TUTORIAL - 2

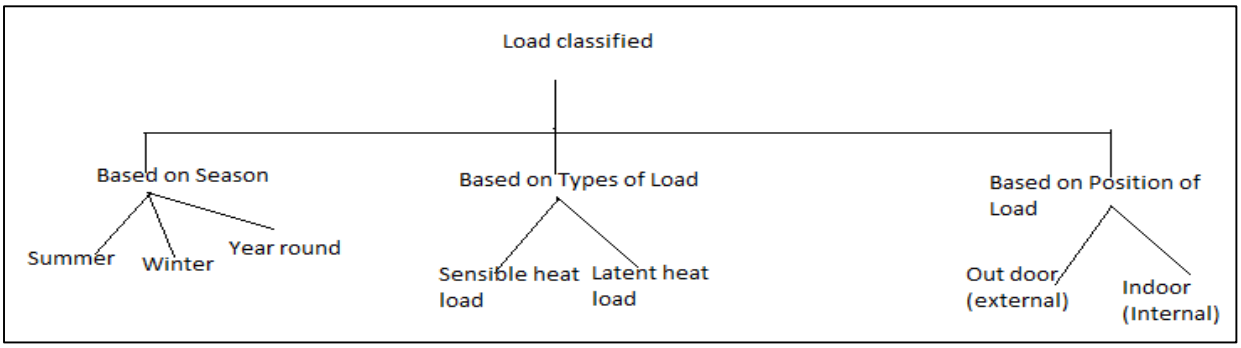
Thermal performance and heating-cooling

Load calculation of a building

1. Write Various Ways to Conserve Energy in Residential Buildings, Hospitals and Industries.

1) Seal exterior cracks/openings/gaps with caulk, gasketing, weather stripping.
2) Consider new thermal doors, thermal windows sand roofing insulation.
3) Install wind breaks with exterior doors.
4) Replace single pane glass with insulating glass.
5) Consider covering some window and skylight areas with insulations wall panels inside the building.
6) If visibility is not required but light is required, consider replacing exterior window with insulation glass block.
7) Consider tinted glass, reflective glass and shades for sunlit exterior windows.
8) Use landscaping to advantages.
9) Add revolving doors to primary exterior personnel doors.
10) Consider automatic doors, air curtains, strip doors etc., at high traffic passage between conditioned and non-conditioned spaces. Use self-closing doors if possible.
11) Use duck seals at shipping and revolving doors.

2. Which are the four basic loads considering for Heat gain/ Heat loss calculation? Explain also.



I. Based on season:

- **In Summer**:

1. Outer temperature is more than inner temperature.
   Tout > Tin
2. We have to produce cooling effect in building.
3. Amount of heat which must be removed/hours to produce or maintain the design.

- **In Winter**:

1. Outer temperature is less than inner temperature.
   Tout < Tin
2. We have to calculate Heat load.
3. Amount of heat which must be supplied/hours to produce or maintain the design.

- **All year around**: Both heating and cooling.

II. Based on Types of Load:

- **Sensible heat**:

  - Changing in temperature and phase remain constant is known as sensible heat. For example-DBT cause sensible heat gain.

  - Heat transmission through the building as result of conduction, convection & Radiation through wall, roof, ceiling floor, door, glass etc.

- **Latent heat:**

  - Changing in phases but temperature is constant is called latent heat. For example-Any source that adds water vapour to the air in space.

  - Infiltration and ventilation.

III. Based on Position of Load:

- **Outdoor (External)**:

  - Any load that comes from outside.

  - Outside air introduce for ventilation.

  - Ex: heat produce from electric light.

- **Indoor (Internal):**

  - Any heat produce from internal.

  - For example:-Motor

3. Briefly explain various factors affecting thermal performance of building.

The thermal performance of a building depends on a large number of factors. The factors are design variables, material properties, weather data and a building's usage data.

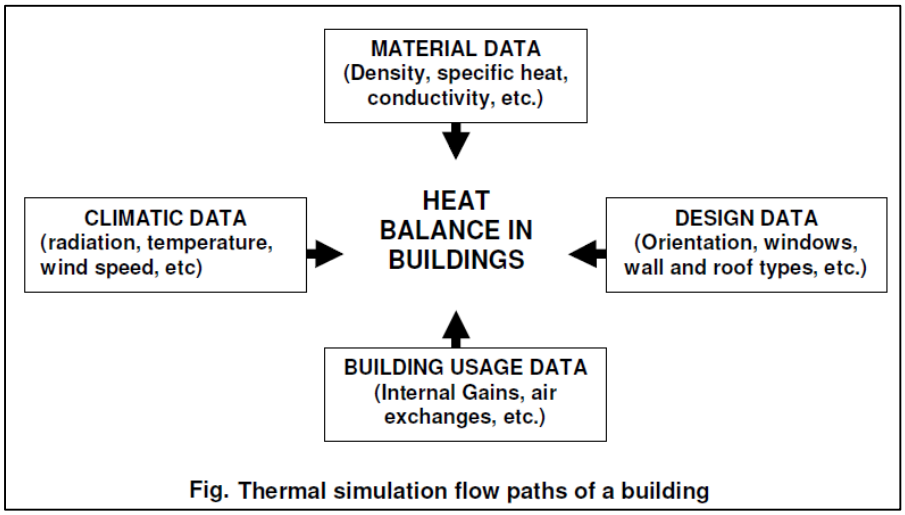


Fig. Thermal simulation flow paths of a building

1) **Design Variables**

Buildings are considered the main responsible for indoor thermal conditions because they form the main contact between indoor and outdoor environment. Many variables must be considered through the building's design will be displayed.

