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SCHOOL OF BUILDING AND ENVIRONMENT

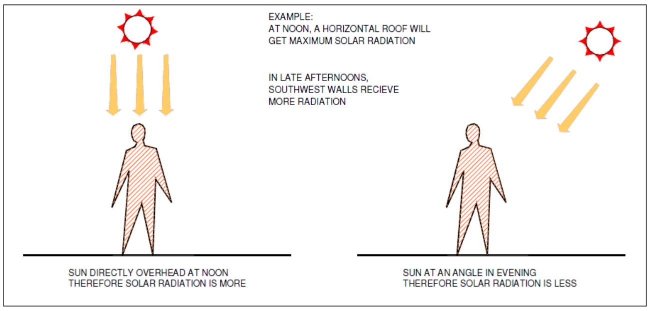
DEPARTMENT OF ARCHITECTURE

UNIT – I - Climate and comfort – SAR1204

Unit I: Climate and comfort

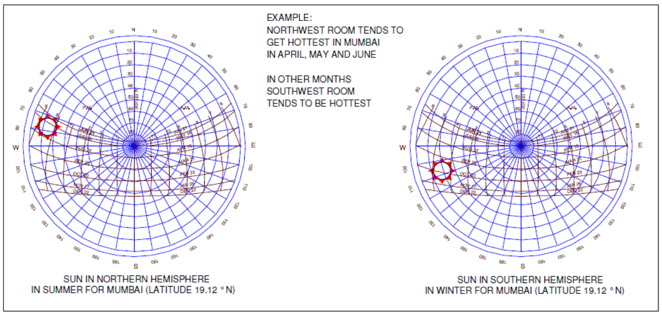
1. Components of Climate :
   - SOLAR RADIATION
   - AMBIENT TEMPERATURE
   - AIR HUMIDITY
   - PRECIPITATION
   - SKY CONDITION
   - WIND

I. Solar Radiation : Solar radiation is the radiant energy received from the sun. It is the intensity of sunrays falling per unit time per unit area and is usually expressed in Watts per square metre (W/m2).
The radiation incident on a surface varies from moment to moment depending on its geographic location (latitude and longitude of the place), orientation, season, time of d ay and atmospheric conditions (Fig.).
Solar radiation is the most important weather variable that determines whether a place experiences high temperatures or is predominantly cold.
The instruments used for measuring of solar radiation are the pyranometer and the pyrheliometer. The duration of sunshine is measured using a sunshine recorder.



EFFECT OF TIME

Fig 1



EFFECT OF SEASON

Fig 2

Fig 3

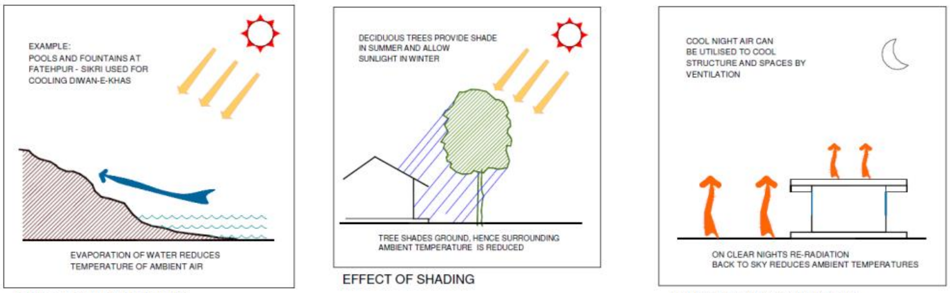
A pyranometer is a type of actinometer used for measuring solar irradiance on a planar surface and it is designed to measure the solar radiation flux density (W/m2) from the hemisphere above within a wavelength range 0.3 µm to 3 µm.

Fig 4

A pyrheliometer is an instrument for measurement of direct beam solar irradiance. Sunlight enters the instrument through a window and is directed onto a thermopile which converts heat to an electrical signal that can be recorded.

II. Ambient Temperature :
The temperature of air in a shaded (but well ventilated) enclosure is known as the AMBIENT TEMPERATURE

It is generally expressed in degree Celsius (ºC). Temperature at a given site depends on wind as well as local factors such as shading, presence of water body, sunny condition, etc. The dry bulb Temperature (DBT) is the value taken in shade using a simple Mercury thermometer kept in a Stevenson's screen can measure ambient temperature.
It is important to know the monthly mean maxima and minima, monthly extreme maxima and minima



EFFECT OF WATER BODY

EFFECT OF SHADING

EFFECT OF SKY CONDITION

Fig 5

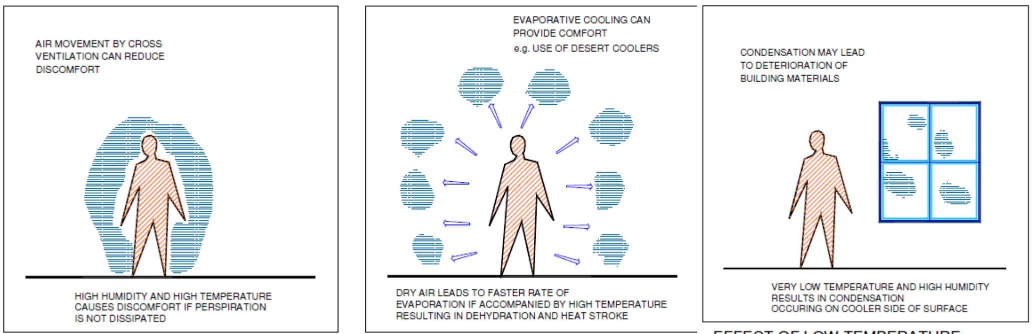
The dry-bulb temperature (DBT) is the temperature of air measured by a thermometer freely exposed to the air, but shielded from radiation and moisture.

III. The HUMIDITY of Air is termed as ABSOLUTE HUMIDITY (AH) i.e., the total amount of water vapour present in a given volume of air. It does not take temperature into consideration.
RELATIVE HUMIDITY (RH) is the ratio of actual amount of moisture present (AH), to the amount of moisture the air could hold (SH) at the given temperature – EXPRESSED AS PERCENTAGE

$$RH = (AH/SH) X 100$$

RH is measured using wet and dry bulb hygrometer.

Fig 6



EFFECT OF HIGH TEMPERATURE AND HIGH HUMIDITY

EFFECT OF HIGH TEMPERATURE AND LOW HUMIDITY

EFFECT OF LOW TEMPERATURE AND HIGH HUMIDITY

Fig 7

IV. Precipitation :

Precipitation is a collective term used for rain, snow, dew etc.

It is measured in RAIN GAUGES and expressed in mm/day. The maximum rainfall data will help in predicting flood and for the design of drainage system.

LIKLIHOOD OF DRIVING RAIN (intense rain with strong winds)

Driving rain is the product of annual rainfall (m) and the average wind velocity (m/s). Thus the unit of driving rain index is (m2/s).

The exposure is moderate at 3-7 m2/s and sever above 7 m2/s.

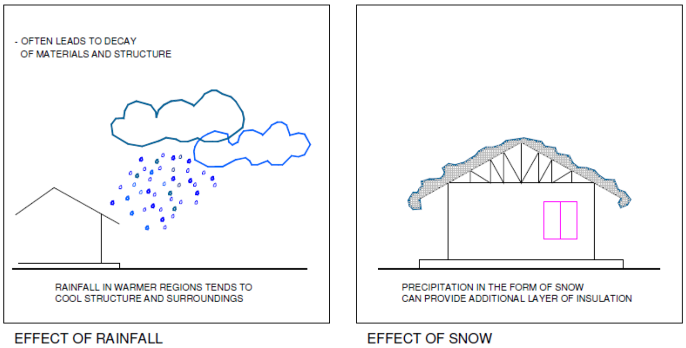


Fig 8

V. Sky condition :

Sky condition generally refers to the extent of cloud cover in the sky or the duration of sunshine. Under clear sky conditions, the intensity of solar radiation increases; whereas it reduces in monsoon due to cloud cover.

The re-radiation losses from the external surfaces of buildings increase when facing clear skies than covered skies. The measurement of sky cover is expressed in oktas. For example, 3 oktas means that 3/8th of the visible sky is covered by clouds.

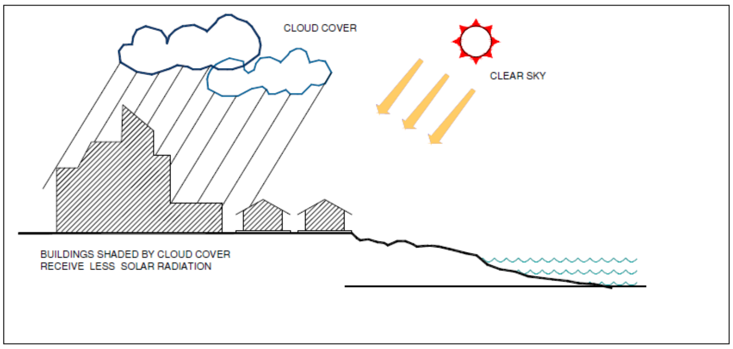


Fig 9

VI. Wind :

Wind velocity is measured by propeller ANEMOMETER.

Measurements are taken in urban areas between 10 – 20 m ht.

The direction of wind are 8 or 16 category – the unit is m/s.

Wind is the movement of air due to a difference in atmospheric pressure, caused by differential heating of land and water mass on the earth's surface by solar radiation and rotation of earth.

It is a major design consideration for architects because it affects indoor comfort conditions by influencing the convective heat exchanges of a building en velope, as well as causing air infiltration into the building.

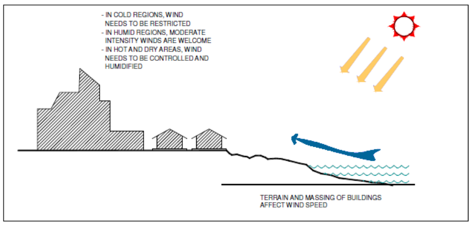


Fig. 2.5 Factors affecting wind

Fig 10

Fig 11

GLOBAL CLIMATIC FACTORS

1. SOLAR RADIATION QUALITY
2. SOLAR RADIATION QUANTITY
3. TILT OF THE EARTH AXIS
4. RADIATION AT EARTH SURFACE
5. THE EARTHS THERMAL BALANCE
6. WINDS – Thermal Forces

I. Solar Radiation quality and quantity :

The earth receives all its energy from the sun

**nm=10-9 m

Ultra Violet (290 – 380 nm)

Visible (380 – 700 nm)

Infra red (700 – 2300 nm)

The Spectral energy distribution varies with ALTITUDE

(Filtering effect – shorter wavelength absorbed by atmosphere)

The intensity of radiation reaching the upper surface of the atmosphere is taken as SOLAR CONSTANT : 1395 W/m2

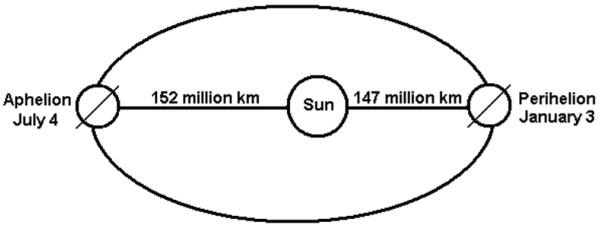


Fig. 1 : Earth's elliptical orbit

Fig 12

II. Tilt of the earth axis :

The plane of the eclliptic is the plane of the Earth's orbit around the sun. The Earth's axis is titled by 231/2 0 from the perpendicular to the plane of the elliptic.

In the other words it makes an angle of 231/2 0 with the plane of elliptic as shown in the Figure 2.

The axis of rotation remains pointing in the same direction as it revolves around the Sun.

As a result, the earth's axis of rotation remains parallel to its position at any other time as it orbits the sun, a property called Parallelism of Axes.

