UNIT - I

Thermal Applications

Principles of heat transfer, steady state of heat flow, conduction through compound media - series and parallel - conductivity of rubber tube and powder materials - 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.

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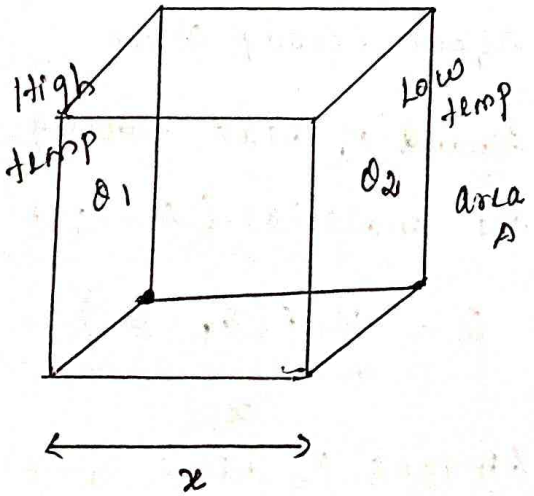
1. Give the expression for Thermal Conductivity

Definition :

It is defined as the amount of heat conducted per second normally across unit area of cross-section of the material per unit temperature difference per unit length.



- Consider a slab of material of length x, metre and area of a cross section A.
- one end - High temperature θ_1
- other end - Low temperature θ_2
- Heat flows from hot end to cold end.
- The amount of heat conducted from one end to the other end is
- directly Proportional to area of cross section (A)
- directly proportional to temperature difference between the ends $(\theta_1 - \theta_2)$

• directly proportional to time of conduction (t).

• inversely proportional to length(x) between the faces.

$$Q \propto A$$

$$Q \propto (\theta_1 - \theta_2)$$

$$Q \propto (t)$$

$$Q \propto 1/x$$

$$Q \propto \frac{A(\theta_1 - \theta_2)t}{x} \rightarrow (1)$$

$$Q = \frac{KA(\theta_1 - \theta_2)t}{x} \rightarrow (2)$$

where

K - proportionality Constant.

It is known as coefficient of thermal conductivity.

$$K = \frac{Qx}{A(\theta_1 - \theta_2)t} \rightarrow (3)$$

$A = 1\,m^2$, $\theta_1 - \theta_2 = 1$ Kelvin

$x = 1\,m$ $t = 1\,s$

$$\boxed{K = Q}$$

Rewriting the expression (2)

$$Q = -KA\frac{d\theta}{dx}t$$

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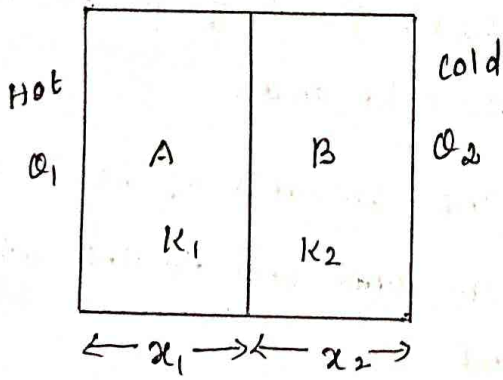
② Derive an expression for heat through conduction of compound media

i) Series



• Consider a compound media of two different materials A and B

• K_1 K_2 - thermal Conductivities

x_1, x_2 - thickness

θ_1, θ_2 - Temperature

θ - surface in contact

After steady state

Amount of heat flowing through the material (A) per second

$$Q = \frac{K_1 A(\theta_1 - \theta)}{x_1} \rightarrow (1)$$

Amount of heat flowing through the material (B) per second

$$Q = \frac{K_2 A(\theta - \theta_2)}{x_2} \rightarrow (2)$$

eqn(1) & eqn(2) are equal

$$\frac{k_1 A(\theta_1 - \theta)}{x_1} = \frac{k_2 A(\theta - \theta_2)}{x_2} \longrightarrow (3)$$

Rearranging the eqn(3)

$$k_1 A(\theta_1 - \theta) x_2 = k_2 A(\theta - \theta_2) x_1$$

$$k_1\theta_1 x_2 - k_1\theta x_2 = k_2\theta x_1 - k_2\theta_2 x_1$$

Rearranging

$$k_1\theta_1 x_2 + k_2\theta_2 x_1 = k_2\theta x_1 + k_1\theta x_2$$

$$k_1\theta_1 x_2 + k_2\theta_2 x_1 = \theta(k_2 x_1 + k_1 x_2)$$

$$\boxed{\theta = \frac{k_1\theta_1 x_2 + k_2\theta_2 x_1}{k_2 x_1 + k_1 x_2}} \longrightarrow (4)$$

Substituting for θ in eqn(1)

$$Q = \frac{k_1 A}{x_1}\left[\theta_1 - \left(\frac{k_1\theta_1 x_2 + k_2\theta_2 x_1}{k_2 x_1 + k_1 x_2}\right)\right]$$

$$Q = \frac{k_1 A}{x_1}\left[\frac{\theta_1(k_2 x_1 + k_1 x_2) - (k_1\theta_1 x_2 + k_2\theta_2 x_1)}{k_2 x_1 + k_1 x_2}\right]$$

$$Q = \frac{k_1 A}{x_1}\left[\frac{k_2\theta_1 x_1 + k_1\theta_1 x_2 - k_1\theta_1 x_2 - k_2\theta_2 x_1}{k_2 x_1 + k_1 x_2}\right]$$

$$Q = \frac{k_1 A}{x_1}\left[\frac{k_2\theta_1 x_1 - k_2\theta_2 x_1}{k_2 x_1 + k_1 x_2}\right]$$

$$Q = \frac{k_1 A k_2 x_1 (\theta_1 - \theta_2)}{x_1[k_2 x_1 + k_1 x_2]}$$

$$Q = \frac{k_1 k_2 A(\theta_1 - \theta_2)}{k_2 x_1 + k_1 x_2}$$

$$Q = \frac{A(\theta_1 - \theta_2)}{\frac{k_2 x_1}{k_1 k_2} + \frac{k_1 x_2}{k_1 k_2}}$$

$$Q = \frac{A(\theta_1 - \theta_2)}{\frac{x_1}{k_1} + \frac{x_2}{k_2}} \longrightarrow (5)$$

$$\boxed{Q = \frac{A(\theta_1 - \theta_2)}{\Sigma(x/k)}}$$

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ii) Materials in parallel

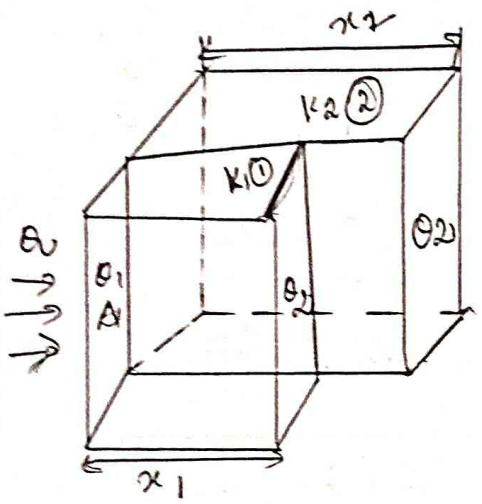
- Consider two different materials A and B with thermal conductivities k_1 and k_2 and thickness x_1 and x_2.
- They are arranged in Parallel.
- A and B are at temperature θ_1
- other end faces of A and B

at temperature θ_2.

• A_1 and A_2 are the area of cross section of the materials

Amount of heat flowing through the first material (A) in one second

$$Q_1 = \frac{K_1 A_1 (\theta_1 - \theta_2)}{x_1} \longrightarrow (1)$$



Amount of heat flowing through the second material (B) in one second

$$Q_2 = \frac{K_2 A_2 (\theta_1 - \theta_2)}{x_2} \longrightarrow (2)$$

$$Q = Q_1 + Q_2$$

$$= \frac{K_1 A_1 (\theta_1 - \theta_2)}{x_1} + \frac{K_2 A_2 (\theta_1 - \theta_2)}{x_2}$$

Amount of heat flowing per second

$$Q = (\theta_1 - \theta_2) \left(\frac{K_1 A}{x_1} + \frac{K_2 A_2}{x_2} \right)$$

Net amount of heat flowing per second parallel to the slab

$$\boxed{Q = (\theta_1 - \theta_2) \sum \frac{KA}{x}}$$

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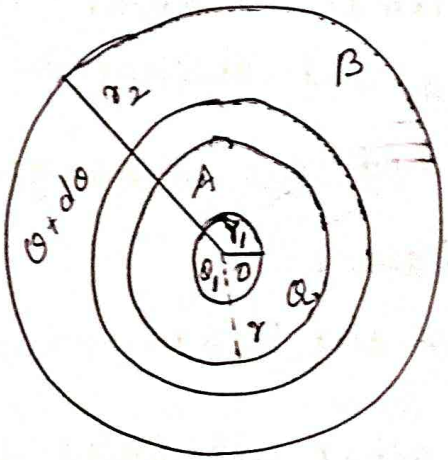
(3) Derive an expression for Radial flow method

i) Spherical shell method ii) Cylindrical shell method

i) Spherical shell method



• Two thin spherical shells - A and B

• radii - r_1, r_2

• thermal conductivity - K

• distance r and r+dr from o at temperature θ and θ+dθ

$$Q = -KA \frac{d\theta}{dr}$$

$$Q = -K 4\pi r^2 \frac{d\theta}{dr} \longrightarrow (1)$$

where

$$A = 4\pi r^2$$

Rearranging eqn (1)

$$\frac{dr}{r^2} = \frac{-4\pi K}{Q} d\theta \longrightarrow (2)$$

Q - constant, Values of r as a steady state

Integrating eqn (2) between the limits r_1 and r_2 and the corresponding temperatures θ_1 and θ_2

$$\int_{r_1}^{r_2} r^{-2} dr = -\frac{4\pi K}{Q} \int_{\theta_1}^{\theta_2} d\theta$$

$$\left[\frac{r^{-2+1}}{-2+1}\right]_{r_1}^{r_2} = -\frac{4\pi K}{Q} (\theta)_{\theta_1}^{\theta_2}$$

$$\left[\frac{r^{-1}}{-1}\right]_{r_1}^{r_2} = -\frac{4\pi K}{Q} (\theta_1 - \theta_2)$$

$$\left(\frac{1}{r}\right)_{r_1}^{r_2} = \frac{4\pi K}{Q} (\theta_1 - \theta_2)$$

$$\int_{r_1}^{r_2} \frac{dr}{r^2} = \int_{\theta_1}^{\theta_2} -\frac{4\pi K}{Q} d\theta$$

$$\frac{1}{r_1} - \frac{1}{r_2} = \frac{4\pi K (\theta_1 - \theta_2)}{Q}$$

$$\boxed{K = \frac{Q(r_2 - r_1)}{4\pi r_1 r_2 (\theta_1 - \theta_2)}}$$

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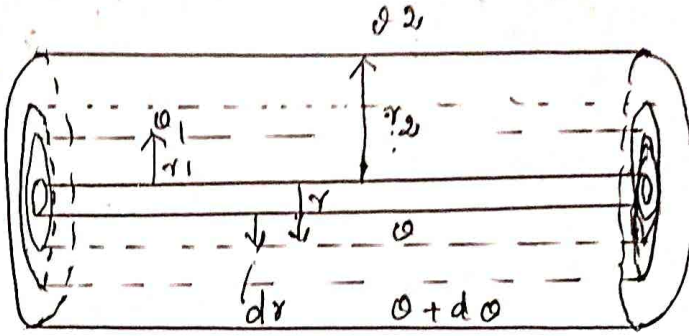
ii) Cylindrical Shell method



- l - length
- r_1, r_2 - inner and outer radius
- θ_1 - inner surface
- θ_2 - outer surface

Amount of heat flowing per second through this elementary cylinder

$$Q = -KA \frac{d\theta}{dr} \longrightarrow (1)$$

Surface area of the imaginary cylinder

$$A = 2\pi r l$$

$$Q = -2\pi r l K \frac{d\theta}{dr} \longrightarrow (2)$$

Rearranging the eqn(2)

$$\frac{dr}{r} = \left(-\frac{2\pi l k}{Q}\right) d\theta$$

Integrating both sides

$$\int_{r_1}^{r_2} \frac{dr}{r} = -\frac{2\pi l k}{Q} \int_{\theta_1}^{\theta_2} d\theta$$

$$\left[\log_e r\right]_{r_1}^{r_2} = -\frac{2\pi l k}{Q} \left(\theta\right)_{\theta_1}^{\theta_2}$$

$$= -\frac{2\pi l k}{Q} (\theta_2 - \theta_1)$$

$$\log_e r_2 - \log_e r_1 = +\frac{2\pi l k}{Q} (\theta_1 - \theta_2)$$

or $\log_e \left(\frac{r_2}{r_1}\right) = \frac{2\pi l k}{Q} (\theta_1 - \theta_2)$

$$Q = \frac{k\, 2\pi l (\theta_1 - \theta_2)}{\log_e \frac{r_2}{r_1}}$$

$$\boxed{k = \frac{Q \log_e \frac{r_2}{r_1}}{2\pi l (\theta_1 - \theta_2)}}$$

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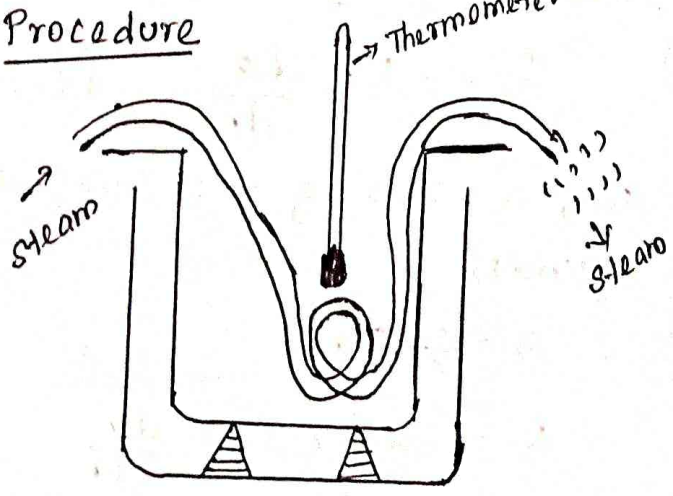
(4) Derive an expression for thermal conductivity of Rubber

Principle :

It is based on the principle of radial flow of heat through a cylindrical shell

Procedure



- A big empty Calorimeter with stirrer is weighed (W_1)
- Filled with two thirds of water and again weighed (W_2)
- A known length l of a rubber tube is immersed in water in the Calorimeter.

The calorimeter is stirred well and initial temperature θ_1°C is noted.

• one end of the rubber tube is connected to a steam generator and steam is passed through it.

• The steam is passed continuously till there is a rise of 10°C in temperature.

• The time taken (t second) for this rise in temperature is noted.

• The final temperature of the water (θ_2°C) in the calorimeter is also noted.

