

CLIMATE RESPONSIVE ARCHITECTURE

HANDLED BY C. PRADEEPA, ASSISTANT PROFESSOR.



GLOBAL CLIMATIC FACTORS

GLOBAL PRESSURE & WIND



CLIMATE



- Region with certain conditions of temperature, dryness, wind, light,etc.
- Integration in time of the physical states of the atmosphere environment, characteristic of a certain geographical location.
- Integration in time of weather condition.
- Tropical climate are those where heat is the dominant problem, where for the greater part of the year buildings serve to keep the occupants cool, rather than the warm, where the annual mean temperature is not less than 20C.





SOLAR RADIATION QUALITY



- The earth receives almost all its energy from the sun in the form of radiation, thus the sun is the dominating influence on climate.
 - The spectrum of solar radiation extends from 290 to 2300nm. According to human means of perception we can distinguish:

0

 \bigcirc

- Ultra-violet radiation, 290 to 380 nm, producing photo-chemical effects, bleaching, sun burn, etc.
- Visible light, 380(violet) to 700nm (red)
 - Short infra red radiation, 700 to 2300nm radiant heat with some photo chemical effects.



The spectral energy distribution varies with altitude due to the filtering effect of the atmosphere. Some of the shorter wavelengths are absorbed by the atmosphere and reradiated at much longer wave lengths.eg. Long infrared up to 10000nm



SOLAR RADIATION QUANTITY

- The intensity of radiation reaching the upper surface of the atmosphere is taken as the solar constant.
- The earth moves around the sun in a slightly elliptical orbit.one revolution is completed in 365 days, 5 hours, 48 minutes and 46 seconds.
- This orbit results from the gravitational pull of the sun and centrifugal force due to the earth's inertia and momentum.





TILT OF THE EARTH'S AXIS

- The earth rotates around its own axis, each rotation making one 24 hour day.
- The axis of this rotation is tilted to the plane of the elliptical orbit, at an angle of 66.5 and the direction of this axis is constant.
- Maximum intensity is received on a plane normal to the direction of radiation.
- If the axis of earth were rectangular to the plane of the orbit, it would always be the equatorial regions which are normal to the direction of solar radiation.
- Due to the tilted position, however the area receiving the maximum intensity moves north and south between the tropic of cancer and the tropic Capricorn.
- This is the main cause of seasonal changes.





- On 21 June areas along latitude 23.5N are normal to the sun rays, longest daylight period are experienced.
- latitude 23.5S experiences the shortest day and a radiation minimum.



•When the Sun is vertically above the equator, the day is of equal length all over Earth i.e.on 21 March and 23 September.

RADIATION AT THE EARTH'S SURFACE



- This earth –sun relationship affects the amount of radiation received at a particular point on the earth's surface three ways:
- 1.The cosine law, which states that the intensity on a tilted surface equals the normal intensity times the cosine of the angle of incidence.
- 2. atmospheric depletion, i.e the absorption of radiation by ozone, vapours and dust particles in the atmosphere. The lower the solar altitude angle, the longer the path of radiation through the atmosphere thus a smaller part reaches the earth's surface. This atmospheric depletion is also affected by the momentary state of the atmosphere its purity, vapour, dust, smoke etc., content.
- 3. duration of sunshine, ie the length of the daylight period.





The angle of incidence

THE EARTH'S THERMAL BALANCE



◆The total amount of heat absorbed by the earth each year is balanced by a corresponding heat loss.

♦ Without this cooling the thermal balance of the earth could not be maintained.

♦ The temperature of the earth and its atmosphere would increase and would soon cease to be favourable to most forms of life.







- The earth's surface releases heat by three processes:
- 1. by long-wave radiation to cold outer space.
- 2. by evaporation: the earth's surface is cooled, as liquid water changes into vapour and mixes with air.
- 3. by convection: air heated by contact with warm earthy surface becomes lighter and rises to the upper atmosphere, where it dissipates its heat to space.



Length of path through the atmosphere

WINDS THERMAL FORCE:

- Winds are basically convection currents in the atmosphere tending to even out the differential heating of various zones.
- The patterns of movements is modified by the earths rotation.



• At the maximum heating whe air is heated by the hot surface, it expands its pressure is decreased it becomes lighter, it rises vertically and flows off at a high level towards colder regions.

Part of this air, having cooled down at the high level, descends to the surface in the subtropic regions, from where the cooler heavier air is drawn in towards the equator from both north and south.

- The area where the air rises, where these northerly and southerly winds meet where the tropical front is formed is referred to as the inter tropical convergence zone.
- The area experiences either completely calm conditions or only very light breezes of irregular directions and is referred to by sailors as "doldrums".









TRADE WINDS: THE CORIOLIS FORCE

- The atmosphere rotates with the earth.
- As it is light in weight and behaves as fluid held against the earth's surface only by gravity and friction, it has a tendency to lag behind the earth's rate of rotation where this rotation is the fastest, i.e at the equator.
- There is a "slippage" at the boundary layer between the earth and its atmosphere caused by what is known as" Coriolis Force".