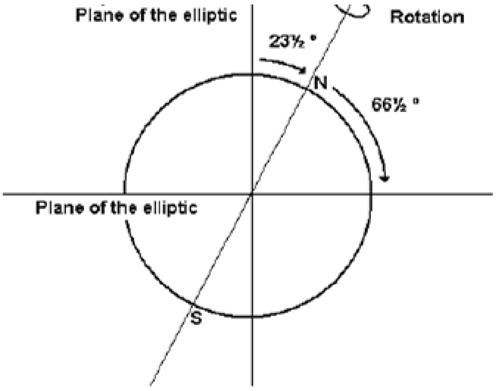


Fig. 2 : Earth's elliptical orbit

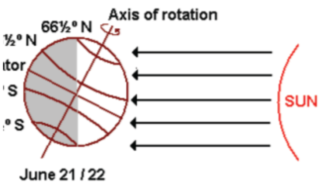


Fig. 3 : Summer Solstice

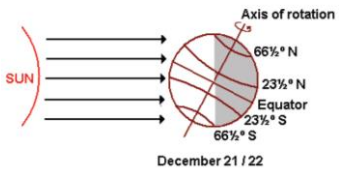


Fig. 4 : Winter Solstice

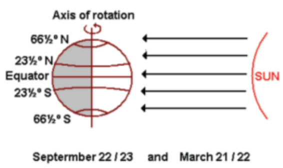
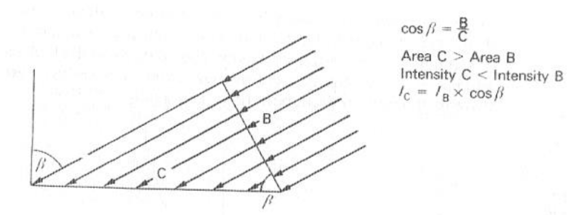


Fig. 5 : Autumnal and Spring Equinox

Fig 13

III. Radiation at earth surface :

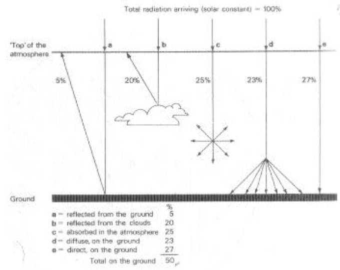
The COSINE LAW – The intensity of TILTED SURFACE equals the normal intensity times the cosine of the angle of INCIDENCE



The SOLAR DEPLETION – The Absorption of radiation by ozone, Vapours, Dust particles

The lower the solar altitude angle, the longer the path of radiation thus a smaller part reaches the earth surface.

The duration of SUN SHINE – The length of daylight period.



IV. THE EARTH's THERMAL BALANCE :

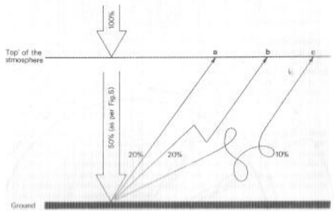
The total amount of HEAT ABSORBED by the earths surface is balanced by the corresponding heat loss – without this cooling, the thermal balance of the earth could not be maintained.

The earth surface losses heat by

Radiation

Evaporation

Convection



V. WINDS – Thermal Forces :

Winds are convection currents in the atmosphere, tending to even out the differential heating of various zones

At maximum heating zones (between Tropic of cancer and Capricorn) the air is heated by hot surface and flows of a higher level towards colder regions.

Part of the air having cooled down at high level descends to the surface in the sub tropic region

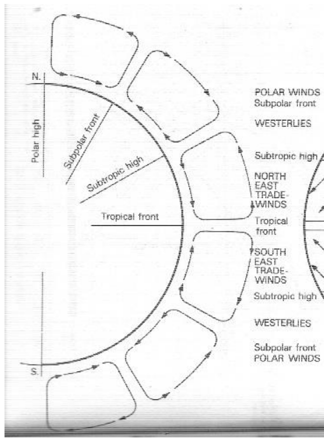


Fig 14

TRADE WINDS – The atmosphere rotates with earth. As it is light and behaves like fluid held against the earth surface only by gravity and friction it has a tendency to lag behind earth rotation

There is a slippage between the earth and the atmosphere caused by CORIOLIS FORCE

North easterly winds - north of equator and South easterlies - south of equator

MID LATITUDE WESTERLIES –

Around 30 N & S there are two bands of continually high barometric pressure. Wind in these region are light and variable

30 – 60 N and S strong westerly wind prevails.

The total Angular Momentum of earth is constant. If it is reduced at the equator by easterlies.

POLAR WINDS –

Further towards the poles from latitudes 60 N and south, the air flow patterns comes under the influence of thermal forces similar to equator

SITE CLIMATE

- Site climate’ is also called as ‘microclimate’, the climate prevailing in a particular area, can imply any local deviation from the climate of a larger area, whatever the scale maybe.
- ‘Site climate’ establishes the scale - whatever the size of the project, it implies the climate of the area available, because of the site features.

LOCAL FACTORS

- AIR TEMPERATURE
- HUMIDITY
- PRECIPITATION ON HILLS, PRECIPITATION OVER TOWNS
- SOLAR RADIATION
- WIND VELOCITY GRADIANTS

- Designing should be done in such a way to take advantage of the favourable & mitigate the adverse characteristics of the site & its climatic features.

- The nature and extent of climatic deviations – are likely to effect – so should be assessed at the early designing stage.

- The factors governing the climate of a zone are:

Topography – slope , orientation, exposure, elevation, hills or valleys, at or near the site.

Ground surface – whether natural or man-made, its reflectance, permeatibilty and the soil temperature (affect on vegetation) and this in turn affects the climate(woods, shrubs, grass, paving, water, etc.)

Three-dimensional objects - these includes trees , tree-belts, fences, walls & buildings, as they may influence air movement , may cast a shadow and may sub-divide the area into smaller units with distinguishable climatic features.

AIR TEMPERATURE:

At any point near the ground, the air temperature is dependent upon the amount of gain or loss at the earth’s surface.

Heat exchange varies between day and night , with the season, latitude and the time of year, always influenced by the amount of cloud cover.

During the day, surfaces are heated by solar radiation, the air nearest to the ground acquires the highest temperature.

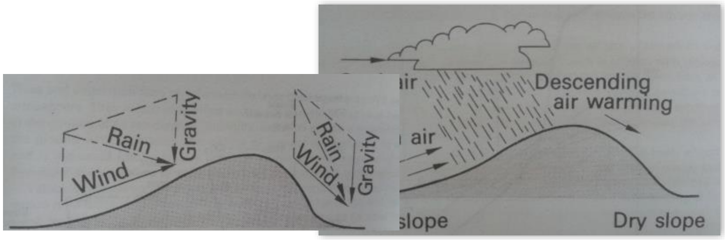
At night, on clear nights, the ground loses much heat by radiation and soon after sunset its temperature falls below that of the air, i.e., the direction is reversed from air to the ground.

HUMIDITY:

AT GROUND	AT 2M
HIGH	LOWER
LOW	HIGHER

- It depends on air temperature as on the actual amount of water vapour present in the air.
- During the day, the lowest layer of air is being heated by the ground surface, its RH is rapidly decreased.
- At night, the situation is reversed.

PRECIPITATION ON HILLS:



- The cause of above phenomenon is that the hill forces the air mass to rise, as it rises it cools & can no longer support the moisture carried. Thus, deceasing air mass and increasing temperature, increasing the capacity to absorb more moisture rather to precipitate.
- A higher frequency of rains are seen over city centres. If rainfall occurs associated with high wind velocities, resulting in driving rains, effect may be pronounced on the windward side than on the leeward side, explaining the parallelogram of forces.

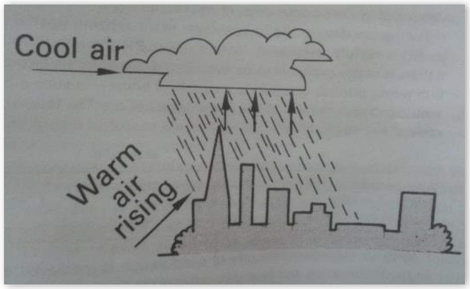


Fig 14

SOLAR RADIATION

The amount of solar radiation may be influenced by local factors three ways:

- The intensity on a theoretical horizontal plane above the ground is affected by local variation in the transparency of the atmosphere. Atmospheric pollution, smoke, smog or dust and local cloud formation can produce substantial reductions.
- The intensity on the actual ground surface is influenced by the slope and orientation of the site.
- The daily amount of radiation may also be influenced the slope.

SPECIAL CHARACTERISTICS

- Thunder-storms are macroclimate phenomena, but local topography can influence their path, their intensity and even their frequency.
- Dust and sand-storms are influenced by local factors , both by ground surface providing sand and dust to be carried by the wind, and by topography in funnelling or diverting the wind or by causing local eddies.

VEGETATION

- Although considered as an effect of climate, vegetation can play a major role in site climate

- Trees and vegetation form an intermediate layer between the earth's surface and the atmosphere.
- The moderating effect can be referred with respect to air temperature, humidity, radiation and air movement.

IMPACT OF RAINFALL IN THE DESIGN OF BUILDINGS

- In regions having high rainfall, a pitched roof will most often be used. In regions having driving rainfall and where ventilation is important, one of the most difficult problems which a designer must attempt to solve is to provide large openings, but at the same time give protection from driving rain, insects, smells and noise, without radically reducing air movement.
- Broad eaves can be provided to shade the walls and openings, provide protection from driving rain and sky glare and permit the openings to be kept open most of the time.
- Large projecting eaves and wide verandahs are needed in the warm-humid season in the out-door living areas, to reduce sky glare, keep out the rain and provide shade.
- Brise-soleils, louvers and other sun breaks used to protect openings during the hot-dry period, are also advantageous in the rainy season, serving as protection against rain.
- Rain protection and special protective measures are needed if rain is frequent and heavy - such as deep verandahs, wide overhangs and covered passages.
- With heavy rainfall occurring even in one month of the year, special provisions for roof drainage will be necessary.
- In low cost building, spouts at roof level or eaves discharge is acceptable if the foot of the walls is surrounded by a concrete path or approx 0.5 m wide, sloping away from the building.

THERMAL COMFORT

- Our life cycle comprises activity, fatigue and recovery.
- Recovery is essential to counter balance against mental and physical fatigue through recreation, rest and sleep.
- This can be affected by unfavorable climatic conditions and the resulting stress on body and mind causes discomfort, loss of efficiency and breakdown of health.
- Thermal comfort is the condition of mind that expresses satisfaction with thermal environment and is assessed by subjective evaluation. (ANSI/ASHRAE Standard 55)
- The task of the designer is to create the best possible indoor climate or even the environment for the users as they judge the quality of design based on physical and emotional point of view.
- Thermal comfort is considered to be a necessary component of workplace contentment and production.

- The thermal comfort has to be satisfied in spaces where people will spend most of their lives. For e.g. Schools are the buildings where children spend most of their active day time.

- Thermal discomfort in school buildings can create unsatisfactory conditions for both teachers and students which is disturbing for them, reducing their working productivity, attention and performance in studies.

INDICES OF THERMAL COMFORT

- Thermal comfort refers to the subjective feeling of temperature in an environment.
- Optimum levels of thermal comfort helps in maximizing productivity.
- Measurement of thermal comfort levels are complex and many indices have been proposed over the years.

THERMAL COMFORT SCALE

- A single scale which combines the effects of various thermal comfort factors (such as air temperature, humidity, air movement and radiation) is called a THERMAL INDEX or COMFORT SCALE.
- The designer has to handle four such factors to understand the effect of climatic conditions on the body's heat dissipation process.
- It depends on the environmental factors of air temperature, relative humidity, air velocity and solar radiation, also the incorporation of highly variable personal factors like the amount of clothing being worn, A person's resting metabolic rate, level of physical activity.
- To create such a scale , experiments were done in specially built rooms where climatic conditions could be produced.
- The subjects were placed in the room and were asked to fill questionnaires after each variation in the conditions according to a set scale ranging from 'very hot' to 'very cold'.
- The answers were then evaluated statistically and plotted on a graph to find relationship among the factors.
- At least 30 or more scales were devised in this process.

OUTDOOR THERMAL COMFORT

- The outdoor thermal environment is greatly influenced by the built environment, e.g. anthropogenic heat, evaporation and evapotranspiration of plants, shading by trees and man-made objects, and ground surface cover such as natural grass and artificial paving, etc.
- Outdoor spaces provide a pleasurable thermal comfort experience for people and effectively improve the quality of urban living. People experience different thermal sensation while carrying out the outdoor activities in streets, plazas, playgrounds, urban parks, etc.

