Chapter Two

Climatic Data

1. Introduction

The climatic data required for building design are quite distinct from those needed for agricultural purposes. This chapter specifies the climatic data required for architectural design and how they should be presented. The essential data include dry bulb temperature, humidity, vapour pressure, precipitation, wind, sky conditions and other phenomena. The use of climatic data sheets and climatic charts for recording and presenting the data is discussed. The site climate may differ from that at the recording station due to variations in climate.

2. Collecting the Data

There is need to obtain basic climatic data and analyse such data for climatic design. These data include temperature, humidity, vapour pressure, precipitation and wind, solar radiation, cloud cover and other phenomena such as thunder and sandstorms. These data are sometimes available in publications, but meteorological stations are the most reliable source. There are some points that need to be borne in mind during the collection of data. Climatic data for one year is often offered. Unfortunately, this is insufficient for design purposes. What is needed are averages for at least five to ten years. The unit of measurement should be ascertained, and when necessary conversions should be performed. Meteorological stations were not established to collect data for building design. They are more inclined towards aviation and agriculture. One must therefore know which data are relevant to building design and in which form they should be presented. This chapter discusses the basic climatic data needed for design, the instruments used, the common units of measurement and the form in which the data should be presented.

Plate x: Exterior of Stevenson's screen. Source: Http://www.tsrye .fsnet.co.uk/stevensons.htm

Plate x: Interior of Stevenson's screen. Source: Http://www.tsrye .fsnet.co.uk/stevensons.htm

3. Dry Bulb Temperature

The air temperature measurements are made inside a Stevenson screen. The Stevenson screen is a louvered cabinet painted white and standing on legs about 1.25 m above the ground. The Stevenson screen prevents solar radiation and ground surface temperatures from affecting the readings. It some times houses other instruments like hydrograph or aneroid barometer used in measuring atmospheric pressure. Size varies from big, medium and small depending on the sizes of the thermometer to be put in to it and whether other instrument are to be housed in it. Stevenson Screen was designed and invented by the father of Robert and Louis Stevenson. The louvers side and door enable a stable air flow over the thermometer. They are permanently inclined at an angle so as to prevent light from entering into it and altering the atmospheric condition. The area of open surface is made large enough not to restrict air flow. Air temperatures are recorded with the aid of minimum and maximum thermometers as well as a normal dry bulb thermometer.

Temperature readings are usually made in degrees Celsius (C) but sometimes in degrees Fahrenheit (F).

The monthly mean temperature. This is the average of temperatures recorded for a particular month. This is usually an average of hourly or daily temperatures.

Mean daily maximum temperature. This is the average of the maximum temperatures of each day of a particular month, taken over a numbers of years. It is the average temperature at the hottest time of the day.

Mean daily minimum temperature. This is the average of the minimum temperature of each day of a particular month, taken over a number of years. It is the average temperature at the coolest time of the day.

The mean daily range. This is the difference between the mean daily minimum and the mean daily maximum temperatures.

Mean monthly maximum temperature. This is the average of the maximum temperatures recorded during a particular month over a number of years.

Mean monthly minimum temperature. This is the average of the minimum temperatures recorded during a particular month over a number of years.

Extreme monthly maximum temperature. This is the highest temperature ever recorded during a particular month.

Extreme monthly minimum temperature. This is the lowest temperature ever recorded during a particular month.

The annual mean temperature. This is the average of the highest monthly mean maximum temperature and the lowest monthly mean minimum temperatures.

The annual mean maximum temperature. This is the average of the maximum temperatures recorded during the year.

The annual mean minimum temperature. This is the average of the minimum temperatures recorded during the year.

The annual mean daily range. This is the difference between the mean daily minimum and maximum temperatures over the whole year.

The soil-earth thermometer

The soil-earth thermometer is used to measure the soil temperature. It is suitable for use in soil, compost, mushrooms, heated seed beds and plant rearing. It has an aluminum casing which protects the end and a large red top to make it easy to see and to pull out from the soil.

Figure x: Soil-earth thermometer.

Range: -10°C to +60°C (+20 to +140°F).