Observation

Mass of the empty calorimeter with stirrer = W_1 kg

Mass of the calorimeter + water = W_2 kg

Mass of the water = $(W_2 - W_1)$ kg

Initial temperature of the water = θ_1°C

Final temperature of the water = θ_2°C

Rise in the temperature of water = $(\theta_2 - \theta_1)$

Time for which steam is passed = t s

Length of the rubber tube immersed in water = l

Inner radius of the rubber tube = r_1

outer radius of the rubber tube = r_2

Specific heat capacity of calorimeter = Specific heat capacity of water = s_2

Heat gained by the calorimeter = Mass × specific heat capacity × change in temperature

$= W_1 \times s_1 \times (\theta_2 - \theta_1)$ → (1)

Heat gained by the water = $(W_2 - W_1) \times s_2 \times (\theta_2 - \theta_1)$ → (2)

$$Q = \frac{W_1 s_1 (\theta_2 - \theta_1) + (W_2 - W_1) s_2 (\theta_2 - \theta_1)}{t}$$

$$K = \frac{Q \log_e (r_2/r_1)}{2\pi l (\theta_1 - \theta_2)} \quad \rightarrow (3) \quad \rightarrow (4)$$

Substituting eqn (3) in eqn (4)

$$K = \frac{\left\{W_1 s_1 + (W_2 - W_1) s_2\right\} (\theta_2 - \theta_1) \log_e \left(\frac{r_2}{r_1}\right)}{2\pi l t \left[\theta_s - \frac{\theta_1 + \theta_2}{2}\right]}$$

θ_s - temperature of steam

$\frac{\theta_1 + \theta_2}{2}$ = Average temperature inside of rubber tube.

(5) Write short notes on fenestration

• It refers to the presence of openings in a building, most notably the doors and windows.

Definition :

Any opening in a building such as windows, doors, curtain walls and skylights which are designed to permit the passage of air, light, vehicles or people is called fenestration

Fenestration system

- Glazing - Glass is used for transmission of natural light
- Windows - use wooden frame
- Curtain walls - attached to the building structure.
- Sloped glazing - used to provide interior day lighting
- Exterior doors - include entrance and exit doors.
- Emergency route - escape route in case of fire in low rise buildings.

Main components of fenestration

a) Glazing
b) framing
c) shading devices and screens.

Heat transfer through fenestration

• The short wave solar radiation incident on the fenestration system.
• Solar energy is transmitted through opening.
• incident solar energy is absorbed by the fenestration.
• radiative exchange between fenestration.
• The conductive and convective heat transfer caused by inside/outside temperature difference.

Total heat transfer

Q_{solar} = heat transfer from solar radiation
• positive number

$Q_{thermal}$ = heat transfer between indoor and outdoor air
• This is positive or negative depending on temperature.

The total heat transfer through fenestration

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

⑥ Write short notes on Thermal insulation and its Benefits.

Definition:

It is the reduction of heat transfer between objects in thermal contact or in range of radiative influence.

1) General principles of thermal insulation

- directly proportional to its thickness.
- Provision of an air gap is a very important insulating agent.
- depends on orientation also.
- Heat is transferred by Conduction, convection or radiation.

2) Thermal insulating materials

The materials which are used for thermal insulation are known as thermal insulating materials.

a) organic materials

b) Inorganic materials

a) Organic materials

Examples: Cattle hair, silk, Wool, Glass wool, charcoal etc

b) Inorganic insulating materials:

Examples: still air, Mineral Wool, Glass wool, charcoal etc

3) Methods of thermal insulation

- **use of materials with low thermal conductivity**

. Low thermal conductivity should be used for walls and roofs.

- **Thickness of walls and roofs**

Thicker the wall or roof, lesser is the heat transfer.

- **Provision of air spaces**

Air spaces in walls and roof increase thermal insulation

- **Heat insulation by Orientation**

minimum transfer of heat during summer and maximum transfer of heat in winter.

- **Thermal insulation by shading**

improve thermal insulation to some extent.

- **using thermal insulating materials**

i) Thermal insulation of roofs

- Water proof course is essential.
- Providing a 25mm thick Concrete mixed with coconut pith.

- For external insulation, Asbestos Cement sheets on bricks are used.

ii) Thermal insulation of walls

- Fixing thermal insulating materials on inside and outside of the walls.
- Applying light coloured white wash.
- Creating air space in walls
- Thickness of wall may be provided.
- hollow wall or cavity wall construction may be used.
- Curtains be provided

iii) Insulating doors and windows

- Providing Sunshades
- Using curtains with heavy folds.
- using insulating glass or double glass with air space between them.

Benefits of thermal insulation

- By thermal insulation, the room remains cooler in summer and warmer in winter than outside.
- Energy saving

Thermal insulation decreases the transfer of heat between inside and outside of the room.

- reduces thermal stresses of roof
- No heat absorption
- Expansion joints can be avoided.

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9) Write notes on heat gain and heat loss estimation

Heat gain estimation

Heat gain : A heat gain is the rate at which heat enters inside the building or generated within a space at a given instant

$$Q_g = AU(T_i - T_o)$$

Q_g - Heat gain through transmission by the wall, roof, ceiling
A - Area of the wall, roof
U - Thermal transmittance, air to air
T_i - inside air temperature
T_o - outside air temperature

Heat loss estimation

Heat loss : A heat loss is the rate at which heat flows out from a building to the surrounding environment

$$Q_L = Q_t + Q_v + Q_i$$

Q_t - Heat loss due to transmission through walls, windows, doors, floors

Q_v - Heat loss caused by ventilation

Q_i - Heat loss caused by infiltration

Heat loss by transmission

$$Q_t = A U (T_i - T_o)$$

Q_t → Transmission heat loss

A - Area of exposed surface

U - Overall heat transmission coefficient

T_o - outside air temperature

Heat loss by ventilation

$$Q_v = c_p \rho q_v (T_i - T_o)$$

Q_v - ventilation heat loss

c_p - specific heat capacity

ρ - Density of air

q_v - volume of air flow

Heat loss by infiltration

$$Q_i = c_p \rho n V (T_i - T_o)$$

n - Number of air shifts.

V - volume of the room

$$Q_L = AU(T_i - T_o) + c_p \rho q_v (T_i - T_o) + c_p \rho n V (T_i - T_o)$$

$$Q_L = [AU + c_p \rho q_v + c_p \rho n V] (T_i - T_o)$$

$$Q_L = [AU + c_p \rho (q_v + nV)] (T_i - T_o)$$

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(8) Write notes on Thermal performance of Buildings

Definition :

It refers to the process of modelling the energy transfer between a building and its surroundings.

- For a conditioned building, it estimates the heating and cooling load. Selection of Heating, Ventilation and Air conditioning (HVAC) equipment be correctly made.
- For a non-conditioned building it calculates temperature variation inside the building over a specified time.

Heat exchange processes between a building and the external environment

- Heat flows by conduction through various building elements such as walls, roof, ceiling, floor etc.
- Solar radiation is transmitted through transparent windows and is absorbed by the internal surfaces of the building.
- Evaporation of water resulting in a cooling effect.

Factors affecting Thermal Performance of Buildings

i) The main factor is the insulation value of the materials used in the building. This value is known as the U-value of the material.

ii) Design variables (walls, roof etc)

iii) Material properties (density, specific heat, thermal conductivity)

iv) Climate data (solar radiation, wind speed etc)

v) A building's usage data (equipment)

(9) Write short notes on Thermal comfort

Thermal comfort describes the human satisfactory view of the thermal environment.

Factors influencing thermal indoor environment.

- Radiation
- Convection
- Evaporation

Common heat sources

- Electrical equipment
- Sun radiation
- human presence

Common sources of cold

- window surfaces
- Poorly insulated walls
- thermal bridges in the constructions.

Factors that influence thermal comfort

Air temperature

it can easily be influenced with passive and mechanical heating and cooling

Mean radiant temperature

weighted average temperature

Air velocity

quantifies the speed and direction of the air movements in the room.

Humidity

moisture content of the air

Clothing level

The amount of insolation added to the human body

Average comfort rating

- Combining all the factors mentioned above, an average comfort rating can be predicted.

Thermal comfort affects the work performance

- Cause attention distraction
- disturb well-being
- reduce the ability to concentrate properly

• Indices of Thermal Comfort

Air temperature

measured from a dry bulb thermometer

Air temperature and humidity

Convey the thermal comfort levels

Cooling power

- Air temperature
- Humidity
- Air movements

Effective temperature

Effective temperature is the temperature in an environment with 100% humidity and no air movements which will induce the same level of thermal comfort as in the present situation

Corrected effective temperature

- CET determined by 4 factors
  - air temperature
  - humidity
  - air movements
  - radiant heat
- Corrected effective temperature is measured using a combination of
  - globe thermometer
  - wet bulb thermometer
  - air speed measurement.

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(10) Discuss about climate and Design of Solar Radiation

Weather

The weather of a place denotes the state of the atmospheric environment over a period of time

Climate :

Integrated weather condition over several years is known as climate.

Design of Solar radiation

- The building should be sufficiently shaded to prevent solar radiation from entering the house.
- It must be ventilated to reduce discomfort due to high humidity.

Basic Principle

- Geographic location
- Time of day
- Season
- Local landscape
- Local weather

Diffuse and Direct Solar Radiation

- Air molecules
- Water Vapor
- Clouds
- Dust
- Pollutants
- Forest fires
- Volcanoes

Solar radiation design

i) Active Solar design
ii) Passive Solar design

i) Active Solar design

It uses outside energy and equipment like electricity and solar panels to help capture and utilize the energy of the sun.

2) Passive Solar design

It doesn't use any outside energy or require much special equipment, but simply takes advantage of existing natural phenomena, like the direction of the sun or the insulation properties of concrete

Solar Passive Design

- Modulating the micro climate of the site through landscaping.
- optimizing the orientation and building form.
- optimizing the building envelope and windows design to reduce the cooling demand.
- Applying day light integration to reduce the artifical lighting demand.
- Adopting low energy passive cooling strategies.

Site specific considerations during design

- Latitude, sun path and insolation
- Seasonal variations in solar gain
- Micro climate details related to breezes, humidity, vegetation and land contour.

Design elements for Residential Buildings in Temperature climates

- Placement of room-types, internal doors and walls and equipment in the house.
- Orienting the building to face the equator.
- Minimizing windows on other sides, especially western windows.
- Using thermal mass to store excess solar energy during the winter day.

(11) Explain about shading devices

A shading device is a component of a window and facade that protects space from direct sunlight, over heating, glare and provides increased day light, privacy or view to the outside.

Functions of shading devices

- Well designed sun control and shading devices are reduce building peak heat gain and cooling requirements.
- Improve the natural lighting quality of building interiors.
- can improve user visual comfort by controlling glare and reducing contrast ratios.
- Can also function as reflectors.
- use of shading devices is an important aspect of many energy-efficient building design.
- inhibit the solar radiation incident on a building.

Importance of sun shading devices

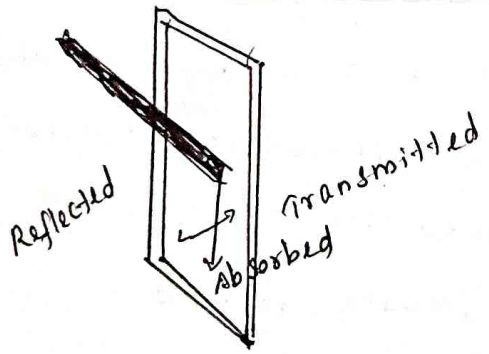
- to provide greater comfort for occupants.
- Can improve building energy performance.

- can prevent glare
- Increase useful daylight availability.
- Provide sense of security.

Solar Shading

when sunlight hits a plane of glass it splits into three components.

- Reflected - no effect on heating
- Absorbed - transfer heat conduction also emits heat.
- Transmitted - Heat up surface behind it.



- Determined by angle of incidence.

i) Types of shading devices

- 2 types

i) Internal shading devices

ii) External shading devices

Internal shading devices

- Can reduce heat energy passing through a window.
- ability to reflect the incoming solar radiations back through the window.
- more effective than the dark coloured shading devices.
- major disadvantage of internal device is that they trap heat on the interior of the glass.
- should not block the natural ventilation
- Limit the glare resulting from solar radiation.

External shading device

- Controls the amount of radiation entering the building externally.
- Horizontal, vertical or egg crate devices
- Vegetation and other buildings can also act as shading devices.
- 3 types of sun shading devices.
  - Vertical devices
  - Horizontal devices
  - Egg crate devices.

Vertical Swing devices:

Consisk of pilasbers, blades or projecking fins in 45" a vertical Posikion

Horizontal Swing devices

usually in the form of Canopies, long Verandas, movable horizontal louvre blades or roof over hangs.

Egg crate devices:

Combinakions of vertical and horizontal devicis.

- usually in the form of grill blocks or decoravive screens

Designing shading device

i) understand the sun path of the place.

ii) Select shading type
- Horizontal - Vertical - Egg crate

iii) Identify category
- Fixed Adjustable

iv) Calculate design dimensions understand horizontal and Vertical shadow angles.

(12) Discuss about central heating

Definition:

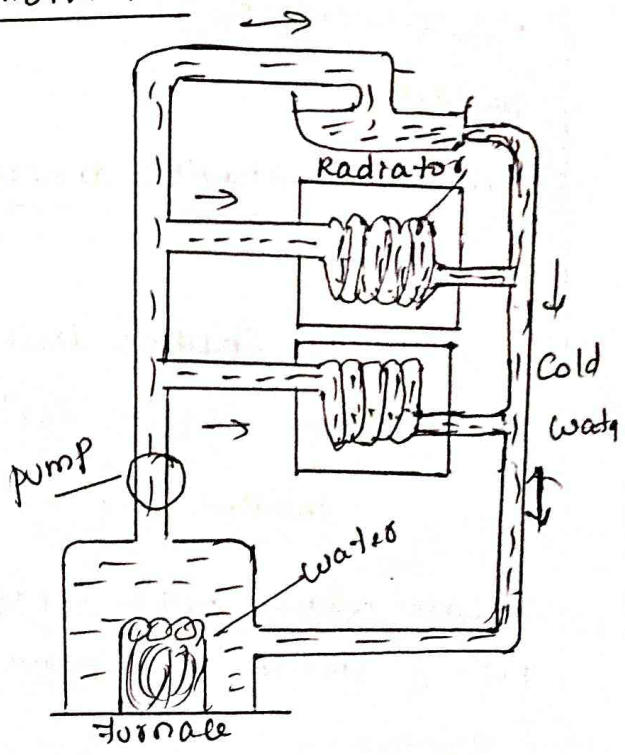
A central heating System Provides warmth to the whole interior of a building or portion of a building from one point to multiple rooms.

Principle:

The heat is distributed through out the building, by forced air through ductwork, water circulating through Pipes or steam fed through pipes.

The most common method of heat generation involves the combustion of fossil fuel in a furnace or boiler.

Construction



. Circulating hot water be used for central heating
. A gas supply lines or distinct heating supply lines.
. A boiler which 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.

Working

. Water is heated by the boiler.
. Hot water from the boiler rises up and passes through the radiators of different rooms with help of pump.
. 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 follow a closed loop.

Advantages.

. Low cost system
. does not require high electrical power
. Central heating system

Disadvantages

. Pumping efficiency should always be high, which is practically impossible.
. Different methodologies should be adopted for different shapes and sizes of the buildings.

unit : II

Ventilation and Refrigeration

Requirements, Principles of natural 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.