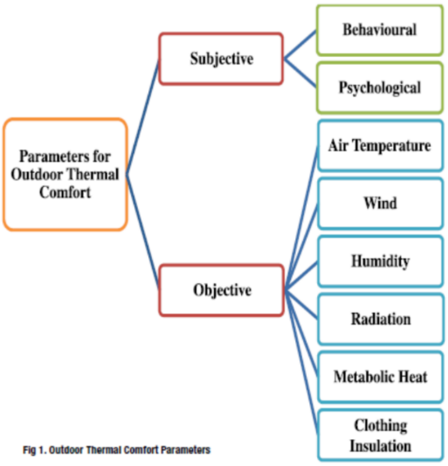


Fig 1. Outdoor Thermal Comfort Parameters

Tab. 1

INDOOR THERMAL COMFORT

- Thermal comfort takes into account a range of environmental and personal factors when deciding on the temperature and ventilation that will make the indoor environment feel comfortable for people.
- Parameters need to consider for indoor thermal comfort

The Environment	The Individual
• Air Temperature • Radiant temperature (from the source of heat) • Relative air humidity • Ventilation • Air movement • Climatic and seasonal variations(Outdoor temperatures and conditions) • The building design (type of insulation, glass windows with film to reduce glare, etc)	• The way different people bodies balance the different demand made on them • The amount and type of special clothing or personal protective equipment that is worn • The type of work being done • The age, sex, state of health and degree of fitness of the individual • How long the individual is exposed to the hot/cold environment • Specific groups of people like children and pregnant women

Tab. 2

Fanger's Predicted Mean Vote Model (ASHRAE, 2001; Fanger, 1970)

Figure 1: ASHRAE Thermal Sensation Scale

-3	-2	-1	0	1	2	3
cold	cool	slightly cool	neutral	slightly warm	warm	hot

- The PMV model combines four physical variables (air temperature, air velocity, mean radiant temperature, and relative humidity) and two personal variables (clothing insulation and activity level) into an index that can be used to predict thermal comfort.
- In these studies, participants were dressed in standardized clothing and completed standardized activities, while exposed to different thermal environments. In some studies the researchers chose the thermal conditions, and pa rticipants recorded how hot or cold they felt, using the seven-point ASHRAE thermal sensation scale. In other studies, participants controlled the thermal environment themselves, adjusting the temperature until they felt thermally 'neutral' (i.e. neither hot nor cold; equivalent to voting '0' on the ASHRAE thermal sensation scale).
- The static predicted means vote (PMV) model was shown to be partially adaptive by accounting for behavioral adjustments, and fully explained adaptation occurring in HVAC buildings.
- In centrally controlled HVAC buildings, the occupants have little or no control over their immediate thermal environment.
- The PMV/PPD model is inapplicable to naturally ventilated premises because it only partially accounts for processes of thermal adaptation to indoor climate.
- There is a clear dependence of indoor comfort temperatures on outdoor air temperature especially in buildings that were naturally ventilated.

SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF ARCHITECTURE

UNIT 2 – CLASSIFICATION OF CLIMATE – SAR1204

Unit II: CLASSIFICATION OF CLIMATE

KOPPEN CLIMATE CLASSIFICATION SYSTEM

ATKINSON CLIMATE CLASSIFICATION

CHARACTERISTICS OF TROPICAL CLIMATE

PARAMETERS AFFECTING CLIMATE ZONES

Latitude

Altitude

Low and high pressure zones

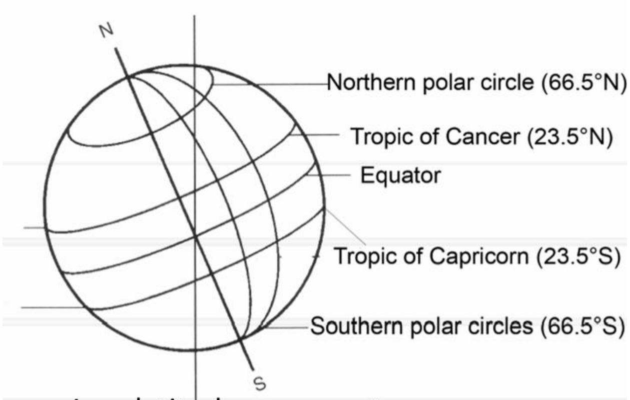
Global wind patterns

Proximity to oceans and large seas

Ocean currents

Latitude zones :

- Latitude is defined as a measurement of distance in degrees north and south of the equator
- The word latitude is derived from the Latin word,"latus",meaning "wide."
- There are 90 degrees of latitude from the equator
- to each of the poles, north and south.
- Latitude lines are parallel, that is they are the same
- These lines are sometimes referred to as parallels



- Low latitudes: 0-30°N/S
- Mid-latitudes: 30°N/S-60°N/S
- High latitudes:>60°N/S

Fig 1

KOPPEN CLIMATE CLASSIFICATION SYSTEM

Koppen has classified the climate into 5 types.

A CLIMATES _ TROPICAL WARM AND WET

B CLIMATES _ DRY OR ARID

C CLIMATES _ SEA OR MARITIME

D CLIMATES _ CONTINENTAL

E CLIMATES _ POLAR

I. A CLIMATES _ TROPICAL WARM AND WET

Near equator the sun is at high angle and its low pressure area. Often it rains and warm around.

Avearge temperature per month at least 18 ºc.

II. B CLIMATES _ DRY OR ARID

Away from equator its warm, dry and desert type and these are high pressure areas.

Maximum 400 mm precipitation.

III. C CLIMATES _ SEA OR MARITIME

Colder than 18 ºc in coldest month but warmer than -3 degrees.

IV. D CLIMATES _ CONTINENTAL

Coldest month colder than -3 degrees on average.

V. E CLIMATES _ POLAR

Warmer month is on average colder than 10 ºc.

Sub Climates

Ef _ Always frost, only snow, nothing grows, Et _ Tundra, no trees

Bs _ Semi-arid, 200-400mm precipitation, Bw _ Desert, maximum 200mm precipitation

Af _ Year round precipitation, Aw _ Winter drought, As _ Summer drought.

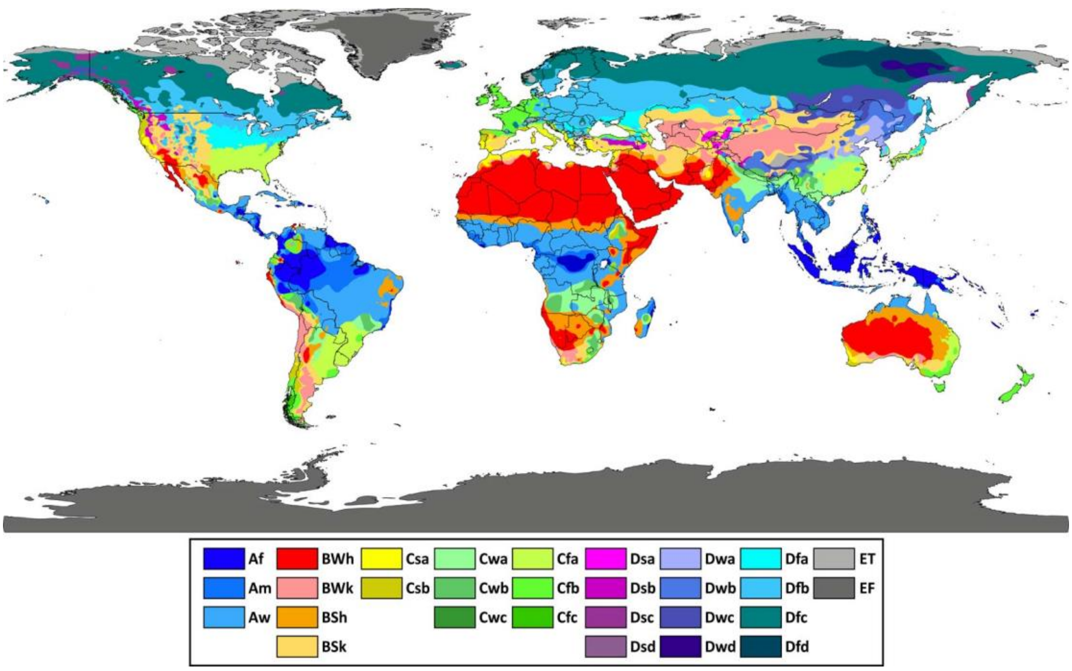


Fig 2

1. Cold climate (cool)
2. Temperate climate (moderate)
3. Hot dry climate
4. Warm humid climate (humid tropics)

Cold climate: Lack of heat (under heating) or an excessive heat dissipation

Temperate climate: There is a seasonal variation between under heating and over heating, but neither is very severe

Hot dry climate: Overheating, since the air is dry evaporative cooling mechanism of the body is not restricted

Warm humid climate: Overheating is not great as in hot-dry areas, but it is aggravate by very high humidity, restricting the evaporation potential of human body.

Fig 2

Climate Classification for architecture

This is based on the nature of the human thermal problem in relation to particular location

A Cold climate | Lack of heat | Causing excessively body heat loss

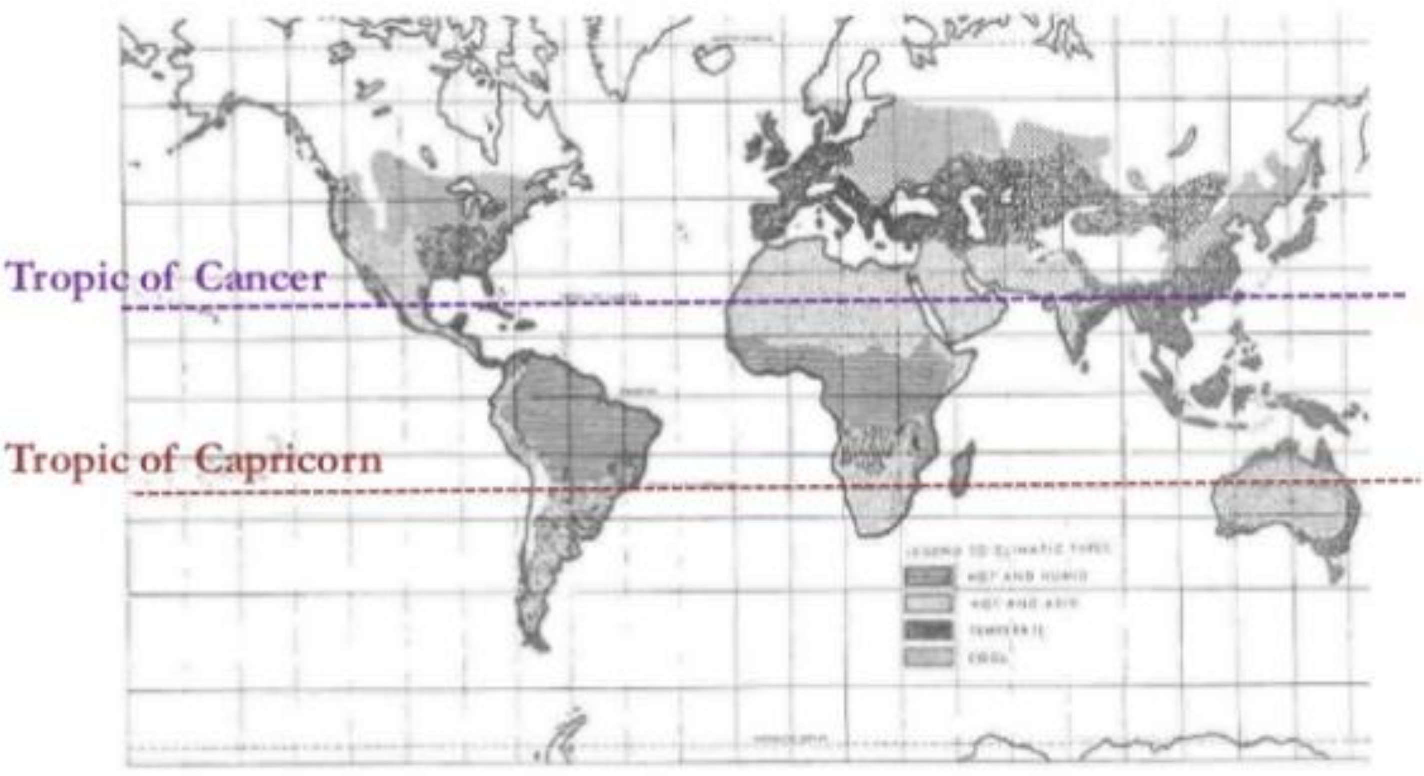

Retain heat

B Warm climate | Too much heat | Causing Inadequate heat dissipation

Remove heat

C Moderate climate | Seasonal variation between above two climates


Fig 3



Climate zones for building thermal design

Fig 4

Characteristics of Tropical Climate

A tropical climate is a kind of climate typically in the tropics

Defined as non-arid climate in which all 12 months have mean temperature above 64.4 °F (18.0 °C)

Cover the largest area of earth (20% of land surface and 43% of ocean surface) - the home to almost half of the world ’s population

South Florida, The Caribbean, Central Africa, Coastal India, Southeast Asia, North Queensland, Hawaii, Central America, or most of Brazil.