The actual wind is the resultant of thermal forces and the coriolis force north-easterlywinds north of the equator and south-easterly winds south of the equator.these are known as North east and south east trade winds.

POLAR WINDS



- Towards the poles from latitudes 60N and S, the air flow patterns come once more under the influence of thermal factors.
- The pattern is similar to that near the equator.
- Air at the surface moves from the coldest to the slightly warmer regions, i.e away from the poles.
- As the circumferential velocity of air at the poles is almost nil, the air will lag behind the rotating earth as it moves away from the poles.
- The northerly is deflected into northeasterly and the southerly into south-easterly polar winds.





ANNUAL WIND SHIFTS



- During the course of each year the global wind pattern shifts from north to south and back again, remaining broadly symmetrical about the inter tropical convergence zone.
- The location of the ITCZ follows the maximum solar heating,i.e, the zenith path of the sun, with a delay about a month.
- As a consequences of this annual shift most regions of the earth experience seasonal changes not only in temperature but also in wind directions and in rainfall.





INFLUENCE OF TOPOGRAPHY

- On a continental scale, wind and weather are the result of an interaction between broad global flow patterns and regional pressure and temperature patterns created by the sun's differential heating effect on land, forest and water.
- The force, direction and moisture content of air flows are strongly influenced by topography.
- Air can be diverted or funneled by mountain ranges.
- Air flow deflected upwards, as it cools releases its moisture content.







VISIBLITY REMAINS BETTER IN MOUNTAINS -LESS POLLUTION



CLIMATE RESPONSIVE ARCHITECTURE

THE ELEMENTS OF CLIMATE



- Temperature: data
- Humidity: data
- Precipitation Climatic information
- Temperature:measurement
- Driving rain
- Sky conditions
- Solar radiation:measurement
- Solar radiation: data
- Wind: measurement
- Wind : data
- Special characteristics
- Vegetation
- Graphic representation



CLIMATIC INFORMATION

- The designer is interested in those aspects of climate which affect human comfort and the use of buildings.
- They include averages, changes and extremes of temperature, the temperature differences between day and night, humidity, sky conditions, incoming and outgoing radiation, rainfall and its distribution, air movements and special features such as trade winds, thunder storms, dust storms and hurricanes.
- Climatic records as gathered at airports and meterological stations are not primarily intended for the use of designers.

	Site						
	1	2	3	4	5	6	
Maximum Monthly Temperature							
Minimum Monthly Temperature							
Mean Monthly Temperature							
Temperature Range							
Mean Monthly Precipitation							
Total Annual Precipitation							
Month with Greatest Precipitation							
Month with Least Precipitation							

	Average temperature °C		Aver. temperature Fahr.		Rainfall mm	Rainfall	Rainy Humid
	Min	Max	Min	Max		inches	days
Jan	25	30	77	86	55	2,2	10
Feb	25	30	77	86	80	3,1	12
Mar	24	30	75	86	160	6,3	14
Apr	24	29	75	84	220	8,7	16
May	23	28	73	82	250	9,8	20
Jun	23	28	73	82	280	11,0	20
Jul	22	28	72	82	250	9,8	22
Aug	22	27	72	81	150	5,9	18
Sep	23	28	73	82	65	2,6	11
Oct	24	29	75	84	25	1,0	8
Nov	24	29	75	84	25	1,0	7
Dec	25	29	77	84	30	1,2	6

TEMPERATURE MEASUREMENT



- The temperature of the air is measured in degree celsius most often with mercury thermometer.
- Readings taken at specified times of the day, or if a maximum minimum thermometer is used one reading daily can give the momentary temperature as well as the maximum and minimum temperatures reached in the past 24 hours.



The dry bulb or" true air temperature" is a value taken in the shade, the inside a louvered wooden box, known as the "Stevenson screen" at a height of 1.20 to 1.80 thermometer being mounted m above the ground

Thermograph can be used, which is based on a bimetallic thermometer and gives a continuous graphic recording of temperature variations.



TEMPERATURE DATA



- Monthly mean temperatures can be given for each of the 12 months.
- The average is taken between each day's maximum and minimum and then the average of the 30 days average is found.
- To give an diurnal variations this can be supplemented by monthly mean maxima and minima.
- These will establish the monthly mean range of temperatures.
- It will be useful to indicate the highest and lowest temperatures ever recorded for each month, i.e., the monthly extreme maxima and minima to establish the monthly mean range of temperatures.

Sydney, Australia 33° 86' S, 151° 21' E, elevation: 128 feet



Mean maximum and minimum temperatures are for the period 1971 to 2000. Extreme maximum and minimum temperatures are for the period 1878 to 2000. © 2008 Encyclopædia Britannica, Inc.



Locations of climate stations with mean temperature data.