The thermometers are housed in glass tubes with the bulbs embedded in wax. The thermometer, in its glass tube is attached to a length of chain, and inserted into metal tubes sunk in the earth to the required depth of 30, 50 and 100 cm. They are extracted from the metal tubes to make the reading which needs to be done as quickly as possible. This is because the temperature at depth will most likely be quite different to the air temperature, and soon change. Being embedded in wax, however, minimises this change.

4. Humidity

Three basic expressions are usually used in the description of humidity - the absolute humidity, the saturation-point humidity and the relative humidity.

The Absolute Humidity (AH): is the amount of moisture present in the air measured in grams per kilogram (g/kg) or grams per cubic metre (g/m3).

The Saturation-point Humidity (SH): is the maximum amount of moisture the air can hold at a particular temperature measured in grams per kilogram (g/kg) or grams per cubic metre (g/m3).

The Relative Humidity (RH): is the ratio of the actual amount of moisture present in the air to the amount of moisture the air could hold at the given temperature expressed as a percentage; i.e. the ratio of the absolute humidity to the saturation-point humidity expressed as a percentage. From the definitions above, it

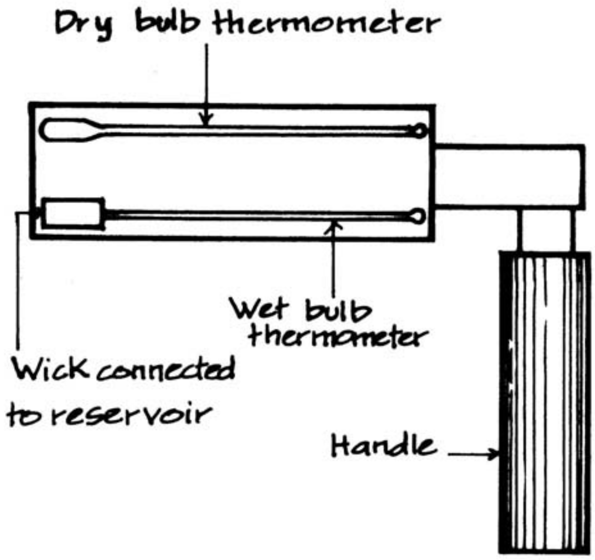

Figure x: Whirling hygrometer

follows that:

$$RH = AH / SH \times 100 (\%)$$

The humidity is usually measured with the wet-and-dry bulb hygrometer. See figure 1. This consists of an ordinary mercury thermometer for the measurement of dry-bulb air temperatures and a second mercury thermometer covered with a wet gauze for the measurement of wet-bulb temperatures.

A preferred instrument for the measurement of humidity is the hygrograph, which makes use of a revolving drum for the continuous recording of humidity levels. In the absence of a hygrograph humidity readings are taken at a time when they are likely to be near the maximum (at 6 or 7 am) and the minimum (at 2 or 3 pm). After obtaining readings from the wet-and-dry bulb hygrometer the corresponding relative humidity is found using the humidity slide rule or the psychrometric chart.

Hygrometers are instruments used for measuring humidity. The simplest form of a hygrometer consists of two thermometers, one of which has its bulb constantly kept wet. Evaporation from the bulb lowers the temperature so that this thermometer usually shows a lower temperature. However, when the air temperature is below freezing, it is possible for the "wet bulb" (actually a thin coating of ice) to be warmer than the dry bulb. Relative Humidity is computed from the ambient temperature as shown by the "dry bulb thermometer" and the difference in temperature shown by the "wet bulb" and dry bulb thermometers. One device that uses the wet/dry bulb method is the sling psychrometer, where the thermometers are attached to a handle or length of rope and spun around in the air for a few minutes.

There are several other types of hygrometers that are commonly used. Frequently, the devices use the stretching of a human or animal hair under tension to determine the ambient humidity. In order to see changes that occur over time, many hygrometers record the value of humidity on a piece of graduated paper so that the values can be read off the chart.