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Tropical Climate and its Types

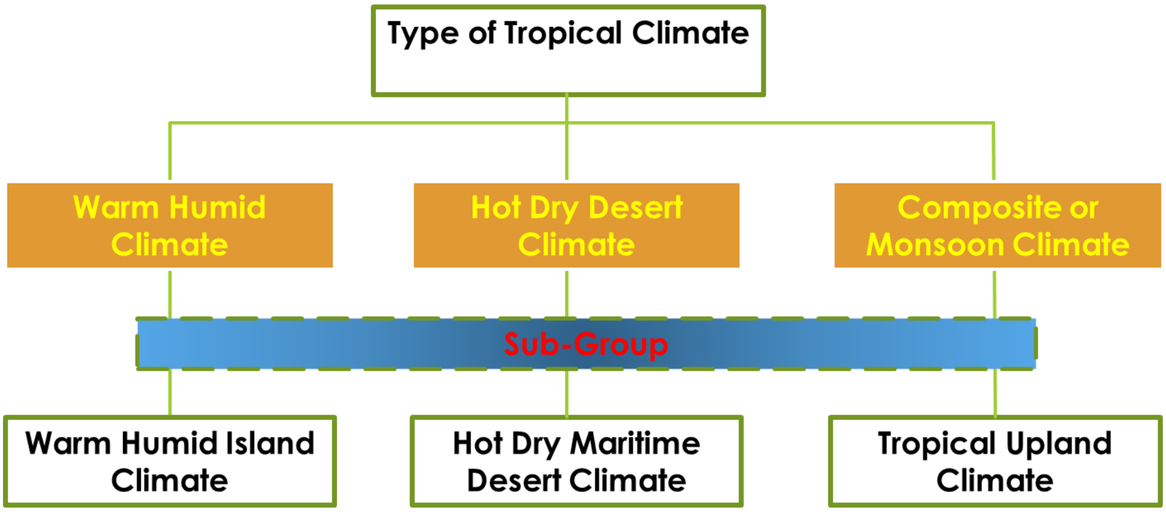


Fig 5

WARM HUMID CLIMATE: Examples: India, Malaysia, Jakarta, Singapore, Hawaii, US

1 Warm humid climate

Found in a belt near the Equator extending to about 15°N and S

Warm humid climate

- There is very little seasonal variation throughout the year
- Main difference is the periods with more or less rain and the occurrence of gusty winds

1 Air Temperature
- During the day between 27° and 32°c
- At night, between 21° and 27°c

2 Humidity
- Relative Humidity (RH) remain high – 75% for most of the time, but vary from 55% to almost 100%

3 Vapour Pressure
- Between 2500 to 3500 N/m2

4 Precipitation
- High precipitation (rainfall) throughout the year
- Generally becoming more intense for several consecutive month.
- Annual rainfall – 2000 to 5000 mm in one year
- Occurrence of gusty winds and electric storms

5 Sky Condition
- Are fairly cloudy throughout the year
- Cloud cover – 60% to 90%

6 Solar Radiation
- normally high / maximum partly reflected and partly scattered by the cloud
- higher sun and longer days is distinctly wettest (as at Palembang, Indonesia) or the time of lower sun and shorter days may have more rain (as at Sitiawan, Malaysia).

7 Wind
- Wind velocities are typically low, calm periods
- Strong wind can occur during rain squalls.

8 Vegetation
- Grows quickly due to frequent rains & high temperature
- Difficult to control
- High humidity accelerates mould and algae growth, rusting and rotting.

1a Warm humid island climate

Islands within the equatorial belt and in the trade winds zone belong to this climate type
Example: Philippines and other island groups in the Pacific ocean
Seasonal variations are negligible

CARIBBEAN

Philippine

1 Air Temperature
- During the day between 28° and 32°c.
- At night, between 18° and 24°c

2 Humidity
- Relative Humidity (RH) remain high from 55% to almost 100%

3 Vapour Pressure
- Between 1250 to 2500 N/m2

4 Precipitation
- is high 1250 to 1800 mm per annum

5 Sky Condition
- Are normally clear or filled with white broken clouds of high brightness
- During storms, skies are dark and dull

6 Solar Radiation
- strong and mainly direct

7 Wind
- The predominant trade-wind blows at a steady 6-7 m/s
- Provides relief from heat and humidity

8 Vegetation
- Less luxuriant and a lighter green cover than warm-humid zone.
- Depends on rainfall

Fig 6

HOT-DRY DESERT CLIMATE: Examples: Baghdad, Saudi Arabia, India,South Africa.

2 Hot dry desert climate

Occur in two belts at latitudes between approx. 15 to 30 N and S of the equator

- Two marked seasons of hot and somewhat cooler period

Fig 7

1 Air Temperature

- During the day between 43° and 49°c.
- At night
  - Cool season between 10° and 18°c
  - Dry season between 27° and 32°c

2 Humidity

- Relative Humidity (RH) is low from 10% to almost 55%

3 Vapour Pressure

- Between 750 to 1500 N/m2

4 Precipitation

- Slight and variable throughout the year
- Limited rainfall – 50mm rain in a few hours
- Flash rain may occurred but some region may not have any rain for several years

5 Sky Condition

- Are normally clear clouds are few due to low humidity of the air
- During storms, skies are dark and dull

6 Solar Radiation

- Strong and mainly direct during the day
- Absence of cloud permits easy release of the heat stored during the day.

7 Wind

- Hot and together with dust and sand
- Occurrence of sandstorm

8 Vegetation

- Sparse and difficult to maintain due to lack of rain and low humidity (ie: palms, cactus)
- Soil is usually dusty and very dry

Fig 8

HOT-DRY MARITIME DESERT

2a Hot dry maritime climate

Maritime desert climates occur in the same latitude belts as the hot dry desert climates where the sea adjoins a large land mass
These climates are regarded to be amongst the most unfavorable climates of the earth
Example: Kuwait, Karachi etc.
There are two seasons, hot and somewhat cooler season

1 Air Temperature
- Daytime mean max is about 38°C
- During cool season it remain between 21°C and 26°C

2 Humidity
- RH is steadily high between 50 – 90%

3 Vapour Pressure
- Between 750 to 1500 N/m2

4 Precipitation
- Very low

5 Sky Condition
- A little more cloud may occur in the form of a thin, transparent haze
- It cause glare

6 Solar Radiation
- Strong and direct during the day.

7 Wind
- Local wind - dust and sand storms may occur

8 Vegetation
- Sparse, not more than some dry grass

Fig 9

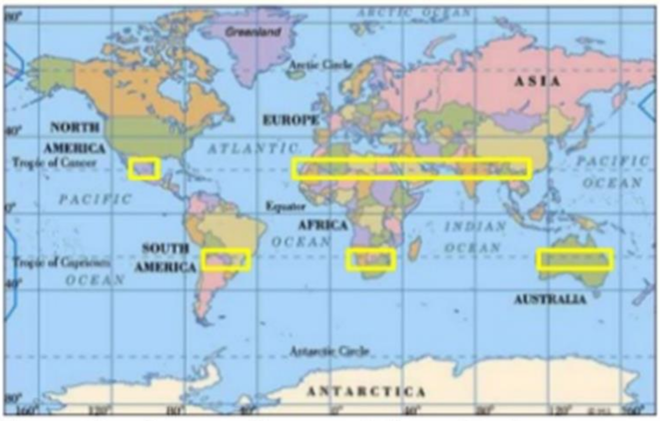
COMPOSITE / MONSOON

Examples: Lahore, Mandalay, New Delhi

Two seasons – Two seasons occur normally. Approximately 2/3 of the year is hot dry and 1/3 is warm humid.

Localities further North and South often have a third season as cool-dry.

3 Composite or Monsoon climate



These climates usually occur in large land masses near the tropics of Cancer and Capricorn, which are sufficiently far from the Equator to experience marked seasonal changes in solar radiation and wind direction

Fig 10

Air Temperature (ºC)

3 Precipitation

- The monsoon rains are intense and prolonged during wet period
- During dry season - little or no rain
- Heavy dew at night, hail and thunderstorm may also occur

4 Solar Radiation

- Strong and direct during the clear periods

5 Winds

- Variable, predominantly north-east and south-easterlies

6 Vegetation

- Green although not very luxuriant during the wet season but wither in the dry season when the ground can turn brown or red

Season	Hot-dry	Warm-humid	Cool-dry
Daytime mean max	32 – 43	27-32	Up to 27
Night-time mean min	21 – 27	24 – 27	4 – 10
Diurnal mean range	11 – 22	3 – 6	11 – 22

TROPICAL UPLAND CLIMATE: Mountainous regions - more than 900 to 1200 m above sea level.Examples: Bogotá, Mexico City, Nairobi.

Fig 11

1 Air Temperature

- Daytime mean max range from 24°C - 30°C
- The night-time mean min around 10°C – 13°C, some locations it may fall below 4°C

2 Humidity

- RH varies between 45 – 99%

3 Vapour Pressure

- The vapor pressure between 800 – 1600 N/m2

4 Precipitation

- Variable but rarely less than 1000 mm

5 Sky Condition

- Normally clear or partly cloudy to the extent of about 40%
  During monsoon rains - the sky is overcast
- Sky conditions vary with the seasons – heavily overcast and dull during the monsoons and clear with dark blue color in the dry season

6 Solar Radiation

- Alternates between conditions found in the warm-humid and hot-dry desert climates

7 Wind

- Fairly strong and steady during warm-humid season
- Hot and dusty during the dry period

CLIMATE OF INDIA

Climate – sum total of weather conditions and variations over large area for a long period of time i.e., for more than 30 years.

Monsoon climate in India.

Weather – a state of atmosphere over an area at any point of time. Say it is rainy – Rainy day. If it is cool outside – weather is cool.

ELEMENTS OF CLIMATE

Temperature

Atmospheric pressure

Wind

Humidity

Precipitation

Weather fluctuates very often within a day on the basis of generalized atmospheric conditions. Year is divided into seasons like – winter, summer and rainy seasons.

CLIMATE OF INDIA – MONSOON TYPE

This type of climate is found in the south and south East Asia

Monsoon – Mausam – wind that changes the direction

In India wind blows from south west to north east and north east to south west

Regional variations in climatic conditions within the country

Two important elements

Temperature	Precipitation
Vary from place to place and season to season	
Eg. Barmer in Rajasthan 48°C to 50°C in June whereas 22°C in Pahalgam and Gulmarg in Kashmir. Decrease in Dras to -40°C in winter.	Variations occurs not only in the time of precipitation but also in the amount of seasonal variations
Kerala tropical climate and warm and moist air. Punjab has continental climate with severe heat and severe cold (alternating). Kargil Kashmir -40°C in winter, but Kerala 20°C to 22°C	Snowfall only in Himalayas and in rest of the places in country is only rain
The annual range of temperature is 3°C in Malabar coat (difference between hottest month temperature and coldest month temperature. Reason is moderating influence of sea. Temperature range is more than 20°C in Deccan plateau	Cheerapunji and Mawsynram in Meghalaya gets about 1100 cm rain in the year. Jaisalmer receives only 9 cm rain in a year. Tura in Meghalaya gets rain in a single day around 10 year of rain in Jaisalmer. Coromandel coast seems dry in July and august, whereas ganga delta and coast of Orissa are hit by strong storms almost on every third day and fifth day of these months.
The day and night temperature difference in Andaman and Nicobar islands and Kerala is 7°C or 8°C. but in Thar desert the temperature difference between Day and Night is 25°C to 30°	Most parts of India receive rainfall during June to September. But coastal areas of TamilNadu get rain in the beginning of winter season. These are the regional variations in terms of precipitation.

Tab 1

Factors that control climate of any place

Latitude,

altitude,

pressure and wind system,

distance from the sea,

ocean currents,

relief features

Latitude :

Earth is spherical in shape. Due to the curvature of the earth, the amount of solar energy received is according to latitude. If equator is receiving vertical rays of the sun, gradually when coming towards the pole rays become slanting, so the air temperature decreases from equator to the poles.