HUMIDITY MEASUREMENT

- The humidity of air can be described as absolute humidity i.e., the amount of moisture actually present in unit mass or unit volume of air, in terms of gramme per kilogramme.
- The relative humidity is however a much more useful form of expression, as it gives a direct indication of evaporation potential.
- The amount of moisture the air can hold depends o n its temperature.
- Relative humidity is the ratio of the actual amount of moisture present to the amount of moisture the air could hold at the given temperature.
- RH=AH/SHX100 %





- Humidity is usually measured with the wet and dry bulb hygrometer.
- This consists of two ordinary mercury thermometers mounted side by side.
- The first one measures the air temperature. The bulb of the second one is covered with a gauze or wick and is kept wet.
- Moisture evaporating gives a cooling effect, thus the reading of wet bulb temperature will be less than the dry bulb temperature.
- As in dry air the evaporation is faster, the cooling is more pronounced and the difference between the two readings is greater in case of 100%RH the two readings will be identical, as there is no evaporation.
- Having made the two readings the corresponding RH can be found from the psychometric chart.





Psychometric chart.



HUMIDITY DATA

- To give an indication of prevailing humidity conditions, it is sufficient to establish the monthly mean the maximum and monthly mean minimum relative humidity values for each of the 12 months.
- This is only possible where continuous hygrograph recordings are available.
- Where these are not available readings are made just before sunrise, e.g at 6.00 hours (maximum value) and at 15.00 hours(minimum value)

VAPOUR PRESSURE



- Another indication or expression of atmospheric humldity is the vapour pressure. i.e the partial pressure of water vapor present in the air.
- The atmospheric pressure is the sum of the partial pressure of dry air and partial vapour pressure.
- P=Pa+Pv
- The air is saturated when the vapour pressure(pv) is equal to the pressure of the saturated vapour of the same temperature(pvs).
- Relative humidity can also be expressed as the ratio of actual vapour pressure to the saturation point vapour pressure.

RH=AH/SHX100=Pv/Pvsx100%





PRECIPITATION



- Precipitation is the collective term used for rain, snow, hail, dew and frost that is for all forms of water deposited from the atmosphere.
- It is measured by rain gauges, i.e. calibrated receptacles, and expressed in millimeter per a time unit.





Rain gauge



The maximum rainfall for any 24 hour period is a useful guide for the predication of flooding and for the design of surface drainage (roofs, paved areas, gutters and downpipes) the maximum hourly rainfall intensity should be known.



Roof drainage

Values indicating the total precipitation for each month of the year would show the pattern of dry and wet seasons. Ever recorded maxima and minima would give an indication of the reliability of rains.





Ground drainage

2007 Rainfall vs 30 year Average



DRIVING RAIN



- The building designer may want to know whether intense rains are associated with strong winds , in other words what is the likelihood of driving rain.
- The driving rain index characterises a given location and express the degree of exposure.
- It is the product of annual rainfall and annual average wind velocity.
- Actual rain penetration will depend instantaneous rain on the intensity and the simultaneous wind velocity.





SKY CONDITIONS



- Sky conditions are usually described in terms of presence or absence of clouds.
- On average, two observations are made per day, when the proportion of sky covered by cloud is expressed as a percentage.Few records exist of night time sky conditions.
- It would be useful for the designer to know the time of day and frequency of observations.
- A single average figure giving the sky conditions for a typical day of a given month may conceal significant differences, e.g. between morning and afternoon conditions, which may affect the design of roofs, overhangs and shading devices.



2007 (Inner ring) VS 30 year average (Outer ring)



ANNUAL AVERAGE SUNNY
ANNUAL AVERAGE CLDY



SOLAR RADIATION MEASUREMENT

- A simple sunshine recorder will register the duration of sunshine, which can be expressed in number of hours per day, as an average for each month.
- A variety of more sophisticated instruments (solarimeter, heliometer, actinometer and pyranometer) are used for the quantitative recording of solar radiation, but reliable and comparable data is few and far between.



Pyranometer

solarimeter



SOLAR RADIATION DATA

- Average daily amounts of solar radiation for each month of the year would give a fair indication of climatic conditions, including seasonal variations.
- This could be supplemented by the highest and lowest daily totals for each month, to set the limits of variations which can be expected for the purpose of detailed design, hourly totals or rather hourly average intensities must be known for typical day of each month-or atleast for a typically high and a typically low radiation day of the year.





WIND MEASUREMENT

- Wind velocity is measured by a cup-type or propeller anemometer, or by a pilot type and its direction is measured by a wind vane.
- An anemograph can produce continuous recordings of wind velocity and directional changes.
- Measurements in urban areas are taken at a height of between 10 to 20m to avoid obstructions.
- Velocities near the ground are a good deal lower than the free wind speed.a wind force scale developed by beaufort in 1806, based on visual observation, is still in use in spite of its completely unscientific nature.