Modern instruments use electronic means of

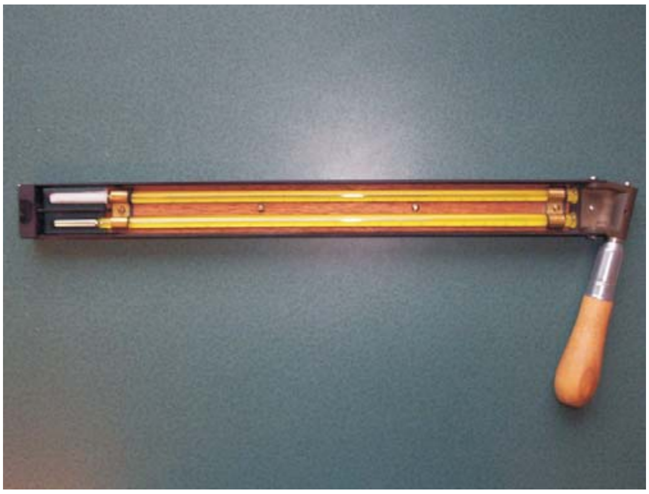

Plate x: Sling psychrometer. Source: http://en.wikipedia.org/wiki/Hygrometer

Plate x: The interior of a Stevenson screen showing a motorized psychrometer. Source: http://en.wikipedia.org/wiki/Hygrometer.

recording the information. The two most common electronic sensors are capacitive or resistive. The capacitive sensors sense water by applying an AC signal between two plates and measuring the change in capacitance caused by the amount of water present. The resistive sensors use a polymer membrane which changes conductivity according to absorbed water. They can be read by common meters or data acquisition boards. Temperature must also be measured, as it affects the calibration of all these sensors.

Besides green houses, and industrial spaces, hygrometers are also used in some saunas, humidors and museums. The sling or motorized psychrometer is used in meteorology.

5. The Psychrometric Chart

The psychrometric chart shows the relationship between the dry bulb temperature, the wet bulb temperature and the relative humidity or vapour pressure. See figure 2. The chart comprises of vertical lines representing dry bulb temperatures, horizontal lines corresponding to the vapour pressure, slanting lines for wet bulb temperatures and curves for the relative humidity. The chart is most commonly used to determine relative humidity from wet and dry bulb thermometer readings. Any of the three variables can be found given the other two.

WBT + DBT => RH

RH + DBT => WBT

RH + WBT => DBT

As an example, let us assume that we have a DBT of 25 degrees C and a WBT of 18 degrees C. We can directly read off the relative humidity as 50% or the vapour pressure as about 10.2 kN/m . For the same DBT of 25 degrees C and a WBT of 20 degrees C the corresponding relative humidity is about 63%.

Further, given a relative humidity of 90% and the DBT as 23 degrees C, we have a WBT of about 21.8 degrees C. Also, a relative humidity of 30% and a WBT of 15 degrees C gives a DBT of about 25.6 degrees.

It may be seen that the WBT with respect to a given DBT increases with relative humidity until

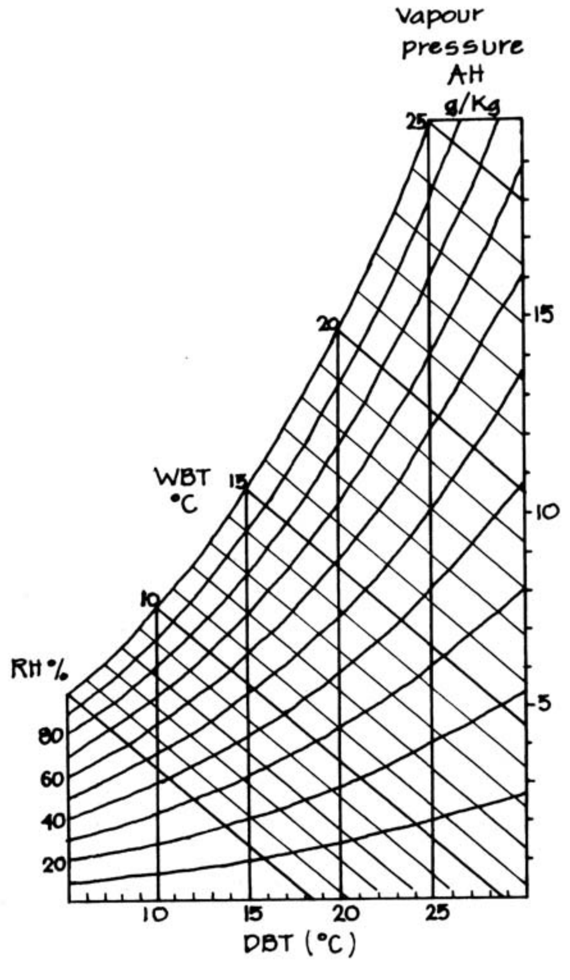

Figure x: The psychrometric chart.

the WBT attains a maximum equal to the DBT at 100% RH.

