce spark.

(iv) A CO_2 fire extinguisher may be ineffective in extinguishing a class A fire because it may not be able to displace enough oxygen to successfully put the fire out.

Uses of CO_2 fire extinguisher

(i) CO_2 fire extinguisher are designed for Class B and C (Flammable Liquids and Electrical Sources) fires.

(ii) CO_2 fire extinguisher will frequently be found in laboratories, mechanical rooms, kitchens, and flammable liquid storage areas.

(iii) Low and high pressure CO_2 is used for the fire protection of machinery spaces, pump rooms, cargo holds, paint stores and galley exhaust ventilation ducts on board ships.

Fire Hoses

The fire hoses lets out a powerful stream of water that extinguishes large fires as shown in Fig.5.21. The hoses usually come in a fire hose reel, which holds 30 metres of tubing. This makes the hose easy to unravel so a fire can be fought quickly. Fire brigades can also attach different nozzles to the end of the hose to fight a variety of fire situations. A .fire hose is one of the standard types of firefighting equipment, and it is efficient against even the largest fires. **Fire Buckets**

A fire bucket is considered the simplest piece of firefighting equipment, but still serves a purpose. The standard red bucket has the word 'Fire' written on it and it is made of metal or plastic as shown in Fig 5.22. It can be filled with water or you can fill it with a flame smothering powder like Flamezorb.

Fire Blankets / Welding Blankets

- Fire blankets are used to smother small fires that start in the workplace or at home. Economy fire blankets or white kitchen blankets are a good choice for a small kitchen or for a caravan.
- These blankets have a special pull tab that allows you to open them quickly.
- Welding blankets are used to protect welders from sparks and splatter. These blankets come in three different weights and sizes.

Flamezorb

- Flamezorb is a powder that effectively smothers tires as shown in Fig 5.23.
- It's non-toxic and easy to clean up.
- Each bag of Flamezorb has enough powder to fill a ten litre fire bucket.
- If you work in an area like a garage forecourt where this is a high potential of spillage, Flamezorb is good to have around.

Fire sprinklers

- The fire sprinklers are the latest fire protecting devices used in hotels, houses etc.
- It consists of a sprinkler as shown in Fig.5.24.

- During tire, the liquid tilled bulb burst and it allows the water to pass through the plug.
- This water is sprinkled through the sprinkler and fire is extinguished.

Prevention and safety measures

Each year, in India more than 250000 die in tires, more than 50,000 are injured in tires and more than 100 firefighters are killed while on duty. Eighty three percent of all civilian fire deaths occurred in residences. In order to protect yourself from fire, it is important to understand the basic characteristics of fire.

- Fire is FAST. In just two minutes, a fire can become life threatening. In five minutes, a residence can be engulfed 1n flames.
- Fire is DARK. Fire produces gases that make you disoriented and drowsy. Instead of being awakened by a fire, you may fall into a deeper sleep. Asphyxiation is the leading cause of fire deaths, exceeding burns by a three-to-one ratio.
- Fire is HOT. Heat and smoke from fire can be more dangerous than the flames. Inhaling the superhot air can sear your lungs.

Fire prevention

Before fire

The following are things you can do to protect yourself, your family, an your property in the event of a fire.

Smoke alarms and carbon monoxide detectors

- Install smoke alarms. Properly working smoke alarms decrease your chances of dying in a fire by half.
- Place smoke alarms on every level of your residence, including the basement.
- Install a working carbon monoxide detector in the common area of the bedrooms.
- Test and clean smoke alarms once a month and replace batteries at least once a year. Replace smoke alarms once every 10 years.

Cooking safety

- Never leave cooking unattended.
- Always wear short or tight-fitting sleeves when you cook.
- Keep towels, pot holders and curtains away from flames.
- Never use oven to heat your home.
- Do not overload extension cords or outlets.

Escaping the fire

- Make sure windows are not nailed or painted shut.
- Have an escape. Review escape routes with your family.
- Teach family members to stay low to the floor, where the air is safer, when escaping from a fire.
- In high-rise, never lock fire exits or doorways, halls or Stairways. Never prop stairway or other fire doors open.

Heating Source

- Place space heaters at least three feet away from flammable, combustible materials.
- Use only the type of fuel designated for your space heater.

Electrical Wiring

- Inspect extension cords for frayed or exposed wires or loose plugs.
- Make sure outlets have cover plates and no exposed wiring.
- Make sure Wiring does not run under rugs, over nails, or across high traffic areas.

During Fire

- If your clothes catch on fire, you should stop, drop, and roll until the fire is extinguished, as shown in Fig.5 .25.
- Do not panic. Call the Fire Department.

Escaping from fire

- Check closed doors with the back of your hand to feel for heat before you open them.
- If the door is hot do not open it. Find a second way out, such as a window. If you cannot escape through a window, hang a white sheet outside the window to alert firefighters to your presence.
- Stuff the cracks around the door with towels, rags, bedding or tape and cover vents to keep smoke out.
- If there is a phone in the room where you are trapped, call the fire department again and tell them exactly where you are.
- If the door is closed slowly open it and ensure that fire and/0f smoke is not blocking your escape

route. If your escape route is blocked, shut the door and use another escape route.

- If clear, leave immediately and close the door behind you. Be prepared to crawl.

After fire

- Once you are out of the building, stay out do not go back inside for any reason.
- If you are with a burn Victim or are a burn Victim yourself call, cool and cover your burns until emergency units arrive.
- If you are a tenant contact the landlord.
- Tell the fire department if you know of anyone trapped in the building.
- Enter your home, only when the fire department tells you it is safe to do so.

ection of corneal curvature.

DENTAL MATERIALS

Polymers, composites, ceramic materials and metal alloys are four main groups of materials used for dental applications.

A large number of materials are tested for porous dental implants, which include stainless steel,Co –Cr –Mo alloy, PMMA,proplast and Daceon, velour coated metallic implants, porous calcium aluminate single crystal alumina, bioglass, vitreous and pyrolytic carbons.
The dental applications include impression materials, dentine base and ceorons, bridges, inlays and repair or cavities, artificial teeth, repair of alveolar bone, support for mandible .