Anemograph

WIND DATA



- The designer must try to determine whether there is a prevailing direction of winds, whether predictable daily or seasonal shifts occur and whether there is a recognizable pattern of daily or seasonal velocities.
- It is also important to note the calm periods in each month.all observatories record the occurrence of storms, hurricanes, typhoons, or tornadoes.





SPECIAL CHARACTERISTICS

- Most regions experience conditions which are particularly unfavourable such as hail and thunder storms, line or arched squalls, earthquakes, tornadoes,hurricanes and dust storms.
- Although such events must be rare it is important to extract from meteorological data their frequency, likely duration and nature.
- The designer must classify rare events into those which affect human comfort and those which may endanger the safety of buildings and the lives of inhabitants.








VEGETATION



- The picture of climate is incomplete without some notes on the character and abundance of plant life.
- Although generally regarded as a function of climate, vegetation can in its turn influence the local or site climate.
- it is an important in the design of out door spaces providing sun shading and protection from glare.
- This section of the climatic survey may range from a few notes about local species of plant life to a lengthy compendium of the major native plants and trees- their shape and colour, also their preferred orientation and situation.





LIGHTING



 If the building envelope is thought of as a barrier between the internal, controlled environment and the external perhaps undesirable conditions it must be realized that it should be as a selective barrier or rather a filter which excludes the unwanted influences whilst admits those which are desirable.

On such desirable effect is daylight.







THE NATURE OF LIGHT

- Light is narrow wave length band of electro magnetic radiation from about 380 to 780 nm.
- Energy radiation shows dual characteristics
 - 1. Energy particles photons
 - 2. Transverse wave motion
- -Wavelength determines the color.
- Light containing all visible waves is perceived as white.
- Human eye's sensitivity varies with the wavelength it is greatest around 550 nm.





TRANSMISSION:

- Materials when exposed to light, transmit a large part of it-"Transparent".
- Materials which block the passage of light- "Opaque".
- Behind an opaque object there will be no light i.e it will cast a shadow.
- Materials which transmit a part of the incident light but break its straight passage scatter it in all directions, creating "diffuse light".
- Light incident on an object can be distributed in 3 ways
- reflected.
- Absorbed.
- Transmitted.





REFLECTION:

- If the paralled rays of incident light remain paralled after reflection from a surface, the surface is a plane mirror- "Specular reflection".
- The angle of reflection is the same as the angle of incidence.
- Convex mirror- reflected rays divergent.
- Concave mirror reflected rays convergent.
- Light reflected from a matt surface diffused.
- Mixture of the two kinds of reflection will occur.
 a) semi diffuse depend on the relative magnitude of the 2 components
 b) spread
- -Some materials have same reflectance for all wavelenghts of light.

-Other materials are selective in their reflectance





Specular Reflection (smooth surfaces)



COLORED LIGHT

- Colored light from different sources can be mixed.
- Resultant color- wavelengths range- sum of the wavelength ranges of components.
- it is a additive process.
- COMPLEMENTARY COLORS: Colors which add up to from white light.
- Colored light can also be produced by filters.
- These are materials with a high, but selective transmittance.
- They may reflect or absorbs most of the wavelengths transmitting only the specified narrow band.





• Subtractive process.

MUNSELL SYSTEM

- Classification of surface colors- Munsell system.
- It distinguished 3 colors concepts:
- 1. Hue: concept of color using the common color terms; red, yellow, green, blue and purple and further subdividing each into 5 categories.
- 2. Value: the light or dark appearance of the color.
- 3. Chroma: the degree of colorfulness or intensity of color distinguishing 14 classes.







PHOTOMETRIC QUANTITIES



- The intensity of a light source is measured in units of candela.
- Flux is a light symbol.
- Illumination amount of flux falling on unit area- lux.
- Luminance Measure of brightness of a surface.
- ILLUMINATION:
- Illumination from a point source reduces with the square of the distance.



THE DAYLIGHT FACTOR CONCEPT:

Due to variability of outdoor lighting levels it is difficult to calculate interior lighting in illumination terms .
In a given building at a certain point the ratio of illumination to the simultaneous outdoor illumination can be taken as constant.
The constant ratio is expressed as the percentage is the daylight factor
Df= E1/E0 x 100 %.





DEVIATIONS WITHIN THE ZONE



- Knowledge of the climatic zone to which a town or settlement belongs and possession of published regional climatic data does not eliminate the need for careful investigation of site climatic conditions.
- It does, however usually provides enough information for the designer to make a preliminary assessment of the climate and may be sufficient to form the basis of sketch designs.
- Every climate town or village and even a precinct in a town may have its own climate, slightly different from the climate described for the region- the macro climate.
- Information published by the nearest meterological observatory describes the macroclimate.
- Such information may be useful guide to the climate of the site, but is seldom sufficient in accuracy as conditions can vary considerably within a short distance from the point of observation.