India – Tropic of cancer passes through the middle of the country from Rann of kutch in the west and Mizoram in the east. Almost half of the country lies to the south of Tropic of Cancer – Tropical region. Remaining Northern part of India lies in a Sub-Tropical region. So climate of India have the characteristics of Tropical and Sub-tropical climates.

Altitude

There is a decrease of 10C for every 166m rise in height. The atmosphere become less dense and the temperature decrease. Therefore hills are cooler during summer. India is covered by different landforms – Mountains, plateaus and plains. So it results in difference in temperatures.

Himalayas have an average height about 6000m on the other hand if I take coastal plains the maximum elevation winds from central Asia entering the sub-continent, it is because of these mountains the sub-continent experiences comparatively milder winters compared to central Asia. The coastal plains on the other hand create a moderating influence on the climate. This is because of the sea breeze and the land breeze.

Pressure and wind systems

Pressure and surface winds

Upper air circulation

Western cyclonic disturbances and tropical cyclones

Based on the rotation and revolution of the earth and the apparent movement of the sun the front pressure belts have developed on the earth and the surface winds move from high pressure areas to low pressure areas. Some important winds on the earth are easterlies, westerlies, polar winds and monsoon winds.

Two different types of winds blow over India

South -west monsoon winds (Onshore winds, Sea to land)

North -east monsoon winds (Offshore winds, Land to sea)

Deflect

Right in Northern hemisphere

Left in Southern hemisphere

The reason behind is Coriolis force

Coriolis force – it is an apparent force caused by earth's rotation. The earth rotates from west to east at a speed of 1600 km/hr, the coriolis force is responsible for deflecting winds towards right in northern hemisphere and towards left in the southern hemisphere. This is also known as the Ferals law.

The pressure and wind conditions over india are unique. During winter there is a high pressure area north of Himalayas, cold dry winds blow from these regions to the low pressure areas over the oceans to the south. In summer low pressure area develops over the interior Asia and North western India causes a complete reversal of the direction of winds during summer.

They are most from high pressure area over southern Indian Ocean in a south easterly direction crossing the equator and turn right towards the low pressure area over the Indian sub-continent. These are known as south-west monsoon winds and these winds blow over the warm oceans gathering moisture and bringing wide spread rainfall over the main land of India.

The upper air circulation in this region is dominated by westerly flow an important component of this is Jet streams. It refers to winds that flow at a great speed. These jet streams are located approximately over 27-300 N and S lalitude and therefore they are known as sub-tropical westerly jet streams. Over India these jet streams blow south of Himalayas although the year except summer.

Then the western cyclonic disturbances, now these are experienced in north and the North western part of the country and they are brought down by the westerly flow. In summer the sub-tropical westerly jet streams move north of Himalayas with the apparent movement of the sun. And the easterly jet streams called the tropical easterly jet streams blow over peninsular India. This is approximately over 140N during summer months.

Now the western disturbances are weather phenomena brought in by westerly flow from the Mediterranean region. They occur in the months of winter and cause rainfall in North and North western part of India. The moisture in these storms usually originate over the Mediterranean sea and the Atlantic ocean, and they travel towards east. Although the amount of rainfall is meager it is highly beneficial to rabi crops especially wheat, now the same winds cause snowfall in the mountains.

Distance from the Sea

Now the sea exerts a moderating influence on climate.

During the day time both the land and sea gets heated. The land gets heated more than the sea, so at land the temperature is high, pressure is low and in water bodies temperature is relatively low, pressure is high. So wind starts blowing from sea to land (SEA BREEZE)-coastal area.

At night land gets cooler than the sea, so at the land the temperature is low and the pressure is high, so the wind starts blowing from land towards sea (LAND BREEZE)

Relief Features

Relief is variations in height (Climate of a place)

In Mountain – Relief is high

In Plateau / plains – Relief is relatively low.

High barriers for cold and hot winds cause precipitation if high enough to lie in path of rain bearing winds.

Leeward side of the mountains remains dry. The Western Ghats obstructs the south west monsoon winds and they are responsible for heavy rainfall along the western coast.

Deccan plateau form the leeward side, where there is relatively low rainfall.

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF ARCHITECTURE

UNIT 3 – Thermal property of building envelope – SAR1204

- TEMPERATURE
- HEAT & SPECIFIC HEAT
- CONDUCTIVITY AND RELAVANCE OF DENSITY
- CONDUCTANCE AND SURFACE CONDUCTANCE
- TRANSMITTANCE
- CAVITIES
- CONVECTION
- RADIATION
- SOL AIR TEMPERATURE
- SOLAR GAIN FACTOR

a) **TEMPERATURE**
   - It is an outward appearance of the thermal state of a body
   - Measured in *CELCIUS SCALE*
   - Temperature of an object is **º c** but an interval or difference is **deg C**
   - Absolute Zero kelvin = -273.15ºC

b) **HEAT**
   - It is a form of energy with certain electromagnetic radiation (700-10000nm)
   - Measured in *joules (J)*
   - 1 BTU = 1055.06J

c) **SPECIFIC HEAT**
   - Amount of heat energy necessary to cause unit temperature increase of a unit mass of substance
   - Measured in j/kg degC

d) **LATENT HEAT**
   - Is the amount of heat energy absorbed by unit mass of the substance at change of state without any change in temperature
   - Measured in *j/kg*
   - *Latent heat of water*
   - *Of fusion 0º C ice to water = 335 kj/kg*
   - *Of evaporation 100ºC = 2261kj/kg*

e) **CONDUCTIVITY AND RELAVANCE OF DENSITY**
   - The rate of **heat flow through** varies with different material and is described as a property of the material - its thermal conductivity or k-value
   - Conductivity is defined as the rate of heat flow through unit area of unit thickness of the material when there is unit temperature difference between the two sides.
   - The unit of measurement is W/m deg C
   - Its value varies between 0.03 W/m deg C for insulating materials and up to 400 W/m deg C for metals
   - The lower the conductivity the better the insulator a material is.
   - Resistivity is the reciprocal of this quantity (1/k) measured in units of m degC/W. Better insulators will have higher resistivity values.
   - **Density** is often an indicator of conductivity, higher density materials have higher k-value but it might not always be true.

- The relationship is due to the fact that air has very low conductivity value , and as lightweight materials tend to be porous, thus containing more air, their conductivity tends to be less.

f) **CONDUCTANCE AND SURFACE CONDUCTANCE**

- Conductance is the heat flow rate through a unit area of the body when the temperature difference between the two surfaces is 1 deg C. The unit measurement is W/m2 degC
- Thermal conduction is the process of heat transfer from one part of a body at a higher temperature to another (or between bodies in direct contact) at a lower temperature.
- This happens with negligible movement of the molecules in the body, because the heat is transferred from one molecule to another in contact with it.
- While conductivity and resistivity are properties of a material, the corresponding properties of body of a given thickness are described as conductance (C) or its reciprocal, resistance (R): C=1/R
- **Resistance** of a body is the product of its thickness and the resistivity of its material and its unit measurement is m2 deg C/W
- R=bx1/k= b/k where b is the thickness in meters.

g) **SURFACE CONDUCTANCE**

- In addition to the resistance of a body to the flow of heat, a resistance will be offered by its surfaces, where a thin layer of film separates the body from the surrounding air.
- A measure of this is the surface or film resistance, denoted by 1/f (m2 deg C/W) f being the surface or film conductance (W/m2 deg C)
- Surface conductance includes the convective and the radiant components of the heat exchange at surfaces.
- If the heat flow from air on one side through the body, to air or the other side is considered, both surface resistances must be taken in to account.
- The overall air-to-air resistance (R_a)is the sum of the body's resistance and the surface resistances.

$R_a = 1/f_i + R_b + 1/f_0$

where $1/f_i$= internal surface resistance

R_b = Resistance of the body

$1/f_0$ =External surface resistance

h) **TRANSMITTANCE**

- The reciprocal of this air-to -air resistance is the air-to-air transmittance or U-value
    - $U=1/R_a$
- Its unit of measurement is the same as for conductance - W/m2 degC.
- This is the quantity most often used in building heat loss and heat gain problems, as its use greatly simplifies the calculations.

THERMAL COMFORT FACTORS AND INDICES

- TEMPERATURE
- HEAT & SPECIFIC HEAT
- CONDUCTIVITY AND RELAVANCE OF DENSITY
- CONDUCTANCE AND SURFACE CONDUCTANCE
- TRANSMITTANCE

- CAVITIES
- CONVECTION
- RADIATION
- SOL AIR TEMPERATURE
- SOLAR GAIN FACTOR

CAVITIES

- If an air space or cavity is enclosed within a body, through which heat transfer is considered, this will offer another barrier to the passage of heat.
- It is measured as the cavity Resistance (R_c).
- The reciprocal of this value is the cavity conductance.
- Almost the value for an empty cavity may be the sum of internal and external surface resistances. It is less if the cavity is less than 50 mm or if strong convection currents can develop inside the cavity.
- An unventilated cavity is a good insulator (R=0.15 m^2degC/W),equal to about 180 mm brick wall.
- The inner leaf of the wall should be the main mass (eg.230mm brick wall) as the insulation should happen outside the main mass and the outer leaf should be the lesser dense mass (ex hollow blocks) reducing the conductivity thereby improving insulation

CONVECTION

- Convection (The transfer of heat by bodily movement of a carrying medium), may be due to thermal forces alone (Self generating) or may be propelled by an applied force.

- The rate of transfer in convection depends on three factor:

    - Temperature difference
- The rate of movement of the carrying medium in terms of kg/s or m3/s
- The specific heat of the carrying medium in J/kg deg C or J/m3 deg C
- These quantities will be used in ventilation heat loss or cooling calculations.

RADIATION

- The rate of heat flow depends on temperatures of the emitting and receiving surfaces and on certain qualities of these surfaces - *the emittance and absorbance.*
- Radiation received by a surface can be partly absorbed and partly reflected: the proportion of these two components is expressed by the coefficients absorbance (a) and reflectance (r) .The sum of these two coefficients is always 1
- Light coloured ,smooth and shiny surfaces tend to have a high reflectance and dark surfaces tend to have high absorbance.
- The theoretical white body is a perfect reflector with coefficients a=0 and r=1 while the theoretical black body is a perfect absorber with coefficients a=1 and r=0
- The practical significance of this is that both light coloured surface and dark coloured surface when exposed to solar radiation will reflect and absorb same amount of heat but the light coloured surface will re-emit much of the absorbed heat where as the dark surface will not and therefore will attain a high temperature.

SOL AIR TEMPERATURE

- In the design of buildings, for surfaces exposed to solar radiation, to calculate heat gain, it is useful to combine the heating effect of radiation incident on the building with the effect of warm air. This can be done using the sol-air temperature concept.
- A temperature value is found out which would create the same thermal effect as the incident radiation in question and this value is added to the air temperature.
    - **$T_s = T_o + (I \times a) / f_o$**
    - Where T_s = Sol-air temperature in ^0C
    - T_o = Outside temperature in ^0C
    - I = Radiation intensity in W/m^2
    - a = absorbance of the surface
    - f_o= Surface conductance (outside) in W/m^2 deg C

SOLAR GAIN FACTOR (θ)

- Solar gain factor(θ) is defined as the heat flow rate through the construction due to solar radiation expressed as a fraction of the incident solar radiation.
- It is expressed as $q / I = (a \times U) / f_o$ (Non dimensional)
    - where q= Extra heat flow rate per unit area cause by radiation
    - U= Transmittance value in W/m^2 degC.
    - I = Radiation intensity in W/m^2
    - a = absorbance of the surface
    - f_o = Surface conductance (outside) in W/m^2 deg C
    - The lesser the solar gain factor the lesser the heat transfer through windows or openings.