The vapour pressure depends on the atmospheric pressure but the psychrometric chart gives a good indication of the vapour pressure for altitudes up to 1000 metres. It can also be used for the estimation of the maximum and minimum relative humidity when only the average humidity or vapour pressure is known.

6. Vapour Pressure

The vapour pressure is another indication of atmospheric humidity and it is defined as the partial pressure of water vapour present in the air.

$$P = Pa + Pv$$

where,

P = atmospheric pressure

Pa = partial pressure of dry air

Pv = partial vapour pressure.

When the air is saturated, the vapour pressure (Pv) is equal to the pressure of saturated vapour at the same temperature (Pvs). The relative humidity can be expressed as:

$$RH = Pv/Pvs \times 100(\%).$$

7. Precipitation

Precipitation refers to rain, snow, hail, dew and frost and is usually measured daily. In our climate, precipitation is usually equated to rainfall.

The rainfall is measured with gauges in millimeters per hour, day or month. The mean monthly rainfall taken over a long period is very useful, especially for the determination of adequate roof slopes. It is also used in climatic analysis such as the Mahoney tables. Sometimes there is need for the extreme maximum and extreme minimum rainfall, the maximum rainfall in 24 hours and the number of days with rain.

Two types of recording rain gauge were devised in the early 20th century, the natural siphon gauge and the tilting siphon gauge. Both consist of a collecting chamber with a float to record the water level connected to a pen arm that rises

Plate x: Natural siphon rainfall recorder. Source: www.fairmonth weather.com.

Plate x: Natural siphon rainfall recorder chamber. Source: www.fairmonth weather.com with the water. This pen connects with a paper chart mounted on a clockwork drum, rotating once day or week. The intensity and duration of rain can be examined from the chart. When the chamber is full, it is emptied by a siphoning mechanism (the tilting siphon continues to collect rain falling while siphoning is taking place). More modern recording rain gauges are of the tipping-bucket design

This Instrument provides a graphical record of rainfall against time, based on the movements of a float in a collecting chamber. Its capacity is unlimited since the chamber is automatically empties itself when full. The natural siphon action which achieves this involves no moving parts other than the float: the instrument thus perfectly reliable compared with some other type of recorder. . It is frequently used in conjunction with a daily rain gauge to provide a permanent record of the start and end of rainfall, together with variations in intensity

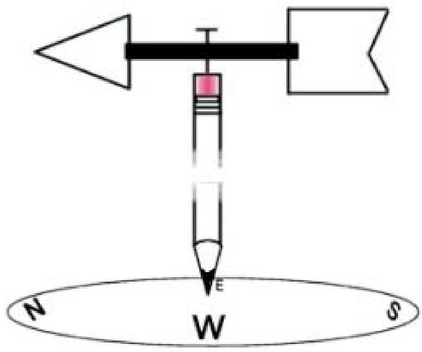

Figure x: Diagrammatic representation of the wind vane.

8. Wind

The wind velocity is usually measured by a cup-type or propeller anemometer, while the direction is measured by a wind vane, also called a weather vane. It is a tool for measuring wind direction. It spins on a rod and points in the direction from which the wind comes. The part of the vane that turns into the wind is usually shaped like an arrow. The other end is wide so it will catch the smallest breeze. The breeze turns the arrow until it catches both sides of the wide end equally. The arrow always points into the wind. The arrow tells you the direction from which the wind is coming. Wind vanes can only measure wind direction a few meters off the ground.

The directions are usually grouped in eight or sixteen categories. The speed is recorded in ranges which can be up to six or eight. The wind data is normally in the form of tables showing frequency of wind speed and direction for each month. They can also be presented graphically on wind roses. See figure 3. For design purposes it is necessary to know the direction of prevailing and secondary winds as well as the maximum and mean wind velocities. The wind pressure which is proportional to wind velocity is used in