SITE CLIMATE

- The term 'site climate' has been chosen deliberately rather than the synonymously used term 'micro climate'.
- The latter can imply any local deviation from the climate of a larger area whatever the scale may be.
- The botanist may consider the microclimate of a single plant leaf, with its temperature and moisture conditions, its population of insects and micro organisms on the scale of a few centimeters.
- For the urban geographer the term 'microclimate' may mean the climate of a whole town. 'site climate' establishes the scale; whatever the size of the project, it implies the climate of the area available and is to be used for the given purpose, both in horizontal extent and in height.

LOCAL FACTORS



- Factors which may cause local deviation from this use:
- Topography: i.e slope, orientation, exposure, elevation, hills or valleys at or near the site.
- Ground surface: whether natural or man made it reflectance, permeability and the soil temperature, as these affect vegetation and this in turn affects the climate.
- Three-dimensional objects, such as trees, or tree belts fences, walls and buildings as these may influence air movement, may cast a shadow and may sub divide the area into smaller units with distinguishable climatic features.



Topography"



Ground surface

AIR TEMPERATURE



Air temperature is dependant upon the amount of heat gained or lost a the earth's surface and any other surfaces with which the air has recently been in contact.

0

0

0

0

- Heat exchange at surfaces varies between night and day with the season, latitude and the time of year, always influenced by the amount of cold cover.
- During the day, as surfaces are heated by solar radiation, the air nearest to the ground acquires the highest temperature
- In calm conditions the air within 2m of the ground remains stratified in layers of differing temperature.



Day

At night, particularly on clear nights, the ground loses much heat by radiation and soon after sunset its temperature falls below that of air.

The direction of heat flow is reversed; from the ground.



Night

TEMPERATURE INVERSION

- This phenomenon is referred to as temperature inversion, as the day time situation of decreasing temperature with increase of height is taken as normal.
- Cold air tends to settle in the deepest depressions and behaves as a liquid.
- It does not flow quite as readily as water, rather like a highly viscous liquid.
- If it flows down the hill and along the floor of a long, sloping valley it can add up to a 'katabatic wind' a concentrated and accelerating flow of a cold mass of air.
- Topography can thus strongly influence air temperature, a difference of 7 to 8 m in height can cause a difference of 5 to 6C in air temperature, under still air conditions.





HUMIDITY

- The relative humidity depends as much on the air temperature as on the actual amount of water vapour present in the air.
- During the day, as the lowest layer of air is being heated by the ground surface, its RH is rapidly decreased.
- With a lower RH the rate of evaporation is increased, if there is water available to be evaporated.
- An open surface of water or rich vegetation would provide an abundant supply of water.
- in such a case strong evaporation would increase the AH of the lowest layers of air.
- With air movement the rate of evaporation is increased, but with the mixing of air the temperature and humidity differences tend to be evened out.





Day

- With air movement the rate of evaporation is increased, but with the mixing of air the temperature and humidity differences tend to be evened out
- At night the situation is reversed.
- Especially on a clear night with still air as the lowest layer cools, its RH increase, the point of saturation is soon reached and with further cooling the excess moisture condenses out in the form of dew (dew point).
- When the dew point temperature is reached the formation of fog will start, and if there is no further rapid cooling and no air movement, a deep layer of fog can develop near the ground.





Night

PRECIPITATION



- When moisture bearing winds occur frequently from the same direction, the effect of hills on rainfall patterns can be very pronounced.
- Where the ground changes level by more than 300m, the windward slope can be expected to receive a rainfall more than the regional average, and the leeward slope correspondingly less.
- With the increase of height or steepness of the hill formation, the effect will be more pronounced.
- In an extreme case it can happen that on a large site located on the top of a hill and extending down to both slopes, the leeward half receives only 25% of the rain received by the windward side.





- The cause of the above phenomenon is that the hill forces the air a mass to rise, as it rises it cools and can no longer support the moisture carried.
- Conversely a descending air mass increase in temperature and it can absorb more moisture rather than to precipitate any.
- A similar situation can develop over towns, where the more absorbent surfaces reach a high temperature and can produce an upward air movement.
- Such a upward current may divert any horizontal air movement in an upward direction, with a similar effects to a hill slope.
- Actually a number of workers have reported a higher frequency of rains of the cloudburst type over dust storms.
- If rainfall generally occurs associated with high wind velocities, resulting in driving rain, the effect will be more pronounced on the windward side than on the leeward slope.



Arid region behind coastal mountain range



SOLAR RADIATION



- The amount of solar radiation may be influenced by local factors by three ways:
- 1. the intensity on a theoretical horizontal plane above the ground is affected by local variations in the transparency of the atmosphere. Atmospheric pollution, smoke, smog or dust and local cloud formations can produce substantial reductions.
- 2. The intensity on the actual ground surface is influenced by the slope and orientation of the site, this effect being negligible around the equator, but increasingly important towards higher latitudes. At mid-latitudes a site sloping toward the pole will receive much less radiation than one sloping towards the equator.





3.The daily total amount of
radiation may also be influenced
by the slope but also by nearby
hills or even trees and existing
buildings, which may cast a
shadow over the site at certain
times of the day.this effect is most
pronounced when such
obstructions lie on the east or
west of the site.