TRANSFER OF HEAT

- The heat exchange processes with the outdoor environment happens in the following ways
- **Conduction** of heat may occur through the walls either inwards or outwards the rate of which will be denoted as **Qc**
- The effects of **solar radiation** on opaque surface can be included in the above by using sol-air temperature concept, but through transparent surface the solar heat gain must be considered separately and denoted **Qs**
- Heat exchange in either direction may take place with the **movement of air** .i.e ventilation and the rate of this will be denoted as **Qv**
- An **internal heat gain** may result from the heat output of human bodies, lamps, motors and appliances. This may be denoted as **Qi**
- There may be a deliberate introduction or removal of heat using some form of outside energy supply. The heat flow rate of such **mechanical controls** may be denoted as **Qm**
- **Evaporation** takes place on the surface of the building or within the building and the vapours are removed this will produce a cooling effect, the rate of which will be denoted as **Qe**
- The thermal balance equation is
- Qi + Qs(+ or –) Qc (+ or –) Qv (+ or –) Qm - Qe = 0
- If the sum of above equation is less than zero ,the building will be cooling and if it is more than zero the temperature in the Building will increase.

Conduction heat flow rate

Conduction heat flow rate through a wall or mass of a given area can be described by the equation

$Q_c = A \times U \times \Delta T$

where Q_c =Conduction heat flow rate

A= Surface area in m^2

U= Transmittance value,in W/m^2 deg C

ΔT= Temperature difference

If heat loss from a building is considered $\Delta T = T_i - T_o$

If heat gain is considered $\Delta T = T_o - T_i$

(ex:Heat transfer in a bedroom from the common wall between a kitchen and a bed room)

If a surface is exposed to solar radiation $\Delta T = T_s - T_i$

where T_s is sol-air temperature .

Convection

Convection heat flow rate between the interior of a building and the open air,depends on the rate of ventilation, i.e. air exchange.

This may be an unintentional air infiltration or deliberate ventilation.

The rate of ventialtion may be given in m^3/s and the rate of ventialtion heat flow is given by the following equation

$Q_v = 1300 \times V \times \Delta T$

Where Q_v = Ventilation heat flow rate,in W

1300 = Volumetric specific heat of air ,J/ m^3 deg C

V= Ventilation rate in m^3/s

T= temperature difference, deg C

If the number of air changes per hour (N) is given the ventilation rate can be found as:

Radiation through windows:

To get heat flow rate through a window,the intensity of solar radiation (I) incident on the plane of window is multiplied by the area of aperture (m^2) .This will be the heat flow rate through an unglazed aperture.

For glazed windows this value will be reduced by solar gain factor (θ) which depends on the quality of glass and on the angle of incidence.

The solar heat flow equation is

$Q_s = A \times I \times \theta$

where A= area of window in m^2

I=radiation heat flow density ,in W/m2

θ= Solar gain factor of window glass.

Internal Heat gain

The heat output rate of human bodies has been given in 2.1.2. Heat output from a body (inside the building) is a heat gain for the building. Thus the heat output rate appropriate to the activity to be accommodated must be selected and multiplied by the number of occupants. The result, in watts, will be a significant component of Q_i.

The total rate of energy emission of electric lamps can be taken as internal heat gain. The larger part of this energy is emitted as heat (95% for incandescent lamps and 79% for fluorescent lamps) and the part emitted as light, when incident on surfaces, will be converted into heat. Consequently the total wattage of all lamps in the building (if and when in use) must be added to the Q_i

Activity	watts
Sleeping	min. 70
Sitting, moderate movement, e.g. typing	130–160
Standing, light work at machine or bench	160–190
Sitting, heavy arm and leg movements	190–230
Standing, moderate work, some walking	220–290
Walking, moderate lifting or pushing	290–410
Intermittent heavy lifting, digging	440–580
Hardest sustained work	580–700
Maximum heavy work for 30-minutes duration	max. 1100

(Average values of data published in many sources)

Heating and cooling (Mechanical Controls)

The heat flow rate of these systems is subject to the designer's intentions and it is deliberately controllable. It can thus be taken as a dependent variable in the equation, i.e. it can be adjusted according to the balance of the other factors.

3.2.7 Evaporation

The rate of cooling by evaporation can only be calculated if the rate of evaporation itself is known. If the evaporation rate is expressed in kg/h, the corresponding heat loss rate can be found:

$Q_e = 666 \times \text{kg/h}$

as the latent heat of evaporation of water around 20°C is approximately 2400 kJ/kg, this gives:

$$2400000 \text{ J/h} = \frac{2400000}{3600} \text{ J/s} = 666 \text{ W}$$

PERIODIC HEAT FLOW

- In nature the diurnal variations produce an approximately repetitive 24 hour cycle of increasing and decreasing temperature.
- The effect of this on a building is that in hot period the heat flows from the environment in to the building, where some of it is stored and at night during cool period the heat flow is reversed from the building to the environment. As this cycle is repetitive it is described as ***PERIODIC HEAT FLOW***
- In the morning the outdoor temperature increases ,heat starts entering the outer surface of the wall. Each particle in the wall will absorb a certain amount of heat for every degree of rise in temperature depending on the specific heat of the wall material. Heat to the next particle will only be transmitted after the temperature of the first particle has increases. Thus the corresponding increase of the internal temperature will be delayed.
- The out door temperature will have reached its peak and started decreasing before the inner surface temperature has reached the same level. From this moment the heat stored in the wall will be partly dissipated to the outside on partly to the inside. As the out door air cools ,an increasing proportion of this stored heat flows outwards and when the temperature falls below the indoor temperature the direction of heat flow is completely reversed.

PERIODIC HEAT FLOW CALCULATION

The steady state equation $Q = A \times U \times {}_{\Delta}T$ can be used to find the balance of heat flow or average heat flow rate over a full cycle in a periodically changing thermal regime. To find the momentary rate of heat flow, it can only be used if the wall or element considered has a negligible thermal capacity.

If the indoor temperature is assumed to be constant (a reasonable assumption in controlled environments), the momentary rate of flow can be calculated fairly simply if it is split in two parts:

a first, the average heat flow rate is found for the full cycle (one day), using the steady state equation, except that the temperature difference is taken between the daily mean out-door temperature and the indoor temperature:

$Q' = A \times U \times (T_m - T_i)$

b the momentary deviation from the average heat flow rate is found: if the time-lag of the wall is ϕ hours, then the heat flow *now* will depend on the out-door temperature φ hours *previously:* T_ϕ The deviation is found by using a temperature difference value between this T_φ and the mean. The transmittance, or U-value, is modified by the decrement factor (μ).

$Q'' = A \times U \times (T_\phi - T_m)$

The two equations can be added to get the equation describing the periodic heat flow rate:

$Q = A \times U \times [(T_m - T_i) + \mu(T_\phi - T_m)]$

where Q = momentary heat flow rate in W
- A = area in m^2
- U = transmittance, W/m^2 degC
- T_m = daily mean out-door temperature, °C
- T_i = indoor temperature (constant), °C
- T_ϕ = out-door (sol-air) temperature
- ϕ hours earlier, °C
- μ = decrement factor
- ϕ = time-lag in hours

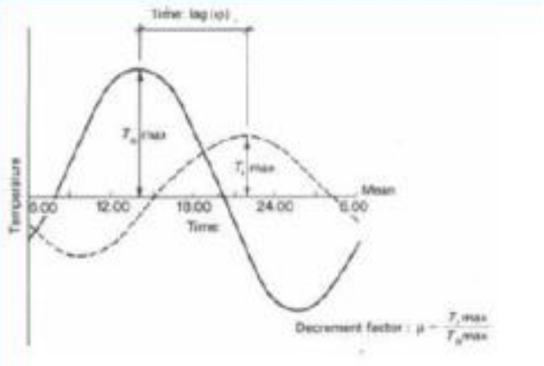

Fig 41 Time-lag and decrement factor

HEAT GAIN AND LOSS

3.2.9 Heat gain calculation

Heat gain is usually calculated for the purposes of air conditioning design. It is obvious tha installation should cope with the warmest conditions at its peak capacity. Again, the hig temperature for 90% of the time is taken as 'design out door temperature' and a solar radi intensity is taken on similar grounds.

3.2.8 Heat loss calculation

The purpose of heat loss calculation is usually for the design of a heating installation. Hea rate for a condition which is the coldest for 90% of the time is calculated,heating installati then designed to produce heat at the same rate.

Under less severe conditions the installation can work with a reduced output, Colder conditio in the remaining 10% of the time normally occur in short spells and may be bridged by the therm inertia of the building (see Section 3.3) and by an 'overload capacity' of the installation. In the U it is usual to take –1 °C or 0°C as the 'design out-door temperature' (T_o).

HEAT GAIN AND LOSS CALCULATION

The calculation method is best illustrated by a simple example:

a 5 × 5 m and 2.5 m high office is located on an intermediate floor of a large building, therefo it has only one exposed wall facing south, all other walls adjoin rooms kept at the san temperature: $T_i = 20$ °C

the ventilation rate is three air changes per hour,

three 100 W bulbs are in continuous use to light the rear part of the room, which is used by fo clerical workers.

The exposed 5 × 2.5 m wall consists of a single glazed window, 1.5 × 5 m = 7.5 m^2 U = 4.4 W/m^2 degC

and a clinker concrete spandrel wall, 200 mm, rendered and plastered, 1 × 5m = 5m^2 U = 1.3 W/m^{2}degC

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Heat gain is usually calculated for the purposes of air conditioning design. It is obvious tha installation should cope with the warmest conditions at its peak capacity. Again, the hig temperature for 90% of the time is taken as 'design out door temperature' and a solar radi intensity is taken on similar grounds.

The above example will be used, except:

T_o = 26°C and the incident radiation	(I) = 580 W/m^2
absorbance of the wall surface	a = 0.4
surface conductance	f_o = 10W/m^{2}degC
solar gain factor for window	θ = 0.75

Solution:

Temperature difference ($_\Delta T$) = 26°C – 20°C = 6 degC for conduction through the window an ventilation heat flow, but for the opaque surface the sol-air temperature must be found 3.1.18):

$$T_s = 26 + \frac{580 \times 0{\cdot}4}{10} = 26 + 23{\cdot}2 = 49{\cdot}2\,^\circ\mathrm{C}.$$

Thus for the spandrel wall $_\Delta T$ = 49 – 20°C = 29 degC.

$Q_c = (7.5 \times 4.48 \times 6) + (5 \times 1.35 \times 29)$

$= (33.60 \times 6) + (6.75 \times 29) = 201.6 + 195.75$ = 397 W

$Q_s = 7.5 \times 580 \times O.75 =$ 3270 W

$Q_v = 1\ 300 \times 0.052 \times 6 =$ 405 W

$Q_i =$ (as before) 860 W

No evaporation loss is considered, thus the thermal balance equation is (see 3.2.1):

$Q_i + Q_s + Q_c + Q_v + Q_m = 0$

substituting the calculated values:

$860 + 3270 + 397 + 405 + Q_m = 0$

$4932 + Q_m = 0$

$Q_m = -4932$ W

The air conditioning system must be capable of removing heat at this rate, or, rounded up, 5 kW

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and a clinker concrete spandrel wall, 200 mm, rendered and plastered, 1 × 5m = 5m^2 U = 1.3 W/m^{2}degC

Solution:

Temperature difference ($_\Delta T$) = 20°C – (–1 °C) = 21 degC.

$Q_c = (7.5 \times 4.48 + 5 \times 1.35)21$
$= (33.60 + 6.75)21 = 40.35 \times 21 = \underline{847\ W},$

the volume of the room is 5 ×5 × 2.5 m = 62.5 m^3.

Thus the ventilation rate is:

$$\frac{62{\cdot}5 \times 3}{3600} = \frac{187{\cdot}5}{3\,600} = 0{\cdot}052\ m^3/s$$

$Q_v = 1300 \times O.052 \times 21 = \underline{1420\ W}$

The three light bulbs and four persons produce:

$Q_i = 3 \times 100 + 4 \times 140 = 300 + 560 = \underline{860\ W}$

As no solar radiation and no evaporative loss are considered (see 3.2.1), the thermal bal equation is:

$Q_i - Q_c - Q_v + Q_m = 0$

substituting the calculated values:

$860 - 847 - 1420 + Q_m = 0$

$-1407 + Q_m = 0$

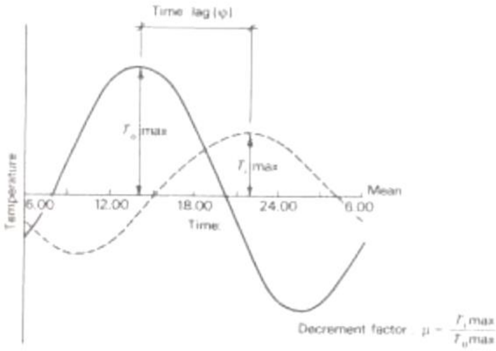
$Q_m = 1407$ W

The heating installation should provide heat at this rate, or, rounded up, at the rate of 1.5 kW.