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① **Briefly Explain about ventilation**

The removal of all vitiated air from a building and its replacement with fresh air is known as ventilation

Factors affecting Ventilation

- Air changes
- Humidity
- Quality of air
- Temperature
- use of building

Ventilation Requirements

- 2 types

i) Health

ii) Thermal Comfort.

Health or permanent Ventilation requirements

- 4 types

i) Depletion of oxygen content

ii) Bacteria Concentration

iii) Removal of vitiated air

iv) Removal of odours

i) Depletion of oxygen content

It can play only a very minor role in the ventilation design of building

ii) Bacteria Concentration

minimum ventilation Standards is the elimination of the risk of infection by air borne micro organisms

iii) Removal of vitiated air

The removal of air polluted by noxious or hazardous gases, vapours, dust and other contaminants produced by certain industrial processes generally requires special attention.

iv) Removal of odours

. The presence of odours in a room very often induces a feeling of stuffiness and discomfort.

. It is especially noticeable to people entering such a room from a fresh atmosphere.

Comfort or occasional ventilation requirements.

. 3 types

i) Removal of excess heat
ii) Air movement for body cooling
iii) Ventilation for cooling or heating of structure.

i) Removal of excess of heat

. Excess heat liberated with in occupied spaces combined with the net heat gain through the various structural elements, particularly in summer, all excess of heat be removed by Ventilation.

ii) Air movement for body cooling

High air movements is also desirable under warm conditions for body cooling purposes.

iii) Ventilation for cooling or heating of structure

. This can be achieved particularly in more massive structures in warm arid climates.

Types of ventilation

. Two types

i) Natural ventilation
ii) Mechanical or artificial ventilation

Principles of Natural Ventilation

. 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 radiators are situated below the still level of the windows and they extend for the full length of the window
· windows, deflectors and radiators should be properly manipulated.
· The exhaust duct is provided near the ceiling of the opposite wall.
· more or less like a chimney.
· windows open from bottom and the deflectors may be curved vanes.
· The outside air is cooler than the inside air.

b) Mechanical or artificial Ventilation

Five methods of artificial Ventilation

i) Exhaust System
ii) Supply System
iii) Combination of exhaust and supply System
iv) Plenum Process
v) Air - Conditioning

Ventilation Measurements

Determination of Ventilation rate

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

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

Wind Action

$$Q = KAV$$

where

Q - the rate of air flow in m^3/hr
K - coefficient of effectiveness
A - free area of inlet openings in m^2
V - wind speed in m/hr

Stark Effect

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

where

Q - the rate of air flow in m^3/hr

A - free area of inlet

h - Vertical distance between inlets and outlets

tr - average temperature of indoor air at height h

to - temperature of outdoor air

Infiltration

It is the random flow of air through unintentional openings (leaks / cracks) driven by wind and difference in pressures.

infiltration can be calculated by using

i) air change method

ii) Crack method.

Crack method

$$V = C(\Delta P)^n$$

where

V - Volume flow rate of air

C - flow coefficient

ΔP - Pressure difference.

Design for Natural Ventilation

i) By wind action

- Inlet openings in the building should be well distributed and should be located on the windward side at a low level.
- The outlet openings should be located on the leeward side near the top.
- The incoming air stream is passed over the occupants.
- when outlets serve also as inlets they shall be located at the same level.
- Inlet opening should not be obstructed by adjoining buildings, trees, sign boards or by partitions inside the path of air flow.

- Maximum flow per unit area of openings is obtained by using inlet and outlet openings of nearly equal areas.
- when the stream of wind is quite constant and dependable, the openings may be readily arranged to take full advantage of the wind.

2) Stack effect -

Natural ventilation by stack effect occurs when air inside a building is at a different temperature than air outside.
- The outside air will tend to enter through openings at low level
- The warm air will tend to leave through openings at high level.

(2) write short notes on Air conditioning

Air conditioning is required for human comfort.

Definition :

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

Principle of Air-Conditioning

The air conditioner continuously draws an air from indoor space and cools it by the refrigeration principle and discharges it back into the same indoor space.

Classification of Air conditioning Systems

i) Comfort air-conditioning
ii) Industrial air-conditioning

i) comfort air conditioning System

Comfort air conditioning system is classified into 2 types

a) Summer air - Conditioning

b) Winter air - Conditioning

c) Year around air Conditioning

a) Summer air conditioning System

During summer the temperature is high and hence the air Conditioning system involves cooling and dehumidification

b) Winter air Conditioning System

During winter, atmospheric temperature is quite low and hence air conditioning involves heating and humidification to provide comfort.

c) Year around air Conditioning

Year around air conditioning system has both summer and winter air conditioning systems.

- one part of the system works in summer and other in winter.

ii) Industrial air conditioning System

To provide the environment with the required temperature and humidity, according to the applications

Classification of air conditioning based on the equipment arrangement

i) Unitary air conditioning :

Small capacity, used for air conditioning of rooms, small offices.

ii) Central air conditioning

Large capacity, used for air conditioning of large commercial buildings.

General principle of Air Conditioning

- Sucking the air through the filter media
- Cooling the air in summer and heating it in winter
- For using the processed air into the rooms or space for proper circulation through grills.

(3) Discuss about Window air conditioner (Room air conditioner)

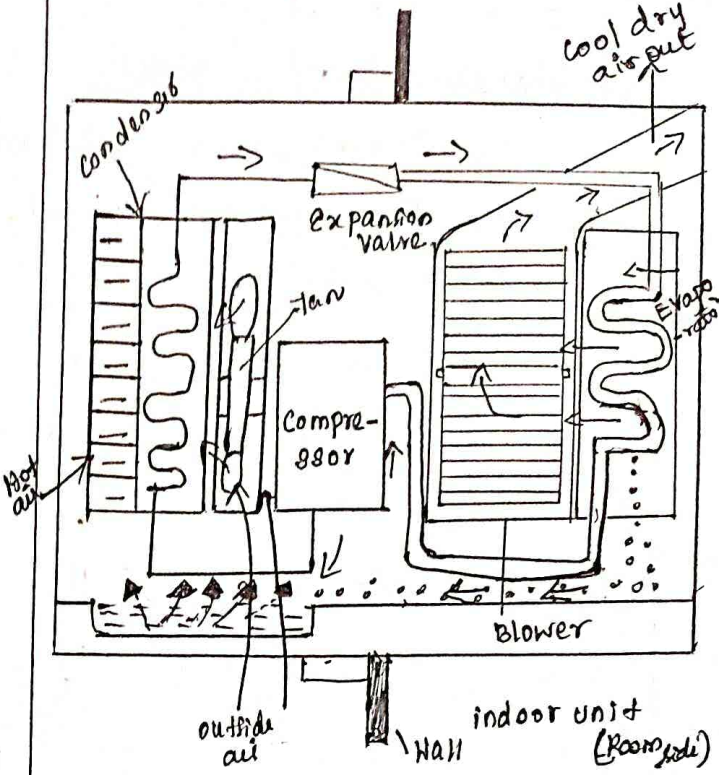
Window air conditioner is also known as room air conditioner.

Construction

- Main components of window air conditioner
  - i) Compressor
  - ii) Condenser
  - iii) Air filter
  - iv) Evaporator
  - v) Motor
  - vi) Fans
  - vii) Thermostat
- Indoor unit consists of an evaporator, air, filter, motor driven fan, control panel, trays etc
- Outdoor unit consists of a compressor unit, condenser, trays and motor driven fan.
- All the components are enclosed in a single unit.
- It follows the vapour compression refrigeration system.

Working

- Evaporator fan sucks the air
- The liquid refrigerant picks up heat from the room air.



- Cool air brings down the temperature and humidity levels in the room.
- provides comfortable conditions.
- Compressor compresses the low pressure vapour refrigerant coming from the evaporator.
- It converts refrigerant into high pressure vapour refrigerant
- The high Pressure vapour refrigerant is then passed into the condenser where it is cooled.
- Cools the refrigerant to become liquid.

. The high Pressure low temperature liquid refrigerant from the condenser enters the capillary tube.
. The low temperature refrigerant from the tube passes to the evaporator coil.
. In evaporator, the liquid refrigerank picks up heat and gets vapourised. This cycle repeats again and again.
. Unit stops automatically.

Advantages of the window air Conditioner

. For each unit, an individual temperature control device is provided.
. For air distribution, ducts are not required.

Disadvantages of the window air conditioner

. The unit is installed outside the wall.
. This unit has a fixed air quantity.

(4) Write notes on Packaged air Conditioner

. It is a bigger version of the window air conditioner.
. It has a higher cooling or heating capacity.
. It is usually able to cool an entire house or a commercial building.

Components

. Compressor
. water cooled or air cooled condenser
. Electrical panel
. Thermostatic expansion valve
. Air filter

Types

a) Packaged air conditioners with water cooled condenser
b) Packaged air conditioners with air cooled condensers.

Construction

. Condenser is cooled by the water.
. Condenser is of shell and tube type.
. Refrigerant is flowing along the tube side and the cooling water is flowing along the shell side.

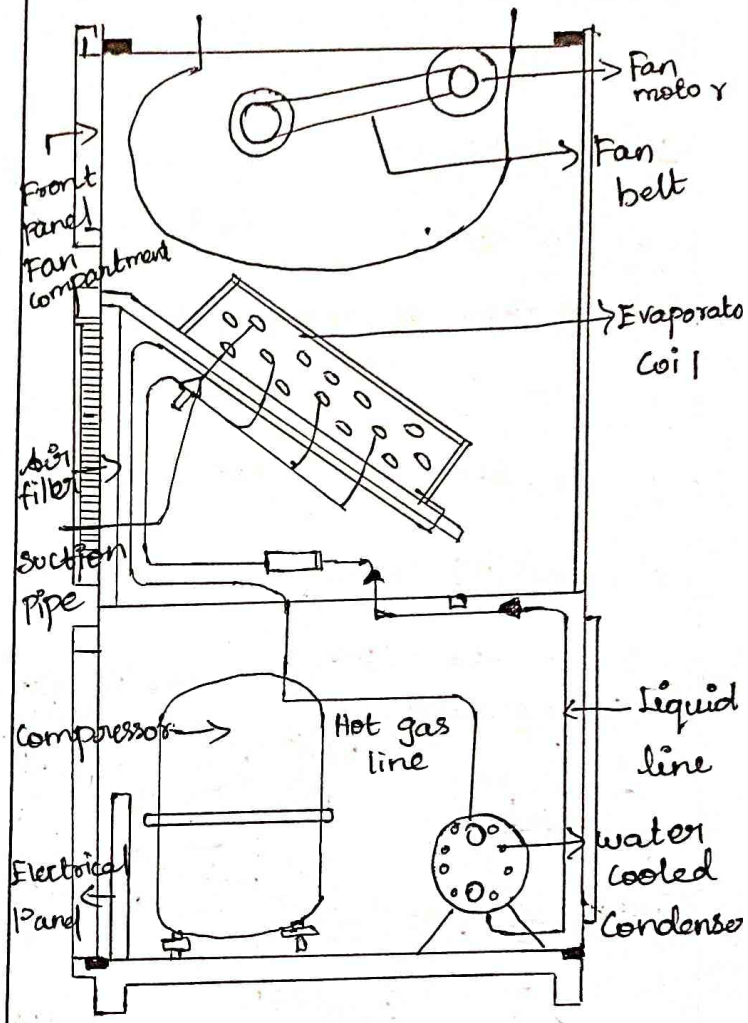
. Water cooled condenser, the compressor is located at the bottom along with the condenser.
. Water is supplied continuously for the functioning of the air conditioning system.
. The centrifugal blower has the capacity to handle large volume of air required for cooling a number of rooms.

Working

. Evaporator fan suck the air
. air is passed through the refrigerant distribution unit
. refrigerant picks up the heat
. air is further cooled by the compressor.
. Cool air is distributed to the room.
. Condensor of the refrigeration system is cooled by circulating the water.

Advantages of Package type Air conditioner

. Installation and assembly labour charges are less
. Duck work is eliminated
. Easy maintenance.
. Individual room control is possible.



Disadvantages of Package Air conditioner

. More noisy operation
. Leakage Problem
. Vibrations are more as compared to other unitary systems.

(5) Explain about chilled water plants

Principle

Chilled water plants, the refrigerant first chills the water, which in turn chills the room air

Construction

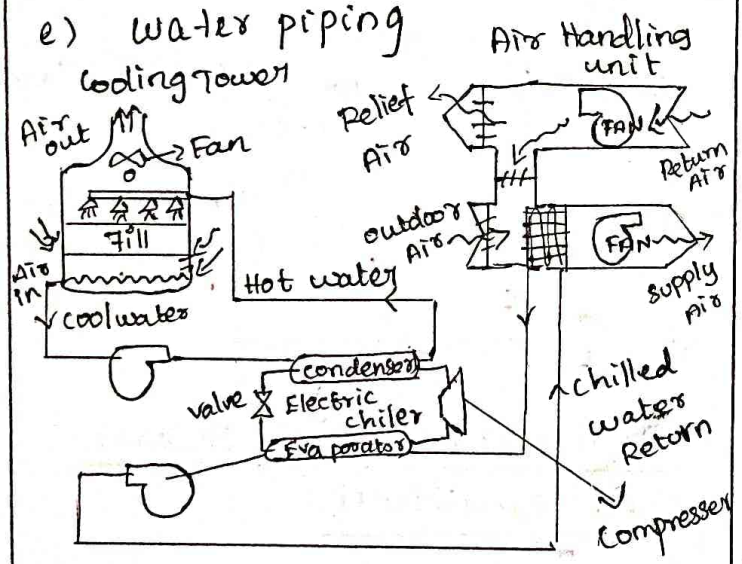
a) chiller

b) chilled water circulation pumps

c) condenser water pumps

d) cooling Tower

e) water piping



Working

. Ordinary water or brine solution is chilled to very low temperatures of about 6 to 8 degree Celsius by the refrigeration plant.

. air handling units are installed.

. The chilled water flows through the cooling coil.

Advantages

. High energy efficiency

. Easy controllability

. Longer life

. Very less space is used

Disadvantages

. More costly to install

. More complicated to operate

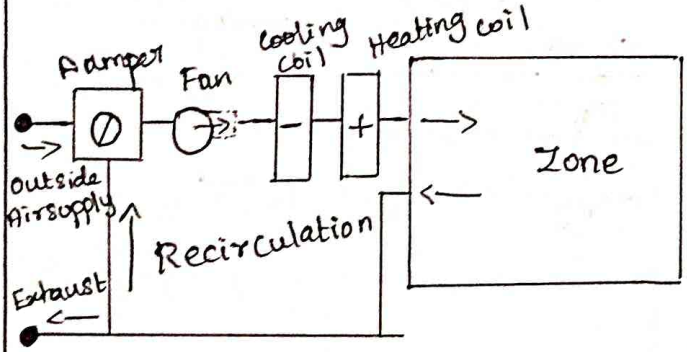
(6) Explain about fan coil systems

Definition

A fan coil unit (FCU) is a simple device consisting of a heating and/or cooling heat exchanger or coil and fan

Construction

- outdoor air mixer
- fan
- heating coil
- Cooling coil



Working:

- A fan coil unit contains a fan which draws the air into the unit then blows it over a cooling or heating coil.
- The air comes out of the FCU either cooler or hotter than outdoor.
- FCUs generally have a chilled water coil for cooling and a hot water coil or an electric heating for heating element.