0

0

When the sun is on these sides, it is at low angle and casts a long shadow.

 Radiation on a vertical building surface will be affected by its orientation, but not by the slope and orientation of the site.





UNIT II

SOLAR GEOMETRY AND DESIGN OF SUNSHADING DEVICE



THE SUN'S POSITION

- The sun's position on the sky hemisphere can be specified by two angles;
- The altitude angle (also known as the "solar elevation angle") describes the angle measured between a line from the observer's position O to the sun and the horizon.

In the Northern Hemisphere, the solar azimuth angle is the angular distance between due South and the projection of the line of sight to the sun.





Thus

- North= 0 deg or 360 deg
- East= 90 deg
- South = 180 deg
- West = 270
- These two angles can be read directly for any date of the year and any hour of the day from the solar charts or sun path diagrams.





Azimuth angle
 Elevation angle
 Sun's path today
 Sun's path on the 21st June
 Sun's path on the 21st
 December
 Sun's path during the equinox
 Sunrise
 Sunset
 Horizon



(also known as "solar path diagram", "sun chart" or

"solar chart")

- This path is formed by plotting azimuth (left-right) and elevation (updown) angles of the sun in a given day to a diagram.
- To find out the position azimuth = 60, elevation = 30, for example, imagine standing at the center of the diagram heading to the true north.
- To find the azimuth angle 60, you must turn 60 degrees to the right.
- Now the altitude angle 30 can be located by raising your head 30 degrees from the horizon.
- It can be seen from the diagram (3. "Sun's path today") that the sun rises from the North-East (azimuth = 60) in Tampere at 05:37. Sunset happens at 21:20 when the sun is in the North-West (azimuth = 300).
- On that day the elevation angle is approximately 50 degrees at noon.

ANGLE OF INCIDENCE & OTHER ANGLE

The altitude and azimuth bearings of the sun enable some further important sets of angles to be computed.

0

0

- The first is the angle of incidence, i.e This is important information as the intensity of direct irradiance is a function of the angle of incidence being a maximum at 0° (the angle of incidence is always measured from the normal to the surface), and dropping off as the cosine of the angle of incidence, until it reaches zero at 90° incidence.
- The second are the shadow angle, that is the angle the sun makes on section (the vertical shadow angle e) and on plan (the vertical shadow angle d). These angles enable the shadows cast and the patches of sunlight on surfaces inside and outside buildings to be predicted and plotted on sections and plans.



The third is the wall solar azimuth, g, of a vertical or tilted surface, which describes the angle between its orientation and the sun's bearing (solar azimuth, f).

ANGLE OF INCIDENCE



- From these two angles the sun's position in relation to the wall surface of any orientation (thus the angle of incidence) can be established.
- The horizontal component of the angle of incidence(δ) will be the difference between the solar azimuth and the wall azimuth. If, for the above example, the wall is facing west (270°):

δ= 270-239= 31°

- The vertical component is the same as the solar altitude angle itself (y), the angle of incidence (δ), i.e. the angle between a line perpendicular to the wall and the sun's direction, can be found by the 'spherical cosine equation'.
- $\cos \beta = \cos \delta x \cos y$
- In our example:
- Cos β = cos 31 ° x cos 40 ° = 0.8572 x 0.7660 = 0.6566
- $\beta = 49^{\circ}$

 \bigcirc





- This angle of incidence will be required both for selection the appropriate solar gain factor in heat gain calculations through windows and for calculating the incident radiation on an opaque surface, e.g. when the solair temperature is to be established.
- As a first step, it must be decided when shading is necessary, at what times of the year and between what hours of the day.
- The best guide to this is the definition of the overheated period.
- This should be quite easy, if the climatic data has been complied.
- Alternatively, a temperature isopleth chart can be used.



SHADOW ANGLES

- The performance of shading devices is specified by two angles, the horizontal and the vertical shadow angles.
- These are both measured from a line perpendicular to the elevation, and indicate the limit, beyond which the sun would be excluded, but within which the sun would reach the point considered.



UNIT III PRINCIPLES OF THERMAL DESIGN IN BUILDINGS



• HEAT:

- Energy
- Appearing as molecular movement in substances or as 'radiant heat'.
- A certain wavelength band of electromagnetic radiation in space (700-10000nm).
- Joules (J).
- HEAT FLOW RATE:
- POWER: ability to carry out a certain work in unit time.
- Joules.
- Unit work is carried out in unit time.
- Power as the rate of energy flow.

• ENERGY FLOW:

- Flow of heat through a wall, the heat removed by a cooling plant, the radiant heat flow-from a electric radiator.
- The flow of electricity through a light bulb, sound energy emitted by a loud speaker.
- Sound energy output of an electric motor.
- Measured in Watts.





• CONDUCTIVITY:

- In conduction through a body or through bodies in direct contact the spread of molecular movement constitutes-flow of heat.
- THERMAL CONDUCTIVITY:K value.
- Rate at which the molecular movement spread varies with different materials and is described as property of material.