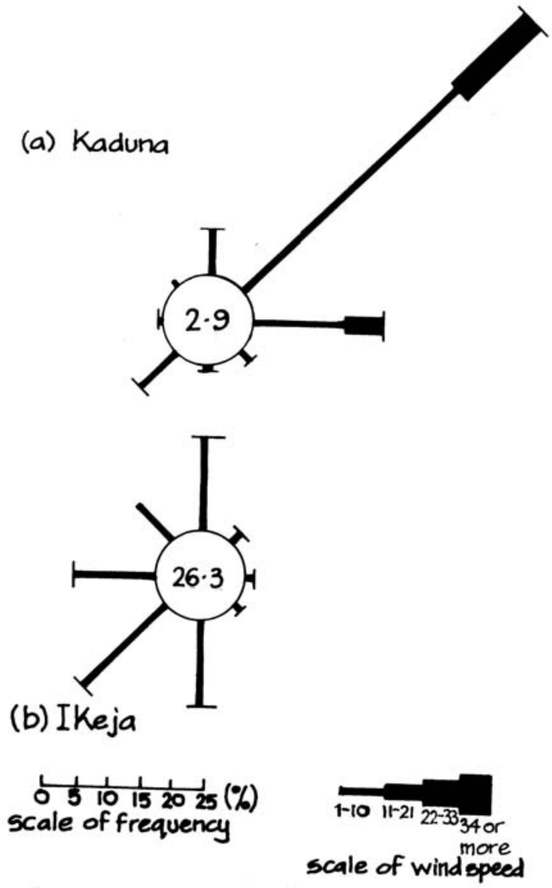

Figure 3: Examples of wind roses.

ventilation. See chapter six. The duration of high-speed gusts is also needed for structural design. The determination of wind loads for roof design should reflect maximum values to avoid blowing off of such roofs.

9. Sunshine.

Campbell Stokes Sunshine Recorder

A Campbell Stokes Sunshine Recorder is a device used by meteorologists to record the actual duration of sunshine. It works by using the optically pure glass ball as a magnifying glass and burning a paper strip. As the sun arcs across the sky it causes the magnifying glass to burn a horizontal line on the paper strip. If the day is in and out of clouds, it burns a series of dots. You may well remember when you were outside and trying to burn something with your magnifying glass, it would not work when the sun was behind a cloud. This sunshine recorder works the same way. The sun has to be out and clear to put a burn mark or line on the strip. From the burn marks you can accurately determine the duration of sunshine for a day. A person would have to change the strip daily, unless it was cloudy the entire day. The sphere is made from well-annealed optical glass and the hours the sun shines are recorded onto a card inserted into the base of the recorder. The cards are marked with hourly intervals. A transparent plastic template is available as an optional extra and is used to help measure the curved trace accurately.

Plate x: Campbell Stokes sunshine recorder.

10. Sky Conditions

The cloud cover refers to the presence or absence of clouds. The average monthly cloud cover is measured in percentages, eighths or tenths.

50% => four-eighths => five-tenths.

The measurements are taken usually twice daily. The average monthly duration of sunshine is measured in hours and can also be obtained from meteorological stations. It is often referred to as sunshine hours. The average intensity of solar radiation usually in W/m can also be obtained from some stations.

11. Other Phenomena

Apart from the basic climatic data the following may also be obtained from meteorological stations:

The number of days with thunder.

The number of days with frost.

The number of days with hail.

The duration and nature of earthquakes, tornadoes, hurricanes and dust-storms.

12. Recording The Data

Climatic data are recorded on forms which include only the relevant data. This provides standardised approach and gives a guide as to the relevance of climatic variables for building design. The forms used are usually climatic data sheets or climatic charts.

Climatic Data Sheets

Climatic data sheets are used for recording the basic climatic data needed by a designer. Their advantage is that they provide a standard approach to recording climatic data and they make it easy to compare data and to make intermediate calculations.

The climatic data sheet (when filled for a particular location), gives background

location, year Zaria	latitude 11° 8′ N	longitude 7° 41′ E	altitude 653·9m
source various	collected by —	notes	