THERMAL MASS AND THERMAL CAPACITY

- The thermal mass of the house is a measure of its capacity to store and regulate internal heat. Buildings with a high thermal mass take a long time to heat up but also take a long time to cool down.
- As a result they have a very steady internal temperature. This is sometimes called the thermal flywheel effect because, like a flywheel, the thermal mass can store and even out fluctuations in temperature.
- Buildings with a low thermal mass are very responsive to changes in internal temperature - they heat up very quickly but they also cool down quickly. They are often subject to wide variables in internal temperature.
- Everything inside the house contributes to its thermal mass according to its capacity to absorb and store heat, known as its 'thermal capacity'.
- The best materials for storing heat are those that are very dense, heat up slowly, and then give out that heat gradually. Brick, concrete and stone have a high thermal capacity and are the main contributors to the thermal mass of a house.
- Water has a very high thermal capacity, so it is well suited for climates that have high diurnal variations. Air has a very low thermal capacity - it warms up fast but cannot stay warm for long.

TIME LAG AND DECREMENT FACTOR



- The two quantities characterizing this periodic change are time lag (Ø) and decrement factor (µ)
- The time delay due to the thermal mass is known as a time lag (Ø). The thicker and more resistive the material, the longer it will take for heat waves to pass through.
- The reduction in cyclical temperature on the inside surface compared to the outside surface is knows and the decrement(µ).

TRANSMITTANCE OF COMPOSITE WALLS

THERMAL GRADIENTS

- In some cases (e.g. for the prediction of condensation) it will be necessary to know the temperature at any point within the wall, i.e. the thermal gradient through the wall, or other constructional elements.
- Wall analysis, assuming internal temperature (T_i = 20^{0}C)

  the outdoor temperature(T_o = 0^0 C)

Draw a cross-section of the wall (Figure 40) to a scale representing the resistance individual layers, instead of the thicknesses. A scale of 1 mm =0.01 m^2 degC/W will be thus the external surface resistance is represented by 7.6 mm and the resistance of the brick shown as 9.9 mm, etc. Alongside this, draw a cross-section of the wall to a physical sc :10.

Set up a temperature scale vertically, which is to apply to both sections (3 mm = 1 degC

Establish the T_o and T_i points at the faces of the resistance section, and connect these poi a straight line. The intersection points of this line with the various layers can now be p across horizontally to the corresponding layers of the physical section. A line connecting th thus derived will represent the thermal gradient through the wall.

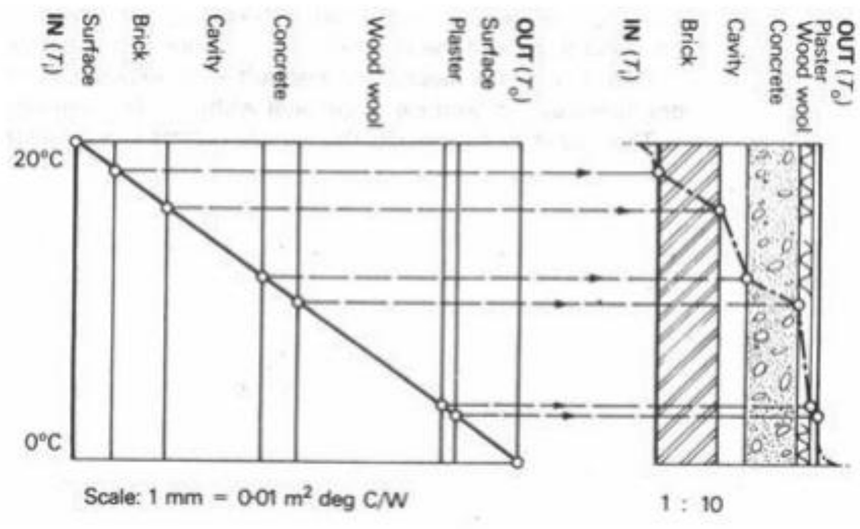


Fig 40   Temperature gradient through a composite wall

(not to scale)

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SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF ARCHITECTURE

UNIT 4 – Ventilation and Day lighting – SAR1204

UNIT IV : Ventilation and Day lighting

FUNCTIONS OF VENTILATION

- It has three distinctly different functions:
  - supply of fresh air
  - convective cooling
  - physiological cooling
- There is a radical difference in the form of provisions for 1 and 2 and for 3: therefore, the first two functions will be considered as ‘ventilation’ but the last function is considered separately as ‘air movement’

SUPPLY OF FRESH AIR

- The requirements of fresh air supply are governed by the type of occupancy, number and activity of the occupants and by the nature of any processes carried out in the space
- For natural ventilation usually certain limited solutions are prescribed and not the expected performance. The provision of ‘permanent ventilators’, i.e. of openings which cannot be closed, may be compulsory. These may be grilles or ‘air bricks’ built into a wall, or may be incorporated with windows. The size of open-able windows may be stipulated in relation to the floor area or the volume of the room.
- The aim of all these rules is to ensure ventilation, but the rigid application of such rules may often be inadequate. To ensure a satisfactory performance of the principles involved must be clearly understood.
- Window wall ratio – 1 : 3

CONVECTIVE COOLING

- The exchange of indoor air with fresh out-door air can provide cooling, if the out-door air is at a lower temperature than the indoor air. The moving air acts as a heat carrying medium.
- A situation where this convective cooling is a practical proposition, can arise in moderate or cold climates, when the internal heat gain is causing a temperature increase, but also in warm climates, when the internal heat gain or solar heat gain through windows would raise the indoor temperature even higher than the out-door air temperature.

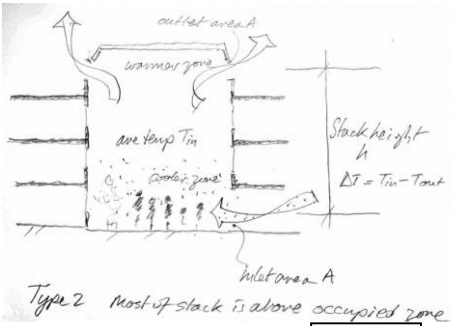


Fig 1

FUNCTIONS OF VENTILATION

- Ventilation i.e. both the supply of fresh air and convective cooling, involves the movement of air at a relatively slow rate. The motive force can be either thermal or dynamic (wind).

- The stack effects relies on thermal forces, set up by density difference (caused by temperature differences) between the indoor and out-door air. It can occur through an open window (when the air is still): the warmer and lighter indoor air will flow out at the top and the cooler, denser out-door air will flow in at the bottom.

- Special provision can be made for it in the form of ventilating shafts. The higher the shaft and the larger the cross-sectional area will have the greater temperature difference: the greater the motive force therefore, the more air will be moved.

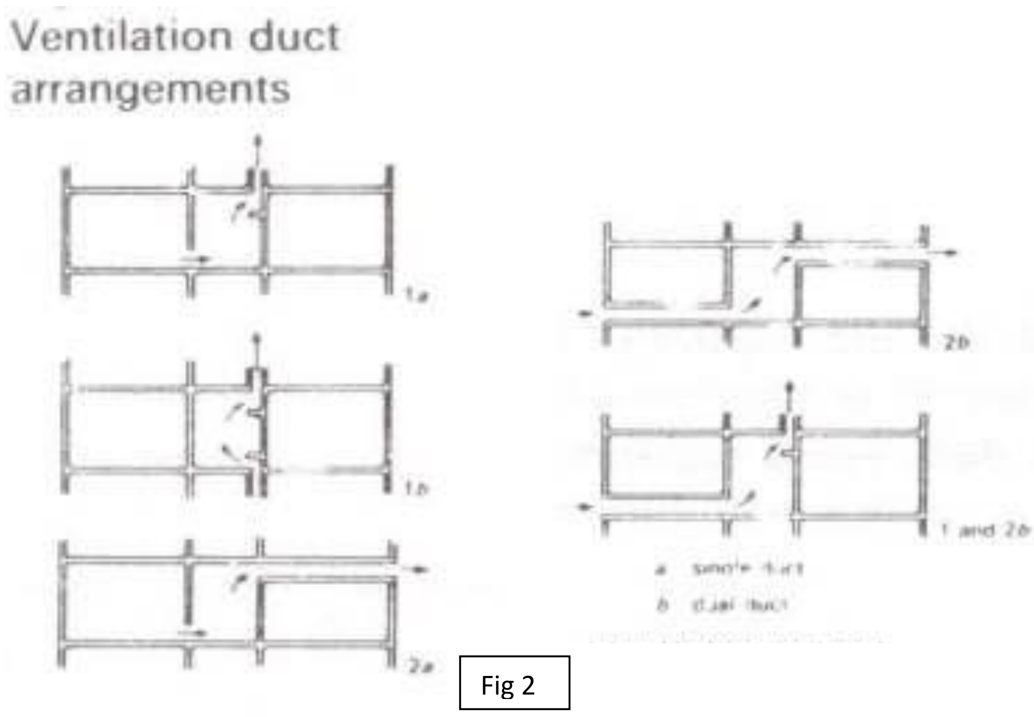


Fig 2

PHYSIOLOGICAL COOLING

- The movement of air passing the skin surface accelerates heat dissipation in two ways
    - increasing convective heat loss
    - Accelerating evaporation
- In very low humidities (below 30%) this cooling effect is not great, as there is an unrestricted evaporation even with very light air movement. In high humidities (above 85%) the cooling effect is restricted by the high vapour pressure preventing evaporation greater velocities (above 1.5 to 2 m/s) will have some effect.
- It is most significant in medium humidities (35 to 60%). Cooling by air movement is most needed where there are no other forms of heat dissipation available, when the air is as warm as the skin and the surrounding surfaces are also at a similar temperature.

WIND SHADOW

- Air – although light – has a mass (around 1.2 kg/m3), and as it moves, has a momentum, which is the product of its mass and its velocity(kg m/s). When moving air strikes an obstacle such as a building this will slow down the air flow, but the air flow will exert a pressure on the obstructing surface. This pressure is proportionate to the air velocity, as expressed by the equation
    - $Pw = 0.612 \times v^2$
- Where Pw = wind pressure in N/m2, V = wind velocity in m/s (the constant is Ns^2/m^4)

➢ The slowing down process effects a roughly wedge-shaped mass of air on the windward side of the building, which in turn diverts the rest of the air flow upwards and sideways. A separation layer is formed between the stagnant air and the building on the one hand and the laminar air flow on the other hand. The laminar air flow itself may be accelerated at the obstacle, as the area available for the flow is narrowed down by the obstacle. As shown in the fig.

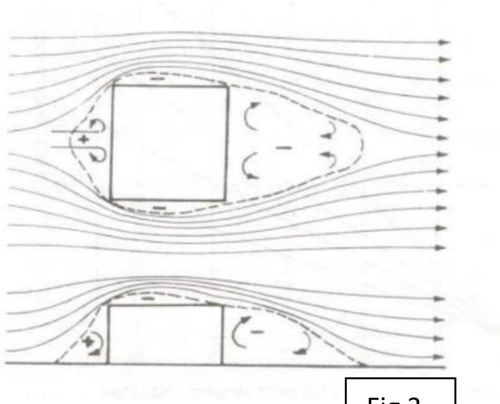


Fig 3

➢ At the separation layer, due to friction, the upper surface of the stagnant air is moved forward, thus a turbulence or vortex is developed. Due to its momentum, the laminar air flow tends to maintain a straight path after it has been diverted, therefore it will take some time to return to the ground surface after the obstacle, to occupy all the available 'cross-section'. Thus a stagnant mass of air is also formed on the leeward side, but this is at a reduced pressure. In fact, this is not quite stagnant: a vortex is formed, the movement is light and variable and is often referred to as **'WIND SHADOW'.**

WIND PRESSURE

➢ Consequently vortexes are formed wherever the laminar flow is separated from the surfaces of solid bodies. On the windward side such vortexes are at an increased pressure and on the leeward side at a reduced pressure. If the building has an opening facing a high pressure zone and another facing a low pressure zone, air movement will be generated through the building.

THE WIND ROSE

➢ Wind speed frequency diagrams do not provide information on the direction that the wind is blowing. This is often done by a graph called a "wind rose."