Types of fan coil unit

i) Two pipe fan coil units

- Have one supply and one return pipe.
- The supply pipe supplies either cold or hot water to the unit depending on the time of year.

ii) Four-pipe fan coil units

- Two supply pipes and two return pipe.
- Allows either hot or cold water to enter the unit at given time.

Advantages

- Relatively low cost of Standard units
- Simple Control System

Disadvantages

- Limited control of fresh air input
- Limited ability to control air distribution
- Limited flexibility with standard units.

(9) Discuss about Water piping

Heating, Ventilation and air Conditioning (HVAC) is the technology of indoor and vehicular environmental comfort

- 2 types

i) 2-pipe HVAC system

ii) 4-pipe HVAC system

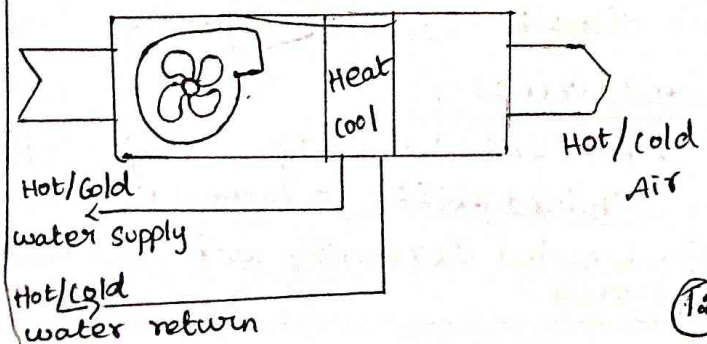
1) 2-pipe HVAC System

- one that uses the same piping alternately for hot water heating and chilled water cooling.

4-Pipe HVAC System

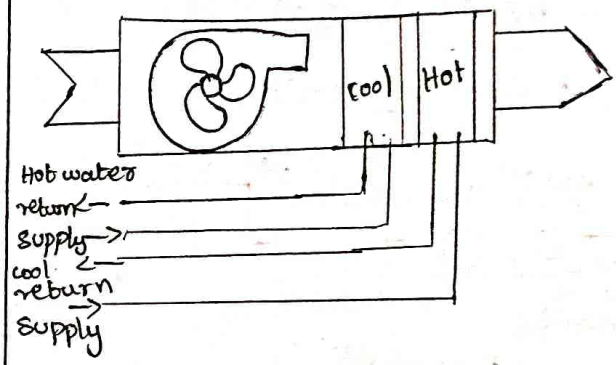
- Have seperate heating and cooling fan coil units and seperate pipes for heating and cooling.
- Hot or chilled water is always available.

2-pipe HVAC system



- Single water coil connected to two pipes.
- Fan coil cannot cool and heat at the same time is dependent of the actual mode of the building.
- Changeover sensor, to determine the mode of the system.

4-Pipe HVAC System



- Consists of two seperate cooling and heating water coils.
- Each coil has its own set of pipes and valve
- fan coil cool and heat at the same time, not dependant of the actual mode of the building.

- 4 pipe fan coil can also use a chill water coil and an electric or gas heater

Advantages of 4-Pipe HVAC

- Four pipe systems have seperate heating and cooling fan coil units and seperate pipes for heating and cooling.
- The system can immediately change over from heating to cooling mode.
- Less time consuming to switch over.
- Four pipe systems can cool some rooms while heating others.

Disadvantages of 4-Pipe HVAC

- They are more expensive to install and maintain
- They are congestion due to the increased piping.

(8) Discuss about cooling load

Definition :

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 refrigerating equipment.

Components of a cooling load

i) Sensible heat gain

Sensible heat gain is due to the direct addition of heat to the enclosed space.

- The heat flowing into the building by conduction through exterior walls, floor, ceilings, doors and windows.
- The heat received from solar radiation.
- The heat gain from the work
- The heat liberated by the occupants.

ii) Latent heat gain

An addition of water vapour to the air in enclosed space results in latent heat gain.

- The moisture in the outside air entering by infiltration
- Condensation of moisture from occupants.
- Condensation of moisture from any process such as cooking foods which takes place within the conditioned space.

Factors influencing cooling load

- Day time heat gain:

how much thermal heat your home gains throughout the day.

- The orientation of our home.

our home faces plays a large role in daytime heat gain

- Levels of insulation from top to bottom.

Insulation plays a large role in stopping heat transfer

- Floor plan

will conduct cool air very differently from one that has many closed rooms and walls.

- Number and types of windows and doors

insulated windows and doors have a big impact on retaining the cool air in our home.

- Number of stories:

warm air rises, so its important factor in the number of stories of our home.

- Number of occupants

People generate heat, which will affect the cooling in our home.

- Square footage

Size relates to the amount of space our cooling needs to adequately cover.

(9) Briefly discuss about Air Conditioning Systems for different

Types of buildings

Types of Air Conditioners

1. Window Air Conditioning System
2. Split Air Conditioner System
3. Central Air Conditioning Plants
4. Packaged Air Conditioners.

i) Window Air Conditioner

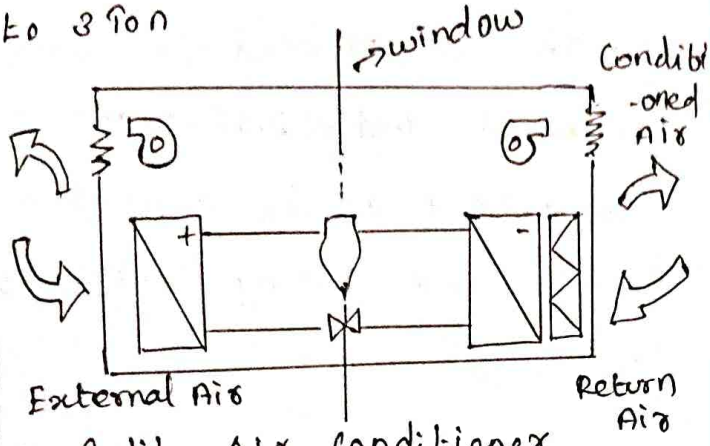
These air conditioners are also known as unitary air conditioning systems.

- window air conditioner is the most commonly used air conditioner for single rooms.

Components

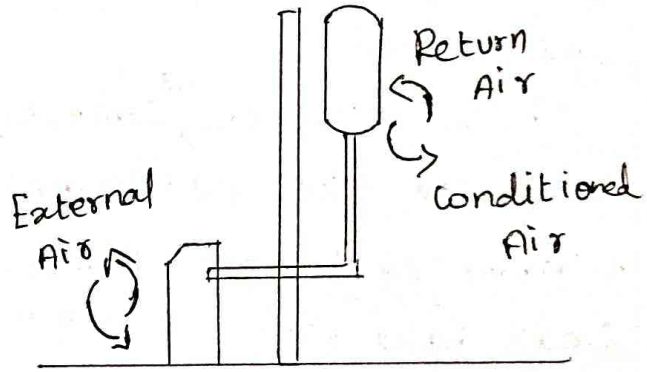
- Compressor
- Condenser
- expansion valve or coil
- evaporator
- cooling coil

- The device is very easy to install and can be used in almost any room that has a window.
- Room air conditioners are generally available in capacities varying from about 0.15 Ton to 3 Ton



2. Split Air Conditioner

- Most popular air conditioning systems in the world.
- It is also known as Ductless Air Conditioning units.
- Split air conditioner comprises of two parts
  - a wall mounted indoor unit
  - an exterior component.
  - outdoor unit includes components like the compressor, condenser and expansion valve fitted outside the room.
  - The indoor unit comprises the evaporator or cooling coil and the cooling fan
- Indoor unit sucks in hot air from the room and cools it before blowing cool air back into the room.
- Outdoor unit cools the refrigerant first, before transporting it to the secondary units indoors.
- Two units are connected by electrical cables and metal tubes carrying the refrigerant.
- A split air conditioner used to cool one or two rooms



Advantages

- Noiseless operation
- Less vibration
- Better circulation of air
- No necessity of wall opening.

Disadvantages of Split Air Conditioner

- High cost of unit
- more leakage
- Control over operation is difficult.

Applications of Split Air Conditioner

These are preferred for offices, schools, auditoriums.

3) Packaged air conditioner

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

Components

Compressor
Condenser
expansion valve
evaporator

- Cooled air is thrown by the high capacity blower and it flows through the ducts
- the compressor and condenser are housed in one casing.
- The compressed gas passes through individual units, comprised of the expansion valve and cooling coil, located in various rooms.

4) Central Air Conditioning System

- Central air conditioning is used for cooling big buildings, houses, offices, entire hostels, gyms, movie theaters, factories etc.
- Very expensive
- high velocity or low velocity

5) Portable Air Conditioner (localized cooling requirement)

- Next generation of window units.
- takes air from the room and cools it, then directs it back into the room.
- Portable air conditioners are designed to cool only one room.

· Easy to install, Versatile and an affordable option.

6. Hybrid Air Conditioning System - A New Development of Energy Conservation

An air conditioning system should provide comfort air conditioning operating as

i) evaporative cooling mode during hot-dry climate

ii) Conventional air conditioning mode during hot-humid climate, in order to conserve energy.

Like hybrid cars, hybrid heat pump systems alternate between burning fossil fuels and using electricity to run.

(10) Write about Protection against fire to be caused by A.C. Systems-

A.C. Systems

Components

i) Refrigeration System - Electric motor driven Compressor

ii) Air Circulation System - Fan motor and pump etc

iii) Electrical Control System

The current through the Fan Coil Unit (FCU) on stand by mode may cause fire in A/C Systems.

Fire Related units of AC

i) Condensing unit outer part of Split AC

2) Fan Coil Unit (FCU) : inner Part of Split AC

3) Isolator

Common Causes of AC fires

· Dust or Contamination in the airflow path can settle over electrical components.

· Allowing combustible materials such as paper, an accumulation of leaves and other debris

· In compressor and fan motors due to bearing frictions excessive temperature rise may also occur.

· Motor capacitors can develop internal resistance over time and can cause sufficient heating to self-ignite.

- Poor or loose connection of the power cord with motor connector may result in over heating to set the air conditioner on fire.
- The air conditioner installed on combustible members too close to curtains, wood structure and other objects may cause fire.
- In summer if air conditioning condenser are in sunlight for long time its temperature may go up to above 40°C
- The non-stop operating of air conditioner may lead to overheating of compressor resulting in compressor burn down or circuit fire.

Protection

- Interior AC coils are to be cleaned and air filters are to be replaced regularly.
- Keep the space around your unit free and clear with any materials or debris at least 3 feet away.
- The poor and loose or long power connection needs to be checked and refixed.
- Avoid direct exposure of CU in a high temperature above 40°C.
- If you want to switch off the AC do it by switch instead of by remote.
- Small and handy fire extinguisher should deploy at every AC point at home as a compulsory.
- RCCB (Residual Current Circuit Breaker) should be fixed.
- Check and Maintain on regular interval by a qualified or Trained A/C maintainer.

Regulated fire protection systems

a) Alarm systems

A fire alarm system detects and alerts people when smoke or fire is present.

- The devices include smoke detectors, heat detectors, strobes, manual fire alarm station, fire alarm control panel etc.

b) Sprinkler System

A sprinkler system is a fire extinguishing system that most times uses water as the extinguishing agent. Sprinkler systems will help to control the fire.

c) Stand pipe system

. A stand pipe system is piping installed in a building that assists to transfer water to house connections located with in the building for fire fighting purposes.

. An external water spray system (EWSS) is a domestic external fire sprinkler system designed to protect homes from bushfires and wildfires.

Detectors :

In dwellings, smoke detectors are often stand-alone devices.

In non-domestic buildings, fire alarm system, incorporating one or more of the following automative devices

- Heat detector
- Smoke detector
- Flame detector
- Fire gas detector.

UNIT : III

Acoustics and Lighting Designs

Methods of sound absorptions - absorbing materials - noise and its measurements, sound insulation and its measurements, impact of noise in multistored buildings - visual field glare, colour - day light calculations - daylight design of windows, measurement of day light and use of models and artificial skies, Principles of artificial lighting supplementary artificial lighting.

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(1) Briefly explain about Sound Absorbing materials.

The special 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.

The important facts in connection with sound absorbing materials

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

. In hall, the speech can be heard clearly and music can be fully enjoyed.

. All the absorbing materials are found to be soft and porous.

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

. It should be remembered in a big hall, the audience is a major absorbing factor.

The requirements of a good acoustical material are as follows

- It should be easily available at a reasonable cost.
- It should be fire resistant.
- It should give pleasing appearance after fixing.
- It should be durable.
- High coefficient of absorption

Classification of Sound absorbing materials

- Classified into four categories

a) Porous absorbents

b) Cavity resonators

c) Resonant absorbing or Panel absorbers.

d) Composite types of absorbents -

a) porous absorbents

- when sound waves strike the porous material, a part of waves is reflected.
- Converted into heat energy
- reflected part is reduced in energy.

Examples

Soft plasters, rock wool, wood wool

b) Cavity resonators

- Chamber or container having a small opening.
- when sound waves enter the resonator, the waves are absorbed due to multiple reflections.

c) Resonant absorbents or Panel absorbers

- The absorbent materials is fixed on a framing with an air space between the framing and the wall.

Examples

Gypsum boards, Wood and hard board panels.

d) Composite absorbers

When the functions of all the three types described above is combined in a single unit, then it is known as composite absorber

Common types of sound absorbing materials.

i) Hairfelt

The average value of coefficient of absorption of 25 mm thick hairfelt is 0.60.

ii) Acoustic plaster

It includes granulated insulation material mixed with cement.

iii) Acoustical tiles

The absorption of sound is uniform from tile to tile and they can be fixed easily.

iv) Straw board

. Also be used as absorbent material.

v) Pulp boards

. Soft boards which are prepared from the compressed pulp.

vi) Compressed fiber board

. material may be perforated or unperforated.

vii) Compressed wood particle board

It provided with perforations and it can also be painted.

viii) Perforated Plywood

. generally suspended from the trusses.

ix) Wood Wool board

This material is generally used with a thickness of 25 mm.

x) Quilts and mats

These are prepared from mineral wool or glass wool and are fixed in the form of acoustic blankets.

(2) Describe the methods of sound absorption

. When a sound wave strikes one of the surfaces of a room, some of the sound energy is reflected back into the room and some penetrates the surface.

• The parts of the sound wave energy are absorbed by conversion to heat energy in the material.

• The level of energy converted to heat energy depends on the sound absorbing properties of the material.

• Room acoustics describe how sound behaves in a space.

• If the room has nearly no sound absorbing surfaces the sound will bounce between the surfaces.

. If the surfaces instead are covered with sound absorbing material, the reflected sound will decrease much quicker and the listner will listner will only hear the direct sound.

. The general sound level in the room will decrease.

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(3) Discuss about sound insulation and its measurement

The art of preventing the transmission of noise inside or outside the hall or rooms of a building is known as sound insulation.

Principle

Sound insulation is to suppress the noise.