		J	F	M	A	M	J	J	A	S	O	N	D	
dry bulb temperature °C	mean monthly maximum	29·7	33·7	36·3	36·5	34·1	31·8	29·0	28·4	29·6	32·1	31·6	30·4	31·9
	mean monthly minimum	13·6	16·5	20·3	22·8	22·1	21·0	20·1	19·8	19·8	19·0	15·0	13·4	18·6
	mean monthly temperature	21·7	25·1	28·3	29·7	28·1	26·4	24·6	24·1	24·7	25·6	23·3	21·9	25·3
	mean daily maximum													
	mean daily minimum													
	mean diurnal range													
	extreme maximum	34	36	38	38	35	32	30	31	31	33	33	31	38
	extreme minimum	8	13	14	18	17	16	17	17	17	17	12	8	8
relative humidity	mean daily maximum (%)	38	32	44	68	84	90	94	96	94	81	53	46	68
	mean daily minimum (%)	16	13	16	27	37	52	64	68	62	39	20	19	36
	mean humidity (%)	27·0	22·5	30·0	47·5	60·5	71·0	79·0	82·0	78·0	60·0	36·5	32·5	52
	mean vapour pressure													
	no of days of fog													
precipitation	mean monthly (mm)	—	1	9	39	102	153	230	281	216	43	2	—	1076
	maximum in 24 hours (mm)													
	days with 0·25mm/more	—	—	1	9	13	13	16	18	13	2	—	—	85
sky	hours of sunshine	8·7	9·5	8·6	8·0	8·2	7·8	6·1	5·1	6·9	8·9	9·5	9·2	8·0
	cloud cover, oktas (or %)													
wind	maximum velocity (m/s)													
	mean velocity (m/s)	1·6	1·5	1·8	1·8	2·1	1·7	1·6	1·3	1·2	1·2	1·6	1·4	1·6
	prevailing direction	NE	NE	NE	SW	SW	SW	SW	SW	SW	NE	NE	NE	
	secondary direction	NW	SW	SW	NE	NW	NW	NW	NW	NW	SW	NW	NW	

Table 2.1

Figure x: Climatic data sheet for Zaria.