CONDUCTANCE:

- Heat flow from air on one side through the body to air on the other side.
- Conductivity and resistivity are properties of material, the corresponding properties of a body of a given thickness as described as conductance (C).





ILLUSTRATING UNIT CONDUCTIVITY = 1W/mK



CONDUCTION:

- Heat is transferred by the bodily movement of a carrying medium, usually a gas or liquid.
- This movement may be self-generating i e., due to thermal forces alone or may be applied force.
- Rate of heat transfer in convection depends on **3 factors**:
- Temperature difference.
- Rate of movement of the carrying medium. Kg/s.
- Specific heat J/kg deg C.
- Resistivity 1/k.
- **Resistance**: Product of is thickness and the resistivity of its material.
- Bx1/k. R-b/k , where b- thickness in m.





MULTI LAYER BODY:



- If a body consists of several layers of different materials.
- Total resistance = sum of the resistance of individual layers.
- $R_{b} = R_{1} + R_{2} + R_{3} \dots$
- $B_1/k_1 + b_2/K_2 + b_3/k_3$.
- Conductance (C_b) = Reciprocal of resistance.
- C _b = 1/R
- C = 1/b/k.




SURFACE CONDUCTANCE:

- In addition to the resistance of a body to the flow of heat, a body to the flow of heat, a resistance will be offered by its surface, where a thin layer of air film separates the body from the surrounding air..
- Measured- surface or film resistance (1/f) m² deg C/W.
- F surface or film conductance (W/m² deg C).
- Surface conductance convective + radiant components of heat exchange.



• AIR TO AIR RESISTANCE (R):

- Sum of the body's resistance and the surface resistance.
- $R_a = 1/f_1 + R_b + 1/f_0$.
- f-film conductance.
- i. e function of surface qualities and of the velocity of air passing the surface.



- TRANSMITTANCE: U value
- Reciprocal of this air- to air resistance is the air- to air transmittance or U value.
- $U = 1/R_a$.
- Unit same as conductance w/m² deg C.
- Used : Building heat loss and heat gain calculations.



RADIATION:

- Partly absorbed and partly reflected.
- Proportion of these 2 components (a) and reflectance (r).
- a + r = 1..
- Light colored, smooth and shiny surfaces higher reflectance
- i.e white surface r =1, a = 0.
- Black body- r = 0, a= 1.
- Emittance (e) available.
- e = heat =1.
- Absorbance = emittance
- a=e.



- SOL-AIR TEMPERATURE:
- SOLAIR TEMPERATURE CONCEPT :For building design purposes, it is useful to combine the heating effect of radiation incident on a building with the effect of warm air.
- $T_s = T_0 \times I \times a/f_0$.
- T_s- sol air temperature in deg C
- T₀ outside temperature in deg C.
- I radiation intensity.
- a- absorbance of the surface.
- F₀- surface conductance w/m² deg C.

SOLAR GAIN FACTOR:



- Combined effect- reflective surface + thermal insulation.
- Reduction : Dark, high absorptive surface with good insulation may be just as effective as more reflective with less insulation element.
- Sol-air temperature- Ts-T0 = lx a /f0.
- Heat flow rate $q = I \times a/f_0 \times U$ (W/m²).
- Solar gain factor a/I = a x U/f₀ (non-dimensional.)



- SOLAR GAIN FACTOR: Heat flow rate through the construction due to solar radiation expressed as a fraction of the incident solar radiation.
- Constant value for external surface conductance $f_0 = 20 \text{ w/m}^2 \text{ deg C}$.

	Solar gain factor	a x U
For Warm Humid Climate.	0.04	0.8
Hot-dry season (composite)	0.03	0.6



VENTILATION AND AIR MOVEMENT

FUNCTIONS OF VENTILATION



- It has three distinctly different functions:
- 1. supply of fresh air
- 2. convective cooling
- 3. physiological cooling



SUPPLY OF FRESH AIR

- Type of occupancy, number and activity of the occupants and by the nature of any process.
- Requirements may be stipulated by building regulations and advisory codes in terms of m³ /h person, or in number of air changes per hour but these are applicable to mechanical installations.
- Natural ventilation: Provision of "permanent ventilators" i.e of openings which may not 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 the openable windows may be stipulated in relation to the floor area or the volume of the room.



CONVECTIVE COOLING

- The exchange of indoor air with fresh out door air can provide cooling.
- The moving air acts a heat carrying medium.



PROVISION OF VENTILATION: STACK EFFECT



- 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 effect relies on thermal forces, set up by density difference (caused by temperature difference)between the indoor and out door air.
- It can occur through an open window; 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.
- The principle is same as wind generation.