a. The Form of Buildings

The building's form, spacing and configuration in its neighborhood affect both the solar and wind factors. They play a large role in determining the amount of solar radiation received by the building's surface and the airflow around it. As the building surface is the exposed component to the outdoor environment, a small ratio of building surface to the volume which is the main characteristic of compact forms is helpful to maintain thermal balance.

b. Building Orientation

The building orientation can affect the building thermal performance by minimizing the direct solar radiation into the buildings envelops either building openings or opaque walls. Many factors must be taken into consideration during the selecting of building orientation. They include the expected shading impact and the sun movements according to latitude, time of day and time of year.

c. The Envelope of the Building

Building envelope has a great influence on both indoor and outdoor space condition. It is one of the main components affects the total heat gain and overall heat transfer coefficient. So it is important for the building envelopes to have a level of thermal resistance and a minimum of thermal bridges in order to avoid the penetration of water vapor inside the buildings.

d. Shading Devices

Shading devices have a useful impact especially in Mediterranean and semi-desert climates. The period of the year, the time of the relative transparency of the materials can affect the shading.

2) Material Properties

Material properties of buildings components play a fundamental role in controlling the process of heat transfer. The most important thermal properties are thermal conductivity, thermal resistance, thermal transmittance and density.

a. Thermal Conductivity λ

The thermal conductivity is a property of the material, which represents "the quantity of heat per unit time in watts, that flows through a 1m thick even layer of material with an area of 1m2, across a temperature gradient of 1 K (Kelvin) in the direction of the heat flow". The lower value thermal conductivity is the less thermal transmission will be.

b. Thermal Resistance of a Material, R

The thermal resistance of a material is the resistance to heat flow between two surfaces at different temperatures. It can be expressed as the R-value which is a function of the material thickness and the reciprocal of its thermal conductivity.

c. Thermal Transmittance, U

The thermal transmittance, U is a direct measure of the thermal insulating ability of a given building component air to air. It is obtained by reciprocating the total thermal resistance of the building component, R (i.e., U = 1/ R). It can be defined as "the quantity of heat that flows through a unit area of a building section under steady-state conditions in unit time per unit temperature difference of the air on either side of the section".

d. Density, Porosity

The density, p (kg/m3), is "the mass of a unit volume of the material, comprising the solid itself and the gas- filled pores". The density plays a great role for the thermal properties: the lighter the material the more insulating and the heavier the more heat storing.

3) Climatic Factors

The climatic factors can affect the design operation of buildings envelop in order to achieve comfort and save energy.

a. Solar Radiation

The solar radiation is "the intensity of sunrays falling per unit time per unit area and is usually expressed in Watts per square meter (W/m2)". Some factors that affect the radiation incident on a surface are geographic location (latitude and longitude of the place), orientation, and season, time of day and atmospheric conditions. Solar radiation is the most weather variable influences the air temperatures.

b. Humidity

Air contains a certain amount of vapor, which is called air humidity .The acceptable rate of humidity differ according to the climate. While a low rate of humidity is preferable in dry climates, it causes discomfort in tropical climate regions. There are an inverse relationship between relative humidity and air temperature. It decreases as the air temperature rises. The decrease in the relative humidity towards midday tends to be the largest in summer.

c. Pressure and Winds

Wind has a great influence on buildings design and their thermal performance. It affects the convective heat exchanges of a building envelope and the air infiltration. It's necessary to avoid the effect of winter wind which increase the infiltration heat loss and utilizing the summer wind in encouraging ventilation .Many factors affect the wind at the local level such as topography, vegetation and buildings configuration.

4) Building Occupancy and Operations

Buildings usage produces heat from their occupancy, lights and equipments. Occupation densities and types of activities affect the total heat gain. It can be significant in crowded spaces .People give off the heat of metabolism to maintain a constant body temperature. Electric lights and equipment give off heat to the building equal to the electrical energy they consume.

4. Explain general procedure for cooling load calculation. OR How is annual heating and cooling load factors calculated?

1. Estimate outside & inside condition.

- Inside temperature, humidity.

- Outside temperature & humidity.

2. Determine the transmission load across the wall, window, roof and floor.

3. Consider the load due to solar radiation through glass.

$$\mathbf{Q = \mu A \Delta T}$$

Where, Q is heat conduction.

ΔT is temperature difference between inside and outside air.

A is surface area.

4. Consider the effect of solar radiation while considering the load due to wall, ceiling and door.

5. Consider the quality of ventilation air and load due to the fresh air.

$$\mathbf{Q = \rho VC(ti\text{-}to)}$$

Where, Q=heat transfer.

P= density kg/m3.

V= flow rate of air

C= specific heat

ti= internal temperature

t2= external temperature.

6. Calculate internal load as occupant load, lighting load and appliances load.

7. Determine the total cooling load and select the air conditioning equipment according to the requirement.

8. The solar gain through transparent elements can be written as:

$$\mathbf{Qs = \alpha s \sum Ai\ Sgi\ \tau i}$$

Where, αs = mean absorptivity of the space

Ai = area of the ith transparent element (m2)

Sgi = daily average value of solar radiation (including the effect of shading) on the ith transparent element (W/m2)

τi = transmissivity of the ith transparent element.

M = number of transparent elements