➢ A wind rose is a polar plot giving the direction, magnitude, and cube of the magnitude of the wind. The data is usually averaged over a year. In some cases, shorter time periods, such as months, may be appropriate.

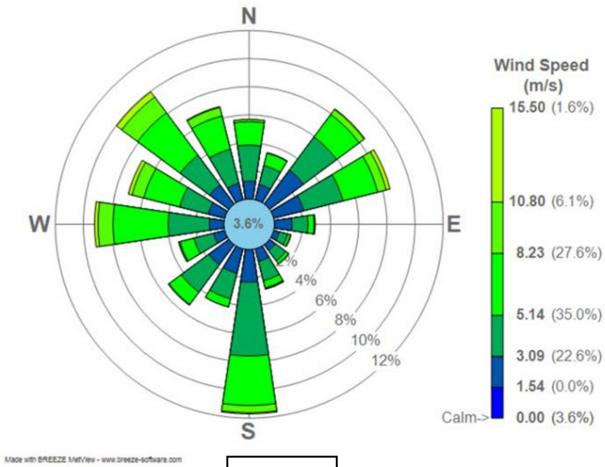


Fig 4

AIR FLOW THROUGH BUILDINGS

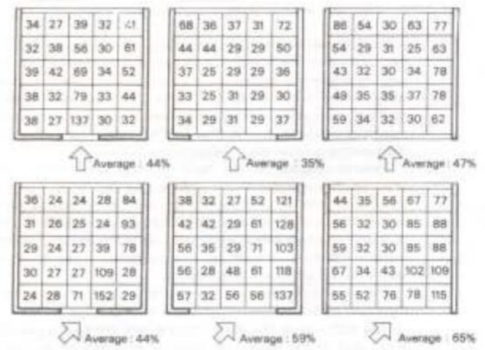
➢ As no satisfactory and complete theory is available, air flow patterns can only be predicted on the basis of empirical rules derived from measurements in actual buildings or in wind tunnel studies.

➢ On the basis of such experimental observations the following factors can be isolated which affect the indoor air flow (both patterns and velocities) :

- Orientation
- External features
- Cross-ventilation
- Position of openings

- o Size of openings
- o Controls of openings

ORIENTATION



- ➢ The greatest pressure on the windward side of a building is generated when the elevation is at right angles to the wind direction, so it seems to be obvious that the greatest indoor air velocity will be achieved in this case. A wind incidence of 45⁰ would reduce the pressure by 50%.
- ➢ Thus the designer must ascertain the prevailing wind direction from wind frequency charts of wind rose and must orientate his building in such a way that the largest openings are facing the wind direction.
- ➢ It has, however, been found that a wind incidence at 45⁰ would increase the average indoor air velocity and would provide a better distribution of indoor air movement.
- ➢ It often happens that the optimum solar orientation and the optimum orientation for wind do not coincide. In equatorial regions a north-south orientation would be preferable for sun exclusion but most often the wind is predominantly easterly.
- ➢ The usefulness of the above findings is obvious for such a situation – it may resolve the contradictory requirements.

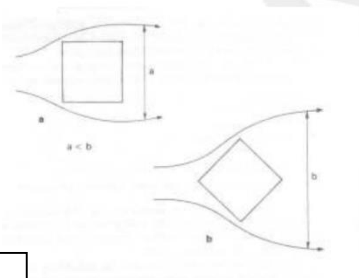


Fig 5

Effect of direction on width of wind shadow

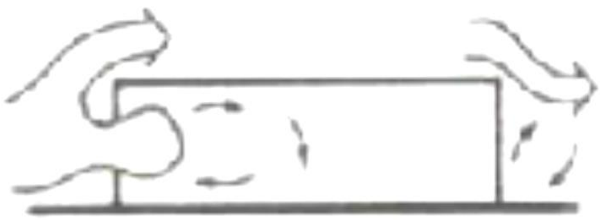
EXTERNAL FEATURES

- ➢ Wind shadows created by obstructions upwind, should be avoided in positioning the building on the site and in positioning the openings in the building. The wind velocity gradient is made steeper by an uneven surface, such as scattered buildings, walls fences, trees or scrub – but even with a moderate velocity gradient, such as over smooth and open ground, a low building can never obtain air velocities similar to a taller one.
- ➢ For this reason (or to avoid specific obstructions) the building is often elevated on stilts. External features of the building itself can strongly influence the pressure build-up. For example, if the air flow is at 45⁰ to an elevation, a wing-wall at the downwind end or a projecting wing of an L-shaped building can more than double the positive pressure created.
- ➢ A similar '**funnelling'** effect can be created by upward projecting eaves. Any extension of the elevational area facing the wind will increase the pressure build-up. If a gap between two buildings is closed by a solid wall, a similar effect will be produced.
- ➢ The air velocity between free-standing trunks of trees with large crowns can be increased quite substantially due to similar reasons. The opposite of the above means will produce a reduction of pressures: if a wing wall or the projecting wing of an L-shaped building is upwind from the opening considered, the pressure is reduced or even a negative pressure may be created in the front of the window.

CROSS VENTILATION

- ➢ Figure shows that in the absence of an outlet opening or with a full partition there can be no effective air movement through building even in case of strong winds. With a windward opening and no outlet, a pressure similar to that in front of the building will be built up indoors, which can make condition even worse, increasing discomfort.

- In some cases oscillating pressure changes, known as ‘buffeting’ can also occur. The latter may also be produced by an opening on the leeward side only, with no inlet. Air flow loses much of its kinetic energy each time it is diverted around or over an obstacle.
- Several right angle bends, such as internal walls or furniture within a room can effectively stop a low velocity air flow . Where internal partitions are unavoidable, some air flow can be ensured if partition screens are used, clear of the floor and the ceiling.



POSITION OF OPENINGS

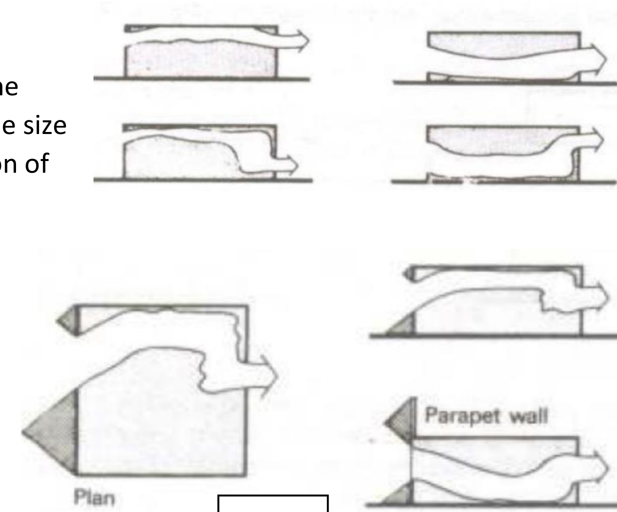


Fig 6

- The relative magnitude of pressure build-up in front of the solid areas of the elevation (which in turn depends on the size and position of openings) will, in fact, govern the direction of the indoor air stream and this will be independent of the outlet opening position.
- Figure shows that Larger solid surface creates a larger pressure build-up and this pushes the air stream in an opposite direction, both in plan and in section.
- To be effective, the air movement must be directed at the body surface. In building terms this means that air movement must be ensured through the space mostly used by the occupants: through the ‘living zone’ (up to 2m high).
- As the figure shows If the opening at the inlet side is at high level, regardless of the outlet opening position, the air flow will take place near the ceiling and in the living zone.
- As a result of this, in a two storey building the air flow on the ground floor may be satisfactory but on the upper floor it may be directed against the ceiling. One possible remedy is an increased roof parapet wall.

SIZE OF OPENINGS

- With an given elevational area – a given total wind force(pressure x area) – the largest air velocity will be obtained through a small inlet opening with a large outlet.
- This is partly due to the total force acting on a small area, forcing air through the opening at a high pressure and partly due to the ‘venturi effect’: in the broadening funnel (the imaginary funnel connecting the small inlet to the large outlet) the sideways expansion of the air jet further accelerates the particles.
- Such an arrangement may be useful if the air stream is to be directed (as it were focused) at a given part of the room. When the inlet opening is large, the air velocity through it will be less, but the total rate of air flow (volume of air passing in unit time) will be higher.

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CONTROLS OF OPENINGS

- **Sashes, canopies, louvers and other elements controlling the openings, also influence the indoor air flow pattern.**
- Sashes can divert the air flow upwards. Only a casement or reversible pivot sash will channel it downwards into the living zone.

Effect of sashes

- Canopies can eliminate the effect of pressure build-up above the window, thus the pressure below the window will direct the air flow upwards. A gap left between the building face and the canopy would ensure a downward pressure, thus a flow directed into the living zone.
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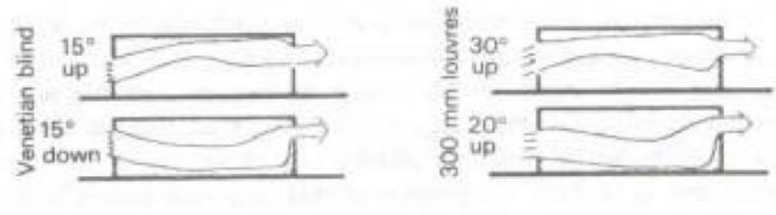
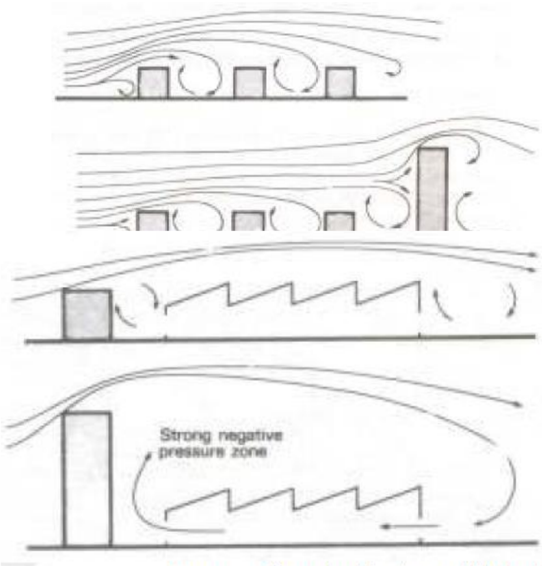


Effect of louvres



Reverse flow behind a tall block

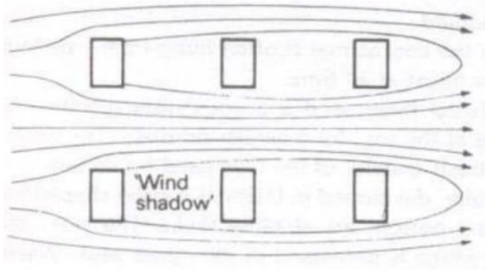
Fig 7

AIR FLOW AROUND BUILDINGS

- When the architect's task is the design of more than one building, a cluster of buildings or a whole settlement, especially in a warm climate, in deciding the layout, provision for air movement must be one of the most important considerations. After a careful analysis of site climatic conditions a design hypothesis may be produced on the basis of general information derived from experimental findings, such as those described below.
- If there are tall blocks in mixed developments air stream separates on the face of a tall block, part of it moving up and over the roof part of it down, to form a large vortex leading to a very high pressure build-up. An increased velocity is found at ground level at the sides of the tall block. This could serve a useful purpose in hot

climates, although if the tall block is not fully closed but is permeable to wind, these effects may be reduced.

- If a low building is located in the wind shadow of a tall block, the increase in height of the obstructing block will increase the air flow through the low building in a direction opposite of that wind. The lower (return-) wing of a large vortex would pass through the building
- If single storey buildings are placed in rows in a grid-iron pattern, stagnant air zones leeward from the first row will overlap the second row.
- A spacing of six times the building height is necessary to ensure adequate air movement for the second row.
- In a similar setting, if the buildings are staggered in a checker-board pattern, the flow field is much more uniform, stagnant air zones are almost eliminated.



Air flow grid-iron layout

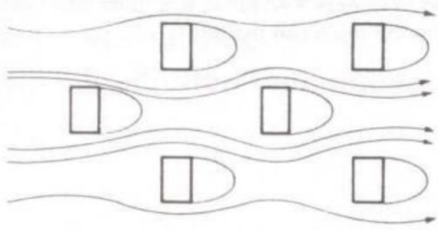

Air flow checker-board layout

Fig 8