Sound insulation measurement

• Sound is transmitted through most walls and floors by setting the entire structure into vibration.

• Vibration generates new sound waves of reduced intensity.

• The passage of sound into one room of a building from a source located in another room or outside the building is termed 'sound transmission'

• The sound reduction index is used to measure the level of sound insulation provided by a structure such as a wall, window, door or ventilator.

• The unit of measure of sound transmission loss is the decibel.

• There are two types of sound insulation in buildings. airborne and impact.

i) Direct sound transmission
ii) Flanking transmission
iii) overhearing
iv) Leakage

Methods of sound insulation

• 3 main categories

i) when the source of noise is in the room itself.
ii) when noise is air-borne
iii) when noise is structure borne

1) when source of noise is in the room itself

Following the methods of sound insulation are commonly used when the source of noise.

i) Improvement in working methods

a) A working method creating less noise may be adopted.
b) The machinery like type writers.
c) The engine should be fitted on the floor with a layer of wood or felt between them.

ii) Acoustical treatment

a) The wall floors and ceilings should be provided with sound absorbing materials.

b) The sound absorbing materials should be mounted on the surfaces near the source of noise.

c) The acoustical treatment of the room considerably reduces the noise level in the room.

2. When noise is air borne

- By avoiding opening of pipes and ventilators.
- By allotting proper places for doors and windows
- using heavy glass in doors, windows and ventilators.

3. When noise is structure-borne

i. Treatment of floors and ceilings with suitable sound absorbing material and antivibration mounts

ii) By using floating floors and suspended ceilings

iii) soft floor finish

2) using double walls with air space between them.

(4) Write a note on impact of noise in multi storeyed building.

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

i) Speech privacy

ii) Background noise

iii) Sound masking

iv) Orientation of buildings.

i) Speech privacy

It is an issue with in office building, including individual work space, inside conference halls and between offices.

ii) Back ground noise:

It can adversely affect the work space.

iii) Sound masking

Tradition al sound masking systems are located in loud speakers above the ceiling.

iv) orientation of building

a) a noise pattern can be more annoying in perpendicular rooms.

b) windows on perpendicular walls do not reduce noise as effectively as those on parallel walls because of the angle of sound.

- In this case, internal building noise from plumbing, boilers, generators, air conditioners and fans can be audible and annoying.

Improperly insulated walls and ceilings can reveal the sound of amplified music, voices, and noisy activities from neighbouring units.

Concluding Remark

Even our classrooms or halls for indoor games are based on the principles stated above.

- The reverberation time is a key factor in designing a good acoustical structure

(5) Write notes on a) visual field glare b) day light calculation or day light factor

a) Visual field glare

Glare is difficulty of seeing in the presence of bright light such as sunlight or artificial light.

Types of glare and its remedies

1. Direct Glare
2. Reflected Glare
3. Disability Glare
4. Discomfort Glare
5. Distract Glare

1. Direct Glare

It is caused by bright areas such as luminaires, ceilings and windows are directly in the field of view.

Remedy: The solution for this type of glare is to avoid exposed to bright sources directly.

2) Reflected Glare

Glare from specular reflections of high brightness of polished or glossy surfaces and can

result in completely blocked vision is called reflected glare.

Remedy: It can be reduced by using polarized lenses.

3. Disability Glare

It is the reduction in visibility caused by intense light sources in the field of view

Remedy: The solution for this type of glare is to fix photo chromic lenses.

4. Discomfort Glare

It occurs due to changing light conditions and can cause squinting, eye fatigue or may even make eyes water

Remedy: The photochromic lenses can eliminate this type of glare.

5. Distract Glare

The kind of glare may cause eye fatigue, annoyance and distraction. It is also experienced at night around headlights or street lights.

Remedy:

An anti reflective treatment is the solution for this Problem.

Factors affecting Visibility

1. Reduction of brightness of the scene by constriction of the pupils.
2. Reduction in contrast by scattering light by particles in the air.
3. Bloom surrounding objects infront of glare.

Methods to reduce glare

- Sunglasses are often wore to reduce glare
- An anti-reflective coating of an eye glass reduces the glare at night
- Some types of eyeglasses can reduce glare due to the imperfections on the surface of the eye

Measurement of glare

Glare is typically measured with luminance meter or luminance camera

Unified Glare Rating (UGR)

It is a measure of the glare in a given environment.

$$UGR = 8 \log \left[\frac{0.25}{L_b} \sum_n \left(\frac{L_n^2 \omega_n}{P_n^2} \right) \right]$$

where

L_b - background luminance

L_n - luminance of each light source numbered

ω_n - solid angle of the light source seen from the observer

P_n - Guth position index.

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ii) Day light calculations

The amount of daylight received into an indoor space or room is defined as a day light factor. It is the ratio between the measured internal and external light levels.

Daylight factor

$$DF = \frac{E_i}{E_o} \times 100 \ (\%)$$

E_i - illuminance due to daylight at a point on the indoors working plane

E_o - Simultaneous outdoor illuminance on a horizontal plane

. 3 possible paths

i) Sky component (SC) :

Light from the patch of sky visible at the point considered.

ii) Externally Reflected Component (ERC)

Light reflected from opposing exterior surfaces and then reached the point.

iii) Internally Reflected Component (IRC)

Light entering through the window but reaching the point only after reflection from internal surfaces.

The sum of three components

$$LUX = SC + ERC + IRC$$

---

(6) Write short notes on :- Daylight Design of Windows :- Heatwave & daylight-

Daylighting design of window is the practice of placing windows or other openings and reflective surfaces. so that natural day light Provides effective internal lighting.

Windows

- Window is used for allowing light, heat and sound.
- Double layered window is used to reduce noise, heat, cold and other environmental factors.

Preferred Window - Wall Ratios

WWR

For view and positive connection out of doors, a minimum 20 percent to 30 percent ratio of window area in wall area is preferred.

High windows

High continous windows are more effective than individual or vertical windows to distribute light deeper into space.

- The top of windows should be close to ceiling line.
- The bottom of windows should not be higher than 48 inches.
- The windows must be seperated into two horizontal strips.
- one strip can be placed at eye level for view and another strip to maximize daylight Penetration.

High Ceilings

More daylight savings are realized if ceiling heights are 100 feet or higher.

Light Shelves

The light shelves can be used between daylight window and view window.

Window and office placement

Daylighting is more cost effective if open plan work

stations are located on the north and south side of the building.

. The open configuration also absorbs less light.

. The inter reflections provide a more uniform distribution of light deep into the space.

Interior Sun control

Similar to exterior sun control, horizontal blinds on the south windows and vertical blinds on the east and west are most effective.

. perforated blinds and translucent shades may cause glare when hit by direct sunlight.

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ii) Measurement of Day light

Luminous flux and intensity

The amount of light being given off by a particular source in all directions is called luminous flux.

. Radiant flux is related measure that quantifies the total power of the light radiation from a source.

Illuminance

. In photometry, illuminance is the total luminous flux incident on a surface per unit area.

. The amount of light falling on a surface is illuminance

Luminance

It is a photometric measure of the luminous intensity per unit area of light travelling in a given direction.

. The S.I unit for luminance is called candela per square metre (cd/m^2)

. Luminance levels can be measured with a luminance meter.

. Using high dynamic range imaging techniques together with a digital camera and luminance mapping surface.

(4) write notes on i) use of models and Artificial skills ii) principles of Artificial lighting iii) supplementary artificial lighting

i) use of models and Artificial skills

Model studies can be used to predict daylight Penetration into any building.

Forms of artificial sky

- Two basic forms

i) Hemispherical artificial sky
ii) Rectangular artificial sky

ii) Principles of Artificial lighting

Artificial light is typically Produced by lighting systems that transform electrical into light.

i) Categories of light

- 3 categories

a) Direct
b) Reflected
c) Indirect.

a) Direct

Direct light is like the sunlight on a clear day.

b) Reflected

Second type is semi direct (or) reflected lighting. It is visible but brightness is less.

c) Indirect light

It is invisible but it falls on working area

Artificial light Sources

Five artificial light Sources

1) Incandescent lamp
2) Fluorescent tube
3) Compact Fluorescent lamp (CFL)
4) Discharge Lamp
5) Light Emitting Diode (LED)

i) Incandescent lamp

- Common electric source is an incandescent lamp.

.. This lamp consists of a filament made up of fine tungsten wire fixed inside the glass support produces light.

- different colour ranges is available.
- house hold use range from 40 to 100 W
- Low energy efficiency.

2. Fluorescent lamp

- Main form of lighting for offices and commercial buildings.
- gas discharge lamp
- Emits ultra violet radiation

3. Compact fluorescent lamp (CFL)

CFL is a fluorescent lamp and it is designed as a more efficient replacement for incandescent lamp.

- It works on the principle of fluorescent lamp.

4. Discharge lamp

The light is produced by the passage of an electric current through a gas or vapour

- Provides high luminous efficiency.

5. Light Emitting Diode (LED)

LEDs use semiconductors to convert electrical energy directly into light.

- highly efficient and long lasting.
- Two-lead semiconductor light source.
- LED torches are becoming very popular.

Forms of Artificial lighting

- Two forms

i) Indoor lighting

ii) outdoor lighting

i) Indoor Lighting

. Key part of interior design.

. The basic physical principles used in optical luminaire are reflection, absorption, transmission and refraction.

Types of Light fixtures

. Five types

1) Ambient
2) Task
3) Accent
4) Informational lighting
5) Decorative lighting

1) Ambient

. Also known as general lighting

. it radiates a comfortable level of brightness with out glare.

2) Task Lighting

. It provides sufficient light on to perform a task that requires more light than the ambient fixtures.

3) Accent lighting

. Sort of a directional lighting that adds drama to a place by creating visual interest.

4) Informational Lighting (Guidance lighting)

. It is designed to see our way safely.

5) Decorative Lighting

Light strips, pendants, chandeliers and sconces are all examples of light fixtures draw attention to themselves.

iii) Supplementary Artificial Lighting

Definition:

Supplementary artificial lighting and daylighting which are combined together to provide an even illumination

Explanation :

- The purpose of supplementing daylight with artificial light is to lit those building spaces where the daylight level is inadequate.
- In the case of multi-story buildings, the maximum number of floors can be accomodated with in a minimum building height.
- Large windows are likely to lead to conditions of sky-glare and excessive heat transfer.
- Interior parts of the room are lit permanently by electric lights to provide necessary illumination
- Factor ($DF_{average}$) in the room under consideration

$$EPSALI = \frac{\pi \times DF_{average} \times (\text{external illumination level})}{10\ (\text{lm/sf or Fc})}$$

PSALI - Permanent supplementary Artificial Lighting of the interiors.

PHYSICS FOR CIVIL ENGINEERING - PH3201

UNIT : IV

New Engineering Materials

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.

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① **Explain in detail about Composites.**

- Combination of two or more materials that are different in chemical Composition.
- Combination of various materials, such as plastics, metals, fibers or ceramics.
- Consists two parts
  - * matrix
  - * Reinforcements.

Classification of Composites

- fiber - reinforced
- Structural
- Particle - reinforced

fiber - reinforced

- Matrix is the medium or the substance in which the fibers are suspended.
- Matrix distributes stress across the fibers.
- Matrix also provides toughness to the fiber reinforced structure.

Role of matrix Materials.

- First applied load, it is sustained by the matrix phase
- Reinforcement takes up the bulk of the applied load.
- Matrix material be ductile
- Second function of the matrix is to protect the individual fibers from surface damage due to mechanical abrasion

or chemical reaction with the environment.

- Finally the matrix seperates the fibers.

Reinforced materials

a) Fibers

b) Particles

a) Fibers

i) Whiskers

- Very thin crystals with extremely large length to diameter ratios.
- Whisker materials include, graphite, silicon carbide, silicon nitride and aluminium oxide.

ii) Fibers

- Either Polycrystalline or amorphous materials having small diameters.
- Common fibers are Polymer aramids, glass, carbon, boron etc

iii) Wires

- Large diameters compared to fibers.

b) Particles

Particles having size of upto 1 μm.

Types of composites

Polymer matrix composites

- matrix material is polymer, reinforced by ceramic.
- Typical polymer matrix resins are epoxy, Polyster and thermo plastics.
- Reinforcements are glass, quartz fiber and kevlar.

Metal Matrix Composites

- Matrix is a pure metal or an alloy.
- Reinforcement is a ceramic phase.

Ceramic Matrix Composites

- Matrix and reinforcements are generally ceramics.

Fibre reinforced plastics (FRP)

- Consists of fibres in a Polymer resin matrix.

a) Glass Fibre Reinforced Plastics (GFRP)

b) Aramid Fibre Reinforced plastics (AFRP)

c) Carbon Fibre Reinforced plastics (CFRP)

a) Glass fibre Reinforced Plastics (GFRP)

- Least expensive of all the fibres.
- used glass fibre is E-glass
- Common polymer materials are Polyesters and Vinyl esters.
- Polysters are used for general structures.

Applications

used in automotive and marine bodies, leaf springs, pipes, storage containers.

b) Aramid fibre Reinforced Plastics.

- Light weight, high tensile strength and high impact strength are important.
- Provide resistance to creep and fatigue.
- Disadvantages of aramid fibre reinforced composites are their low compressive strength, moisture absorption and difficulty in cutting or machining.

Applications.

- used in bullet proof vests, sporting goods, Pressure vessels, missile cases etc.

c) Carbon fibre Reinforced Plastics (CFRP)

- Carbon fibres have the highest specific modules and specific strength.
- Retain high tensile modulus and high strength at elevated temperatures.
- Relatively inexpensive and cost effective.

Applications.

- used in sports and creational equipment, filament wound rocket motor cases, Pressure vessels, Commercial and military aircraft etc.

Processing of fiber Reinforced Plastics

The main steps in producing FRP with any method

i) Mixing the resin and activator.

ii) Placing the reinforcement with in the mould

iii) Impregnating reinforcement with resin.

iv) Dispensing resin into the mould.

v) Curing.

i) Open mould Processes

- Hand lay up process
- Spray up
- Structural laminate bag moulding
  - i) Pressure bag
  - ii) Vacuum bag
  - iii) Autoclave

ii) Closed mould Process

- Cold Press moulding
- Hot Press moulding
- Resin injection
- Injection moulding

iii) Other Process

- Filament winding
- Pultrustion
- Pulforming
- Thermoforming liquid injection moulding
- Blow moulding.

a) Hand laminating

- Technique uses open moulds
- open moulds are single cavity moulds.
- Hand laminating is a labour intensive Process which is difficult to control.

Advantages :

- Low capital investment
- No size limit
- Lot of flexibility

Disadvantages

- Depends on skill of the operator
- Production rate is low
- Control of thickness is a Problem
- only one moulded face.

b) Closed mould Process

- This process uses properly matched set of mould with Position location on closing.
- The moulds are mounted on a hydraulic press
- The reinforcement is placed on the mould.

Advantages

- Good surface finish is obtained on both side.
- Higher Production
- Accurate dimensions.

Disadvantages

- Size of the Part is limited Press size
- Lower fiber content

c) Filament Winding

- Production of simple hallow shapes and is particularly suitable

for Pressure vessels.

- The relative speeds of the mandrel and transverse can be changed to control the winding angle.