WIND EFFECT, STACK EFFECT AND KINNESS





VENTILATION SHAFT

- The higher the shaft, the larger the cross sectional area and the greater the temperature difference; the greater the motive force therefore, the more air will be moved.
- The motive force is the 'stack pressure' multiplied by the cross sectional area.
- The stack pressure can be calculated from the equation: P_s = 0.042 x h x Δ t
 - Where h =height of the stack (m),
 - Δ t = temperature difference (deg C)





PROVISION FOR AIR MOVEMENT: WIND EFFECTS

- Thermal forces will rarely be sufficient to create appreciable air movements.
- The only natural force that can be relied on is the dynamic effect of winds.
- Negative control- wind is too much,-is easy, if windows and openings can be shut.
- Wind is generated by pressure differences- so an air flow through the building is the result of a pressure difference between the two sides.



- Air-although light-has a mass and as it moves, has a momentum, which is the product of its mass and as it moves, has a vectorial quantity, which can be change in direction or in magnitude only by another force.
- When the moving air strikes an obstacle such as 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; P $_{\rm w}$ = 0.612 x v 2
 - where P_w = wind pressure(N/m²),V= wind velocity (m/s)





- This 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.
- 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 it is often referred to as 'wind shadow'.



AIR FLOW THROUGH BUILDINGS



- Air flow patterns is completely predicted on the basis of empirical rules derived from measurements in actual buildings or in wind tunnel studies.
- A wind tunnel is a research tool developed to assist with studying the effects of air moving over or around solid objects .
- The following factors can be isolated which affect the indoor air flow;
- Orientation
- External features
- Cross-ventilation
- Position of openings
- Size of openings
- 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.
- A wind incidence of 45° would reduce the pressure by 50%.
- Thus the designer ascertain the prevailing wind direction from wind frequency charts of wind roses and must orientate his building in such a way that the largest opening are facing the wind direction.





- Building 45° a greater velocity is created along the windward faces, therefore the wind shadow will be much broader, the negative pressure will be increased and an increased indoor air flow will result.
- Optimum solar orientation and 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.

🙈 s r na







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 buildings.
- The wind velocity gradient is made steeper by an uneven surface, such as scattered buildings, wall fences, trees.
- But even with a moderate velocity gradient such as over smooth and open ground a low buildings can never obtain air velocities similar to a taller one.
- For this reason the building is often elevated on stilts.





- External features of the building itself can strongly influenced the pressure build up.
- For example, if the air flow is at 45° 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.



CLASSIFICATION OF TROPICAL CLIMATES

- Climatic zones
- Tropical climates
- Warm humid climates
- Warm humid island climate
- Hot dry desert climate
- Hot dry maritime desert climate
- Composite or monsoon climate
- Tropical upland climate



	Warm Humid climate	Warm Humid Island climate	Hot dry desert climate	Hot dry maritime desert climate	Composite o Monsoon climate	Tropical Upland
Air Temperatu re Mean Max: Mean Min:	27-32C 18-24C	29-32C 18-24C	43-49C 27-32C	38C 24-30C	b/w warm humid and hot dry climate	24-30C 10-13C
Humidity RH: Vapor Pressure:	75% 2500-000 N/sq.m	55-100% 1750-2500 N/sq.m	10-55% 750-1500 N/sq.m	50-90% 500-2500 N/sq.m	20-55%(Dry Period), 55-95%(Wet Period) 1300-1600 N/sq.m	45-99% 800-1600 N/sq.m
Precipitatio n	High	High	Slight and variable	Very low	Intense and prolonged	Variable
Annual Rainfall	2000-5000 mm/annum 500 mm/month	1250-1800 mm/annum 200-250 mm/month	50-155 mm/annum		500-1300 mm/annum 200-250 mm in the wettest month.	1000mm

						s en s a
Sky Conditions	Fairly cloudy	Normally clear	Normally clear	Little more cloudy	Monsoon: Dul Dry season: clear with dark blue color	Clear and partly STY cloudy
Solar Radiation	Strong and diffuse. cause painful sky glare	Strong and mainly direct	Direct and strong	Strong	Alternates between warm humid and Hot dry desert climates.	Direct and strong
Winds	Strong winds occur during Rain squalls	Higher velocities Occur during cyclones	Local whirl winds are often created	Local, coastal winds caused by unequal heating and cooling of land and sea surfaces.	Monsoon winds are fairly strong and steady bring rain clouds and humid air.	Winds are variable drastically deflected by local topography.





TEXT BOOK

1. O.H. Koenigsberger, Manual of Tropical housing and building – Climatic Design, Orient Longman, Chennai, 1975.

REFERENCE BOOKS

1. M. Evans – Housing, Climate & Comfort, Architectural Press, London, 1980.

2. E.Schild & M.Finbow – Environmental Physics in construction & its application in Architectural Design , granadar , london, 1981.

- 3. B.Givoni Man, Climate & Architecture, Applied Science, Essex 1982.
- 4. Donald Watson & Kenneth labs Climatic Design Mcgraw hill NewYork 1983.
- 5. A.Konya- Design Primer for Hot Climates, Architectural Press, London, 1980.