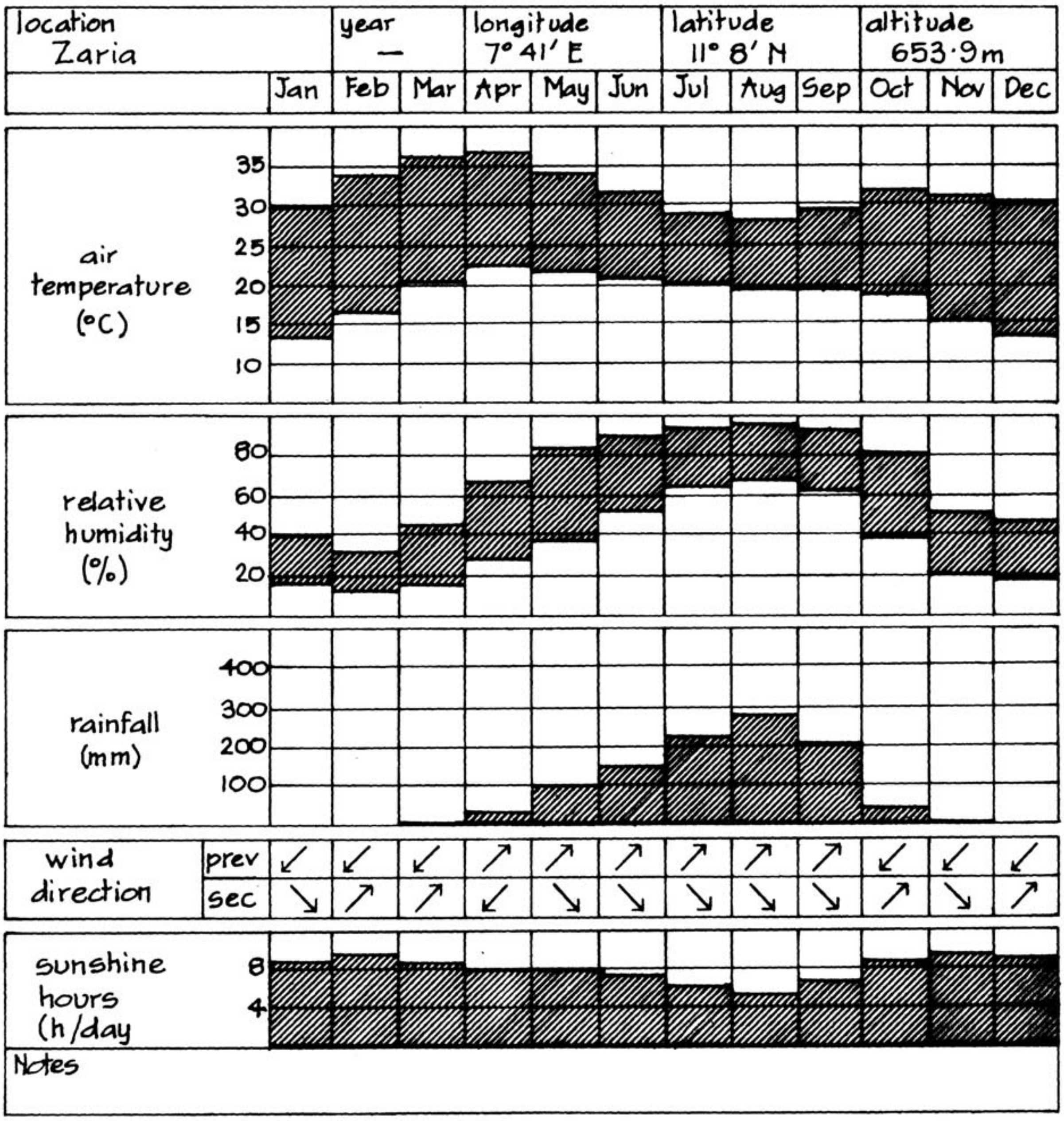

Figure 4: Climatic chart for Zaria.

information about the position of the town on the globe as well as the values of the climatic variables most relevant to design. 12 columns are reserved for the entry of these data for each of the 12 months of the year while the 13th column is for averages or totals. There is a space for notes and additional information. The graphical nature of climatic charts however gives them an edge over climatic data sheets. See Table 1.

Climatic Charts

Climatic charts are used for the graphical presentation of climatic data. They make it easy to understand the climate of a location at a glance. Comparison of the climates of different locations is also much easier. See figure 4.

11 Variations In Climate

Meteorological stations are usually located in open areas where conditions are usually not

Table x: Variation in climate with increasing altitude. Note: the values given are indicative only and may not apply in all situations

Climatic variable	Effect of 100m Increase in altitude
Annual mean temp	0.5 deg C decrease
Range between hottest and coldest monthly temp	0.25 deg C decrease
Range between mean daily max and min. temp	Significant increase.
Relative humidity	Slight increase
Solar radiation	0.25% increase
Total annual precipitation	Up to 100mm increase, but highly dependent on topography and wind direction
Wind speeds	Significant increase unless sheltered by topography

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similar to those found at the building site. There is therefore a climatic variation between the site and the meteorological station from which data were obtained.

Variations in climate are caused by:

Differences in altitude.
The coastal or inland nature of locations.
Nearness to urban centres.
Obstructions caused by ground cover and topography.

Difference In Altitude

There is a general fall in air temperature with altitude as a result of the expansion and subsequent cooling of air. This fall in temperature may be up to 1 degree Celsius for every 100-metre increase in altitude. Higher diurnal ranges and higher wind speeds are also recorded. See table 2.

The Coastal and Inland Nature of Locations

The sea affects the climate of coastal regions for up to 30 km inland. This creates a variation between inland and coastal climates which is more marked in dry climates. With increase in the distance from the sea there is a general decrease in relative humidity, cloud cover, wind speed and rainfall. At the same time solar radiation as well as diurnal and annual temperature ranges are on the increase.

Nearness to Urban Centres

Urban centres with large populations tend to create microclimates different from that of the surrounding region. The urban heat island is formed as a result of high concentrations of buildings, factories, structures, machines and human beings. This is manifested by higher temperatures in cities.

Obstructions Caused by Ground Cover and Topography

This affects mainly the wind speed. The wind speed is usually measured at a height of 10 metres. The wind speed at the level of the human body is usually less since wind speed increases with altitude. This decrease is more marked in wooded, suburban and urban areas as opposed to open areas. This is a result of the obstruction caused by trees, buildings and other elements of the topography. See table 3.

Tests and Exercises

1. Name the climatic elements whose effects are responsible for variations in climatic conditions.

2. What are the major causes of variations in climate?

3. Describe the use of climatic data sheets and climatic charts.

4. Describe briefly the use of the psychrometric chart.

5. Describe briefly the climatic data about special phenomena that can be obtained from meteorological stations and their importance to architectural design.

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