Advantages

- Mechanical properties are superior
- High Production rate
- Good control of fiber orientation
- Good control of thickness
- Good Internal finish.

Disadvantages

- Limited range of shapes

Applications

- Tanks, Pressure vessels, rocket motors, gas bottles, pipes etc

Advantages and Limitations of Composites

Advantages

- High strength, toughness, elastic modulus, fairly good fatigue and impact properties.
- Exhibit good corrosion resistance
- Easy and quick
- shape and size can be achieved with ease.

Limitations

- Polymeric composites cannot be used for high temperature application
- cost of composite is higher than many conventional materials

Applications of composites

- Commercial aircraft:

Used for conditioning duct, radar dome, landing gear door, floorings etc.

- Military aircraft:

used for speed brake, rudder turnion, forward fuselag, elevators etc.

- Missiles

used for remote piloted vehicles, filament wound rocket motors, wings motor cases etc.

- Space hardwares

used for antennas, support trusses, trusses for telescopes, storage tanks etc.

- Automobile and trucks:

used for drive shafts, bumpers, door and window frames, timing and V belts, derive chains etc.

(2) What are metallic glasses ? How are they prepared. Describe their properties and application.

Definition

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

Properties of Metals + Properties of Glass } = Properties of Metallic Glasses

Examples :

Alloys - Fe, Ni, Al, Mn, Cu, Cr

Metalloids - Si, Ge, As, B, P, C, N

Preparation of metallic glasses

i) Melt Spinning System (rapid quenching technique)
ii) Twin roller System
iii) Melt extraction System
iv) Sputtering

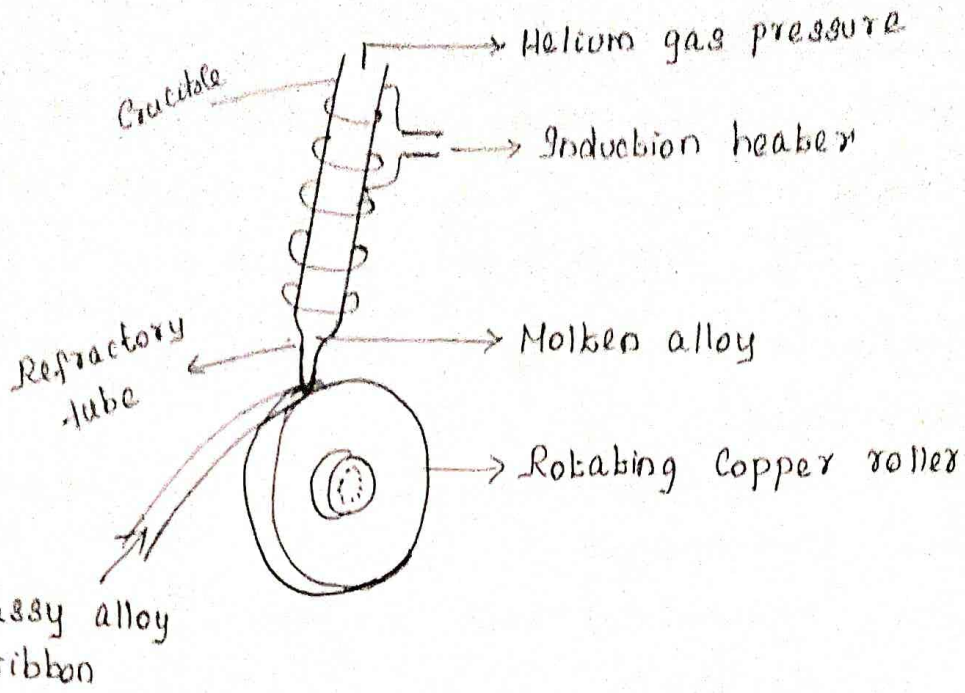
Melt Spinning System [Rapid quenching technique]

Construction

. A melt spinner consists of a copper roller over which a refractory tube with fine nozzle is placed.
. The refractory tube is provided with induction heater.

Preparation

. The metal alloy is melted by induction heating under inert gas atmosphere (helium or argon)



- The properly super heated molten alloy is ejected through the fine nozzle at the bottom of the refractory tube.
- The molten alloy falls on the copper roller which is rotated at high speed.
- The alloy is suddenly cooled to form metallic glass.
- A continuous ribbon of metallic glass be obtained.

Types of metallic glasses

Metallic glasses are divided into two parts

i) Metal - Metal metallic glasses

Combinations of metals only

Examples :

Ni - Nb, Mg - Zn

ii) Metal Metalloid metallic glasses

Combinations of metals and metalloids

metals : Fe, Co, Ni

Metalloids : B, Si, C, P

Properties of metallic glasses

- Metallic glasses have tetrahedral closely packed structure
- Metallic glasses are very high corrosion resistance.
- Have high workability and ductile.
- Electrical receptivity is very high. So eddy current is very small.
- Have very good magnetic property. They can be magnetized and demagnetized.
- They exhibit high saturation magnetization.
- They are highly reactive and stable. So they can act as a catalyst.

Applications of metallic glasses.

- Metallic glasses are useful as reinforcing elements in concrete, plastic and rubber.
- Materials are used in cores of high power transformers.
- Used to make different kinds of springs and razor blades.
- Highly resistively, they are used to make computer memories, magneto resistance sensors etc.
- Used in production of high magnetic fields.
- They are used in reactor vessels, surgical clips, marine cables etc.
- Metallic glasses are not affected by irradiation so they are used in nuclear reactors.

(3) Discuss in detail the characteristics of shape memory alloys and applications of shape memory alloys.

Definition:

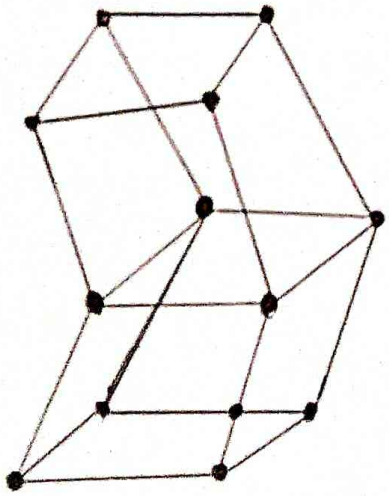
Shape memory alloys are the alloys which change its shape from its original shape to new shape and while heating or cooling it will return to its original shape called as shape memory alloys.

Phases of SMA

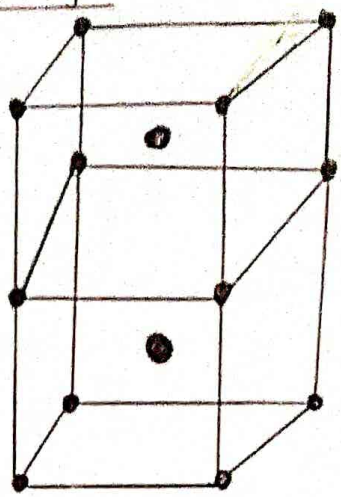
Martensite and austenite are the two phases that occur in SMA.

i) Martensite - It is soft and easily deformable phase.

ii) Austenite - It is a hard phase of high temperature.



Martensite



Austenite

Types of SMA

There are two types of SMA

i) one way shape memory alloys

ii) Two way shape memory alloys

i) one way shape memory alloys

A material which exhibits shape memory effect only when heating is called one way shape memory alloy.

ii) Two way shape memory alloys

A material which exhibits shape memory effect during both heating and cooling is called two way shape memory alloy.

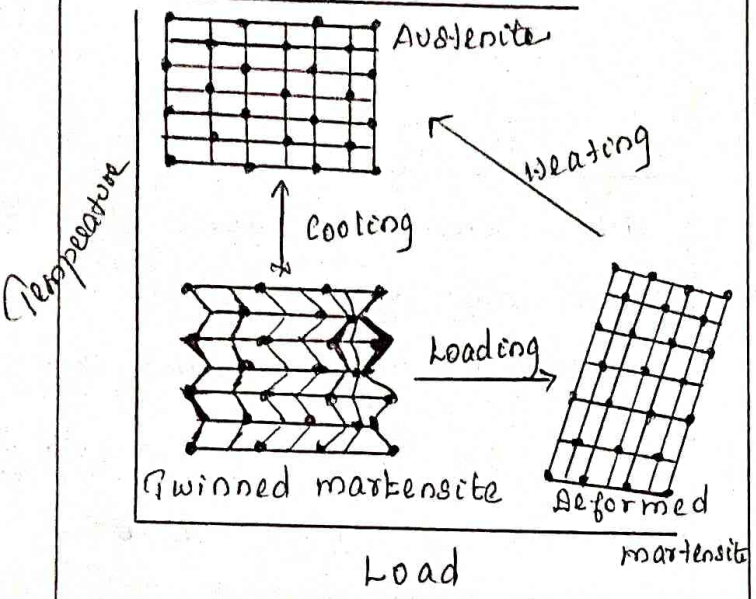
Examples of SMA

Ni-Ti - alloy (Nitinol)

Cu-Al-Ni-alloy

Characteristics of SMA

* Some metallic alloys which exhibit plastic nature when they are cooled to very low temperature. They return to their original shape, when heated to high temperature. This effect is known as shape memory effect.



* The SMA can be deformed with the application of a small force.

For example Ni-Ti alloy deforms to the martensite condition while cooling and regain its original shape in the austenite condition when heated.

* while loading, twinned martensite. when heated deformed martensite becomes austenite and upon cooling gets transformed to twinned martensite.

* The transformation occurs over a range of temperature.

Pseudo Elastic Effect

The phenomenon of deformation of a SMA on application of large stress and regaining of original shape on removal of the load is known as pseudo elasticity.

This pseudo elasticity is also known as super elasticity.

Applications of Shape Memory Alloy

- Shape memory alloy can be used to make toys and ornamental goods.
- (Ni-Ti) SMA's are used to make eye glass frames and medical tools.
- used in artificial hearts and in dental applications.
- SMA's are used as blood clot filter.
- Shape memory alloy closing and opening valves.
- used as couplings for metal pipes.
- used as a fire safety valve.

Advantages of SMA

- They have simplicity, compactness and safety mechanism.
- Have good biocompatibility.
- Mechanical properties are good
- They are non corrosive
- Safe and smart
- High power

Disadvantages of SMA

- Low energy efficiency
- Cost is high
- Limited bandwidth due to heating and cooling restrictions.
- Structural arrangements may some time get deformed.

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(4) Discuss about ceramics

Definition

Inorganic, nonmetallic materials that consists of metallic and nonmetallic elements bonded together primarily by ionic and covalent bonds.

e.g : Metallic Aluminium + Non-metallic oxygen atoms.

Types of Ceramics

i) Natural / Manufactured
ii) Functional classification
iii) Structural classification

i) Natural / Manufactured

Natural Ceramics

- Naturally occurring Ceramics
- Silica, Silicates, clay minerals
- Also called Traditional Ceramics.

Manufactured Ceramics

- Manufactured by artificial methods.

Example : Silicon Carbide

- Also called "Advanced Ceramics" or "High-tech Ceramics" or "fine-ceramics"

ii) Functional classification

* Abrasives - Alumina
* Pure oxide Ceramics - Magnesia, Alumina, Silica
* Fired clay Products - Bricks, Tiles
* Inorganic glasses - Window glass, lead glass

* Cementing Materials - Portland Cement, Lime..
* Rocks - Granites, Sandstones
* Minerals - Quartz, Calcite
* Refractories - Silica bricks

iii) Structural classification

i) Crystalline Ceramics - Atoms are arranged in a regularly repeating pattern in three dimensions (long range order)
Ex: Magnesia, Alumina

ii) Non-Crystalline Ceramics - Atoms exhibit only short-range order (irregular arrangement
Ex: Window glasses

iii) Glass bonded Ceramics

Fired clay Products - Crystalline Phases are held in glassy matrix.

iv) Cement

Crystalline and non-Crystalline phases

Ceramics are classified into two groups
i) Traditional ceramic materials
ii) Engineering ceramic materials

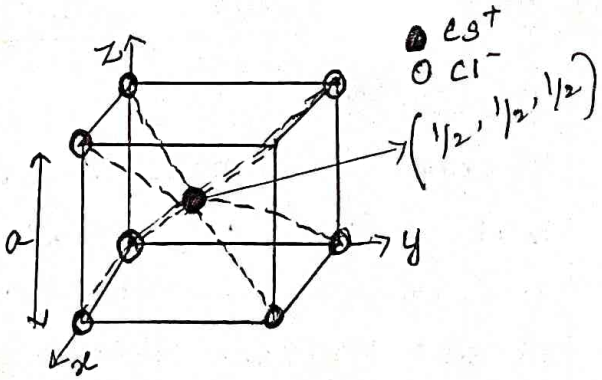
Other classification of ceramics.

i) Crystalline ceramics
ii) Non-Crystalline Ceramics
iii) Bonded ceramics

i) Crystalline Ceramics

• Simple Crystal structure as aluminium oxide, magnesium oxide etc.
• Silicon carbide is used for cutting tools.

Cesium chloride structure:



• Simple cubic structure
• Cesium chloride is a prototype
• Clorine ions are arranged
• Co-ordination number is eight

Rock salt Structure

• oxides and halides crystallize in the closed packed cubic structure
• Structure consisting FCC anions.
• Atomic coordination is 6.

Zinc-Blende Structure

- Two or more cubic ceramic compounds which have atoms in the 4-fold sites
- Atomic Coordination is 4.

Perovskite Crystal Structure

- Possible for more than one type of cation
- Example - Barium titanate ($BaTiO_3$) having both Ba^{2+} and Ti^{4+} cations.

ii) Non-Crystalline Ceramics

- Used for mirrors, optical lenses reinforcement fibres GRP and optical fibres for data transmission

Silicates and silica

- Silicates are composed of Silicon and oxygen, available in the earth's crust.

Example : rocks, soils etc

- A unit cell of silicate is a tetrahedron on which each atom of Silicon is bounded to four atoms of oxygen.
- oxygen atoms located on the edges of a tetrahedron Structure
- Silicon atoms are located at the centre.
- Silicate is treated as negatively charged.

Silica

- silica (SiO_2) is the simple form of silicate.
- Three dimensional network of tetrahedron.
- Three Polymorphic forms of silica
  i) quartz ii) Cristobalite
  iii) tridymite.
- Silica is used in the manufacture of different varieties of glasses.

Structure of glasses

- Solids have three-dimensional Periodic Structures, is a Crystalline Structure
- Materials, which do not have three dimensional structures but random structure, said to be amorphous or glassy.
- Many metal alloys, oxide Compounds and non-oxide compounds form glassy structure.
- Glasses are used for Containers and windows are silica glasses in which oxides such as CaO and Na_2O added.

iii) Bonded Ceramics

- Contain both Crystalline and non-crystalline materials
- Bound together by a glassy matrix.
- Group includes lining and Clay products.
- Bonded ceramics are used as electrical insulators, refractory for furnace, spark plugs etc.

Ceramic manufacturing methods

The various steps be
i) raw material processing
ii) fabrication
iii) densification
The different fabrication processes used for many years
a) Casting
b) extrusion
c) dry Processing

i) Slip Casting

- Casting is a familiar process used for ceramic forming.
- Raw materials are mixed with a suitable suspension of fluid like water in the range of 25-30 vol%.
- Suspension is known as slip.
- Slip is poured into a porus mould which is made of Plaster of Paris.
- The slip is absorbed into the mold
- Thickness of a solid layer depends on the length of time is mold.
- This process is continued until the entire mold cavity becomes solid
- This process is known as slip casting

Advantages

- ability to form intricate shapes at relatively low cost.
- The complex ceramic shapes which are produced using slip casting include turbine engine rotors, automobile wings etc.

ii) Isostatic Pressing

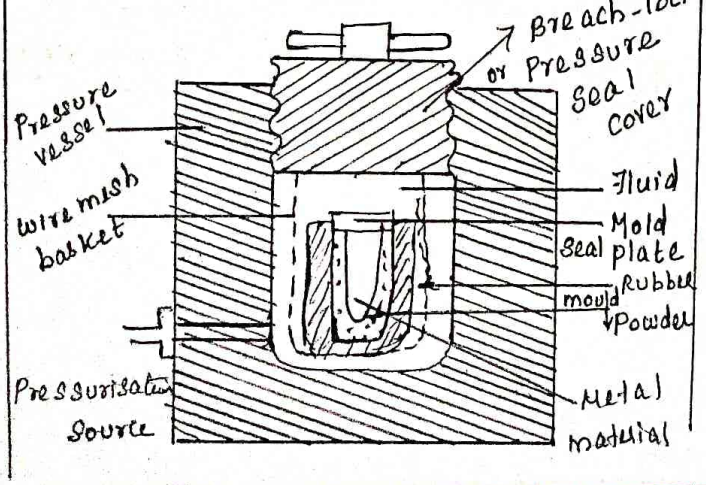
- In isostatic Pressing method, a uniform pressure is applied on all sides.
- Raw material is filled in rubber mold.
- It is sealed with plate and metal mandrel.

- The sealed rubber mold is inserted into liquid.
- Liquid is kept inside the Pressure vessel and non-Compressible.
- The top of the Pressure vessel is closed after inserting the rubber mold.
- A hydraulic pressure is applied to the liquid.
- Uniform pressure is experience by the rubber mould in all directions.
- The friction of rubber mould with the walls is eliminated
- By removing the pressure, the rubber mould is taken out.
- The compacted material is removed by removing the mould sealed plate and metal mandrel.
- The compacted materials are then subjected to densification

Two different methods of isostatic Pressing process

i) Wet bag

ii) dry-bag Processing



- In industry the production units normally operate at a pressure of 400 MPa or even less.
- This method is widely used for Production of variety of Products and sizes.
- The main disadvantages of this method are long cycle time, high labour requirements and low production rates.

Gas Pressure Bonding

Hot isostatic Pressure

The Hot Isostatic Press (HIP) uses the simultaneous application of heat and Pressure.

- The Process as HIPing and the product as being HIPed.

Temperatures can be upto 2000°C and Pressures are typically in the range of 30-100 MPa

- Argon is the most common gas used for HIPing, but oxidizing and reactive gases can be used.
- Two Variants of HIPing
- Encapsulated : using a deformable Container

- Not encapsulated ; shaped and sinter first
- HIPing is used for a wide variety of ceramic components The advantages of the HIPing process are becoming more important as interest in structural ceramics.

Thermal properties

- The most important thermal Properties of ceramic materials
  i) Thermal capacity
  ii) Thermal conductivity
  iii) Thermal shock

i) Thermal capacity

- The specific heats of fine clay bricks are 0.25 at 1000°C and 0.297 at 1400°C

ii) Thermal Conductivity

- Do not have enough free electrons
- The impurity content, Porosity and temperature decrease the thermal conductivity.

iii) Thermal shock

Lithium compounds are added in many ceramic compounds to reduce thermal expansion and provide excellent thermal shock resistance.

Mechanical properties of Ceramics

- Compressive Strength
- Shear Strength
- Tensile strength
- Transverse strength
- Torsional strength
- Modulus of elasticity
- Plastic deformation
- Toughness of ceramic materials.

Compressive Strength

Ceramics like brick, cement and glass are always used in the compression and not in tension.

Shear strength

High shear strengths and low fracture strengths are generally characteristics of ceramics.

Tensile strength

- Tensile strength in ceramics are theoretically high

Transverse Strength or modulus of rupture

- Transverse strength is difficult to ascertain in ceramic materials.

• Torsional strength :

Tensile and cantilever requirements will show the torsional strength of material

• Modulus of elasticity :

High modulus of elasticity ranging from 7×10^{10} to 42×10^{10} N/m^2

• Plastic deformation

Due to the restricted slip most of the materials does not permit plastic deformation

• Toughness of ceramic materials

Due to presence of covalent ionic bonding, ceramics have low toughness.

Electrical Properties

• Electrical properties depends upon composition, texture, size, density of material and also temperature and time.

• Ceramic materials are used as insulators, conductors, semiconductor and dielectrics. Ceramics are also used as ferroelectric and piezoelectric materials.

•Electrical properties of ceramics mainly depend on the following factors

i) Volume resistivity
ii) dielectric strength
iii) dielectric constant
iv) dissipation factor

Chemical Properties

Chemical resistance

• Organic solvents do not affect the ceramics.

• Glazed porcelain is used for chemical vessels.

• oxidic ceramics are completel resistant to oxidation

Ceramic fibers

• Refractory ceramic fibers

• Most ceramic fibers are white to cream in color and tend to be polycrystalines or Polly crystalline metal oxides.

Characteristics and advantages of Ceramic fibres

i) Low thermal conductivity

• Use of much thinner blankets possible for furnace lining.

ii) Weight

• Light weight refractory insulation.

iii) Thermal mass

- Heat storage is directly related to mass.
- Ceramic fibre is a low thermal mass material

iv) Thermal shock :

- Ceramic fibres are resistant to thermal shock.
- Rapid heating and cooling does not affect ceramic fibres.

v) Mechanical shock :

- Flexible
- resilent in most product forms

vi) Chemical attack

- Excellent resistance to chemical attack.

vii) Thermal Expansion

- Thermal Expansion is nil.

viii) Acoustic Properties

- Good acoustical properties in the frequency range of 300 - 3000 cycles/seconds.

ix) Health and Safety

- Inorganic and completely non-combustible
- Safe to handle and work.

Uses and Applications ..

- Ceramic fibers are used as insulation materials, ability to withstand high temperatures.
- Products are in the form of blankets, boards, felts, bulk fibers, paper, textiles etc
- High temperature resistant ceramic blankets and boards are used in ship building as insulation to prevent the spread of fires.
- Ceramic textile products are used flame curtains for furnace openings.
- Ceramic fibers are used as thermocoupling and electrical insulation.
- In automotive industry, Ceramic fibers are used in catalytic converters, heat shields, air bags etc.
- Commercial and domestic appliances using Ceramic-fiber insulation

The refractory fibres have found their applications in

a) Boiler and reformer lining

b) High temperature pipe insulation

c) Furnace door seals and lining

d) Stack lining - low flue gas velocity.

e) Repair of refractory furnace lining and roofs.

f) Packing material in glass tanks.

Piezo and Ferro Electric Ceramics

- Piezo electric crystals undergo a change in Polarisation, they are subjected to a stress.
- Pyroelectric crystal produces Polarisation due to application of electric field.

Hysteresis

Ferroelectric ceramic materials exhibit the hysteresis behaviour.

Ferromagnetic Ceramics

The magnetic ceramic materials are classified into three types

- Spinel
- garnets
- hexagonal ferrites

Hexagonal Ferrites

- Hexagonal ferrites are ferromagnetic materials.
- General formula for hexagonal ferrites is $BaO.6Fe_2O_3$.
- The structure of ferrites is in line with magneto Plumbite, and called magneto ferrites
- All magnetic spins are parallel
- Hexagonal ferrites are classified as isotropic and anisotropic ferrites
- Hexagonal ferrites is one of the important permanent magnets.
- Application like loudspeake and compact dc motors.

Oxide Ceramics

Two important oxide Ceramics

Alumina and Zirconia

High Alumina Ceramics

- High alumina ceramics contain 85% weight of Al_2O_3.
- Alumina is an aluminium oxide (Al_2O_3), which is the oldest engineering ceramic.
- Alumina is produced from bauxite ($Al_2O_3 \cdot 2H_2O$).

Characteristics of alumina

- More stiffer than steels.
- More stronger in Compression
- Very good environmental resistance
- ability to resist high temperature.
- High corrosion resistance
- High dimensional stability

Applications and uses

- Alumina is used as a refractory material for high temperature applications.
- Alumina makes an excellent high voltage insulator.
- Alumina based ceramic tools have very high abrasion resistance.
- Because of its high hardness, it is used as an abrasive material in grinding wheels.
- It is used as pump liners, check valves etc.
- Some applications found on medical use of teeth, bone filler and orthopaedic implants.

Unit : V

Natural Disasters

Seismology and Seismic waves - Earthquake 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.

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① Discuss earthquake ground motion with types, intensity and magnitude.

. An earthquake is a sudden trembling or shaking of the ground caused by movement of the earth surface.

. Sudden slipping of the resulting portion or fault slipping.

Focus

The place where the actual fracture occurs is called the focus of the earth quake. It is not a geometrical point but an extended region.

Epicentre

The point nearest to the focus on the surface of the earth is called the epicentre

Causes of earthquake

. Sudden movement of hot gases and magma.

. Volcanic activities

. Stress caused by water pressure in dams.

. Tectonic plates movement.

Types of earthquakes

i) Interplate earthquakes

ii) Intraplate earthquakes

i) Interplate earthquakes

Earthquake occur at narrow belts along tectonic plate boundaries. These earth quakes are known as interplate earthquakes.

ii) Intra Plate earthquakes

Earthquake occur with in a plate are known as intra plate earthquakes.

Classification of earthquakes

i) Shallow focus earthquakes.
ii) Intermediate focus earth quakes.
iii) Deep focus earthquakes.

i) Shallow focus earthquakes

Have depth of focus less than 70 km.

ii) Intermediate focus earthquakes

Earth quakes with depth ranging from 70 km to 300 km

iii) Deep focus earthquakes

Earthquakes having focal depth greater than 300 km.

Intensity

qualitative measure of the strength of an earthquake.

Magnitude of earthquake

Quantitative measure of the size of an earthquake.

Richter scale

The magnitude of earth quake is usually measured in Richter scale.

Effects of earthquake

i) Ground Shaking :

- Ground shaking is a term used to describe the vibration of the ground during an earthquake.
- Ground shaking is caused by body and Surface Seismic waves.
- Buildings can be damaged by the ground shaking.

ii) Liquefaction of ground

when water and soil are mixed, the ground becomes very soft and acts similar to quick sand.

iii) Ground displacement

If a structure is built across a fault, the ground displacement during an earthquake could seriously damage that structure

iv) Land Slides

Land Slides causes sliding of rocks and soil on the sides of an hilly area.

v) Flood

• An earthquake can cause damage to dams or levees along a river.
• The water from the river would then flood the area, damaging buildings and may be sweeping away.

vi) Fire

Fire can be started by broken gas lines and power lines or tipped over wood or coal stoves

vii) Tsunami

Tsunami are water waves that are caused by sudden vertical movement of a large area of the sea during an undersea earthquake.

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(2) Explain Seismic waves and Seismology

Seismic waves :

A number of different types of low frequency waves which are originated from the focus and travel through the earth surface are collectively called Seismic waves

Types of Seismic waves

i) Body waves

ii) Surface waves

i) Body waves

The waves which travel through the earth are called body waves.

• There are two body waves

i) Primary (P) or Compressional waves
ii) Secondary (S) or Shear waves

i) Primary or P waves

• These are longitudinal waves
• The particles of the earth vibrate about their mean position along the direction of the waves.
• The velocity of the wave is equal to $\sqrt{E/\rho}$

E - elongational elasticity
ρ - density

(3)

• Velociky found ko be 5 miles per second.
• waves also called as Compressional waves.

ii) Secondary or S waves

• These are kransverse waves.
• Parkicles of the earth vibrake ak right angles ko khe direckion of propagation of waves.
• S waves have velociky equal ko $\sqrt{n/\rho}$

n - modulus of elaskiciky

ρ - densiky

• Velociky of s wave is abouk 3 mdes per second.
• Also called as shear waves.

Surface waves

The waves which kravel along the earth surface are called surface waves.

i) Rayleigh waves
ii) Love waves

i) Rayleigh waves

• Thin layer in the close vicinity of the earth's surface.
• P and s waves, start from the epicenkre.
• Arrive ak a huge circle of the earkh.
• Due ko hekerogeneous character of earkh, each single wave starking from the epicenkre, splik inko a number of different sekes of waves.
• Each sek has different wavelength, velociky etc.
• They produce a series of oscillakion inskead of one single "kick or throw" ak, khe observing skakion.

ii) Love Waves

• Anokher kype of surface waves known as Love waves.
• The velociky of khese waves is less in the earth's crust.
• P and s waves, gek inkermingled with Rayleigh waves ko form a complicaked system of waves.
• These are called long L waves or main shock
• waves observed as a long series of oscillations.

Seismology

- Study of the seismic waves constitutes the science of seismology.
- It deals with the earth quakes and seismic waves

Seismograph

- A seismograph, is an instrument used to record the earth tremors or the seismic waves.
- The record of the vibrations called seismogram.

Construction and Working

- It consists of a mass attached to a fixed base
- During earth quake base moves.
- Mass is commonly transformed into an electrical voltage.
- The electrical voltage is recorded on paper, magnetic tape
- Record is proportional to the motion of seismometer.

Modern application of Seismology

i) Investigation of the nature of the interior of the earth.

ii) Prospecting for oils and minerals.

iii) Construction of quake-Proof buildings.

iv) Forecasting of the occurrence of earthquakes.

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(3) **Describe Earthquake site Effects.**

- Amplitude and the frequency content of the earthquake motion varies.
- Depend on the soil cover, underlying observation and topographical location.
- Parameters that govern, behaviour are known as impedance and absorption.
- The second parameter, absorption counteracts the increase in amplitudes.

(15)

• Absorption is the damping

• An elastic wave travels through a layered media, at the interface wave is transmitted and reflected.

• Impedance ratio α_z.

Impedance ratio is defined as

$$\alpha_z = \frac{\rho_2 V_2}{\rho_1 V_1}$$

ρ_1 - density
V_1 - wave velocity } Bottom layer

ρ_2, V_2 are the top layer.

• one dimensional wave Propagation given by

$$A_t = \frac{2}{1+\alpha_z} . A_i$$

A_i - Amplitudes of incident
A_t - transmitted waves.

Effect of site topography

The apex displacements is amplified by a factor of $2\pi/\phi$

ϕ - verter of the wedge.

Basin Effect

The curvature of the basin where the soft soil is deposite can trap the waves and amplify the motion experienced on the surface.

• Increase the duration of the earthquake motion.

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(4) Explain deterministic seismic hazard analysis and Probabilistic Seismic hazard analysis.

Seismic Hazard

Definition :

It is defined as any physical phenomenon such as ground shaking or ground failure that is formed by an earth quake. It may produce adverse effects on human activities.

Types of Seismic Hazard Analysis

- Two ways

i) Deterministically

ii) Probabilistically

i) Deterministic Seismic Hazard Analysis (DSHA)

- The DSHA approach uses the known seismic sources sufficiently near the site and available historical seismic and geological data.

Four Steps in DSHA

i) Identification and characterization of all sources.

ii) Selection of source - site distance parameter.

iii) Selection of the "Controlling earthquake"

iv) Definition of hazard using controlling earthquake.

- Capable of producing significant ground motion at the site.
- Selection of a source-to-site distance parameter for each source zone.
- Selection of the controlling earthquake generally expressed interms of ground motion parameter.
- Ground motion produced at the site by the controlling earthquake.

Advantages

- Peak acceleration, Peak velocity and response spectrum ordinates are commonly used to characterise the seismic hazard.
- DSHA appears very simple procedure.
- DSHA provides a straight forward frame work for evaluation of worst-case ground motions.

Disadvantages

- It provides no information on the likelihood of occurrence of the controlling earthquake.

Applications

- Nuclear power plants
- Large dam
- Large bridges
- Hazardous waste containment facilities.

Problabilistic Seismic Hazard Analysis (PSHA)

PSHA provides a frame work in which the uncertainties can be identified.

Four steps in PSHA

i) Identification and Characterization of earth quake sources.

ii) characterisation of temporal distribution of earthquake recurrence.

iii) Determination of grand motion

iv) computation of Probability of earth quake

i) Identification and characteristics of earth quake sources

- potential rupture locations.
- Earthquakes are equally likely to occur at any point within the source zone.

ii) characteristics of temporal distribution of earth quake recurrence

- Seismicity or temporal distribution
- maximum size of earthquake

iii) Determination of ground motion

- Produced at the site by earth quake in each source zone with the use of Predictive relationships.

iv) Computation of Probability of earth quake

- obtain the probability
- Mechanics of the Probability computations.

(5) Explain cyclone hazard with cause and effect. Write Preventive measures of cyclone.

Cyclones

Cyclones are huge revolving storms in the atmosphere with very strong winds circulating round a central area.

Types of Cyclones

i) Extra tropical cyclones
ii) Tropical cyclones

Cyclones that develop in the regions between the tropics of Capricorn and cancer are called tropical cyclones.

Effect of cyclones

- High pressure gradients
- Causes sea water to inundate low-lying area of coastal regions drowning human beings and livestock.
- A storm surge is an abnormal rise of sealevel near the coast.
- The cyclones erode beaches and embankments.
- Destroy vegetation
- reduces soil fertility.
- Very strong winds associated with cyclones may damage installations, communication systems etc.
- Due to cyclones lead to river floods

Cyclone Management

Preventive measures of Cyclone

- planting more trees on the coastal belt.
- Construction of dams, storm shelter and wind breaks.

Forecasting and Warning

- Minimizing the losses due to a cyclone.
- Advanced systems of cyclone forecasting are now available in almost all the developed Nations of the World.
- Warning should be issued to the government agencies and general public

Relief tasks

- Economic help and support by individuals.
- Community and government
- Awareness should be Spread at all levels of the community to prepare everyone for emergencies.

(6) Explain flood hazards. Mention the effects and methods of flood Prevention

Flood :

The accumulation of large quantity of water at a place or the flow of more water than that can be handled by the drainage of the area is known as Flood.

Factors resulting floods :

- Climatic conditions of the area.
- Nature of the collecting basin.
- Nature of the streams, soil and vegetative cover.
- Rate of melting of snow.
- Amount of rainfall received.

Types of floods

- 3 types

i) Flash flood

ii) River flood

iii) Coastal flood

i) Flash floods

- occur within hours of heavy rainfall.
- clouds, thunderstorms and tropical cyclones
- caused by dam failure or other river obstructions.

ii) River floods

- Caused by Precipitation over large areas or by melting snow
- cover or drain large geographical areas.
- The amount of flooding depends on factors such as ground conditions.

iii) Coastal floods

- associated with cyclonic activities such as hurricanes, tropical cyclones etc.
- Flooding in coastal river basins, similar to river floods.

Causes of Floods

- Heavy rain for a very short period result in floods.
- River can overflow their banks to cause flooding.
- Sea water can be carried by massive winds.
- Excess water can be released from the dam to prevent it from breaking and that can also cause floods.
- Heavy snow over the winter stays unmelted for sometime.
- ice suddenly melts, temperature rises, resulting in flow of water into places that are dry. This is called <u>Snow melt flood</u>.

Effects of Flood Hazards.

Effects on the economy, environment and people

Primary hazards :

- With greater velocities, flood streams are able to carry larger objects such as houses, bridges and automobiles.
- Human can get caught in the high velocity flood waters.
- Floods can cause erosion,

Secondary hazards

- Drinking water gets polluted if sewage treatment plants are in the flooded area.
- Contamination can result in disease and other health issues.

Tertiary or Long term Hazards

- Long term changes
- Destruction of wild life habitat.
- Sediment deposited during flooding may leave farm land in poor condition.

Methods of flood Prevention

- **Plantation on Slopes**

Plantation helps in regulating river flow and controls soil erosion

- **Drainage Management**

Improvement of channels by removing debris and sediments helps in regulating the rate of river flow

Flood plain Zoning

Dividing into different temporal plots, known as flood plain zoning.

Forecasting :

Possible damage can be minimized by forecasting the occurrence of floods and warning the people about the possible danger.

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(7) Explain fire hazards and fire protection

Fire Hazards

Fire hazards include all types of live flames, causes of sparks, hot objects and chemicals that are potential for ignition, or aggravate a fire to become large and uncontrolled.

Types of fire hazards

i) Exposure hazard

ii) Internal hazard

iii) Personal hazard

i) exposure hazard

- Fire spreads into a building through the open air from adjacent building or same building.
- The risk involved in such fire spreading is known as the exposure hazard.

ii) Internal hazard

- Causes damage or destruction of the building itself.
- Related to the fire load.

iii) Personal hazard

- Damage caused to the life is referred to as personal hazard

Causes and Effects of Fire

- Cooking accidents
- Smoking
- Electrical wiring
- Rubbish and waste materials
- Oil leakage
- Non-removal of dry grass and vegetation.

Effects of fire

i) Carbon monoxide

- oxygen from reaching the brain.
- Abundant of fire gases.
- Invisible and odourless.

ii) Carbondioxide

- Gas overstimulates the rate of breathing

iii) Hydrogen Sulphide

- Gas affects the nervous system.
- Pain in the respiratory system.

iv) Nitrogen dioxide

- Extremely toxic
- deadens the throat.

---

ii) Fire Protection

Fire protection is the study and practice of mitigating the unwanted effects of potentially destructive fires.

- Involves the study of the behaviour.
- Investigation of fire
- Deals with research and development, production
- Designed to maintain their durability.
- Apartments and buildings codes are required for fire resistant materials used in ceilings and walls.

Precautions for prevention of fires

a) Class A : ordinary material
Ex: wood, paper etc

b) Class B : Flammable liquids
Ex: oils and greases

c) Class C : Live electrical equipment

Precautions for Class A fires

- Glowing cigarette butts and matches shall not be thrown into waste baskets

or other places of fire hazard.

- Smoking and use of open flames shall be Prohibited where combustible material is kept.
- High standard of cleanliness shall be maintained.
- Trees and vegetation shall not be permitted to grow in the neighbourhood of sub stations.
- Precautions shall be taken to prevent heating of coal stacks, Spontaneous Combustion of coal, dust etc.

Precautions for class B fires

- oil filled containers and equipment in power houses, buildings, store room etc.
- oil filled equipment to prevent spread of spilled oil.
- Empty oil drums, boxes or other combustible material shall never be piled near storage oil tanks and oil filled equipment.
- Petroleum containers shall be labelled and kept securely stoppered.

Precautions for class 'C' fires

- Electrical equipment shall be installed, operated and maintained properly in a manner to eliminate arcs due to poor contacts.
- Flammable gases or material shall not be stored near electrical equipment
- Electric lamps shall not be surrounded by or laid on combustible material.
- Motors shall be equipped with over-current and under voltage protection to prevent excessive heating
- Battery rooms shall have no loose connections.
- Smoking shall be prohibited and combustible shall not be permitted to accumulate in the battery room.

(8) Describe Proofing of materials

Fire Proofing is a type of fire protection measure. It refers to the act of allowing materials to be more resistant to fire outbreaks.

Examples :

- Designed to resist burning
- Natural fibers like wool and cotton can also be treated with fire Proof chemicals.
- High demand for fire proof building materials such as dry wall, Paint, roofing materials and exterior sides.
- Fire Proof Paint available

Fire Proofing Properties of Common building materials

1) Stone :

- Bad Conductor of heat
- Non-Combustible building material.
- Stone is also disintegrate into small pieces when heated and suddenly cooled.

ii) Brick :

- Bricks are not seriously affected until very high temperatures of 1200°C to 1300°C are reached.
- Brick is a poor Conductor of heat.

3. Timber :

- The structural elements made of timber ignite and get rapidly destroyed in case of fire.
- Add to the intensity of fire.

4. Cast iron

- Structural material at present.

5. Glass

- poor conductor of heat
- Expansion due to heat is small.

6. Steel :

- Non-Combustible building material
- good conductor of heat
- rapidly heated in case of a fire

7. Aluminium :

- Good conductor of heat
- Poor fire resisting Properties.

8. Asbestos cement

- Non combustible building material

(8)

- High fire resistance

9. Concrete

- Bad conductor of heat
- Effective material for fire-resisting construction

(9) Discuss fire fighting Equipments

Fire fighting is the act of preventing the spread of and it extinguishes unwanted fires.

Fire fighting equipment

i) Water Extinguisher (Red body)

- used on class A fires
- It allows the user to direct water onto a fire from a considerable distance.
- Water is a conductor of electricity.

ii) Water Extinguisher with Additives (Red body)

- Suitable for class A fires
- Suitable for class B fires

iii) Powder Extinguisher (Red body with blue label/band)

- used on most classes of fire.
- Achieve a good "knock down"
- used on fires involving electrical equipment.

iv) Foam Extinguisher (Red body with cream label/band)

- used on class A or B fires.
- Suitable to extinguish liquid fires.

v) Carbondioxide (CO_2) Extinguisher (Red body with black label/band)

- Used on class B fibres.
- Suitable for fires involving electrical equipment, it is a non-conductor.

vi) class 'k' extinguisher (Red with canary yellow label/band)

- Suitable for commercial catering establishments with deep-fat fryers.

Water expelling extinguishers

a) Soda acid type
b) Gas pressure activated type

c) Constant air pressure type

Soda acid type is the most commonly used.

Soda acid type water extinguisher

Construction

The total liquid capacity of the body is filled to the specific level (9 litres)

- Plunger
- Acid phial
- Cage
- Nozzle
- Bottom handle
- Sodium bicarbonate solution

Working :

. When the plunger is struck, the acid phial (bottle) ruptures.

. The sulphuric acid and sodium bicarbonate solution react together to release carbondioxide (CO_2) gas.

. The CO_2 generated creates internal pressure which forces the water out of the extinguishers.

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(10) Write a note on fire safety regulation

Width of road :

. The road should be more than 12 m width.

. The road should be hard surfaced to carry the maximum weight of a fire engine

Entrance width and Height Clearance

. High rise building should have atleast 2 means of access

. Minimum width is essential to facilate free movement of fire units.

Setback or open spaces :

open space around residential buildings, is essential to facilitate free movement and operation of fire service vehicles.

a) Educational buildings

Except for nursery schools, the open space shall not be less than 6 metres.

b) Institutional buildings

open space shall not be less than 6m

c) Assembly building

Except infront, open space shall not be less than 6m. and front open space shall not be less than 12m.

d) Business Mercantile and storage building.

open space around the building shall not be less than 4.5 m

e) Industrial Hazardous building

, Minimum 4.5 m open space shall be kept around the building for the height upto 16 m.

- open space shall be increased by 0.25 m.

Car parking in setback / open spaces

If the setback area open spaces is more than 12m the provision for car parking can be done in the setback. open spaces at 6 m

Car Parking

- Car parking shall have to be done at the basement with provision for minimum 2 ramps one remote to other.

Staircases :

- Every high rise building should have minimum 2 staircases.
- Width of staircases varies from 1 m to 2m.
- For residential building width of staircases should be 1m.
- out of 2 staircases, 1 can be used as a fire escape staircase
- Width of fire escape should be minimum 0.75m.
- Number of staircases shall be given as per the travel distances
- Spiral staircase shall be provided upto 9m height.
- External staircase normally shall not be allowed.

Lifts

- Minimum 1 lift capable of carrying minimum 8 persons
- one lift shall be designed as a "fire lift".
- Fireman switch shall be provided for each lift.

- Lifts shall not be used as means of evacuation

Fire Alarm System

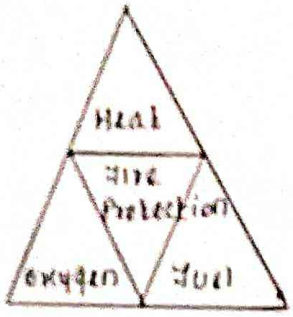
Automatic operated system shall be provided in the building.

Public Address System

- Every high rise building should have a public address system.
- Have 2 way communication to conduct evacuation in a systematic manner.

(ii) Discuss fire prevention and safety measures

Fire Protection Triangle - Heat, oxygen and fuel



- A fire needs three elements - heat, oxygen and fuel.
- With out heat, oxygen and fuel, a fire will not spread.
- A key strategy to prevent fire is to remove one or more of heat, oxygen or fuel

Heat :

- The heat must be controlled and kept away from fuel.
- Heat generated as by Product of a process must be removed Properly.

Heat Safeguards

- Control Sources of ignition
- Chimneys should be inspected and cleaned regularly.
- Ensure Cooking food is always attended.

Smoking

- Providing "no smoking" signs at appropriate locations.
- Ensure smoking areas are away from flammable materials.

Plant and Equipment

- Ensure all work equipment Protects against catching fire or overheating.
- Have electrical equipment Serviced regularly to prevent Sparks and fires.

Portable Heaters

- Do not use portable heaters unnecessarily.
- Should have emergency tip-over switches and thermostatic limiting controls.
- Do not use them to dry clothes.

Hot work

- Identify all hot works
- only allow hot work if no satisfactory alternative

use a hot work permit system including

- Fire resistant Protective clothing.
- clear responsibility
- Routine checking & supervision
- Prevent, suppress and control heat and spark

Electrical Safety

- Check electrical equipment and remove defective equipment.
- Ensure that electrical cords are in good condition.
- Plug appliances and lights into seperate electrical outlets.
- use extension cards safely.
- use only one device per outlet.

oxygen

- Main causes of fire and explosions when using oxygen

a) oxygen enrichment from leaking equipment.
b) use of materials not compatible with oxygen.
c) Incorrect or carless operation of oxygen equipment.

Oxygen Safeguards

- Equipment is leak tight and in good working.
- Check that ventilation is adequate.
- Always use oxygen cylinders
- Never use oil or grease to lubricate oxygen equipment.

Fuel :

- Flammable material.

Fuel safeguards

- Follow the authority's advice on LPG.
- Permit no timber lining on ceilings, corridor walls or stair ways.
- Provide gas detection equipment.