CHAPTER ONE

BASIC CONCEPTS

1. Introduction.
2. Movement of the earth around the sun.
3. Solar time.
4. Solar radiation.
5. Global wind pattern.
6. Spatial systems of climate.
7. Design with climate.

1. INTRODUCTION.

Some preliminary knowledge of science is required to understand certain concepts in Building Climatology. Such information is usually presented to students at lower levels, but it is common to find students with different backgrounds taking this course. This chapter attempts to unify students' perception of basic concepts especially as regards global climate. The motion of the earth and how it gives rise to various seasons and various ways of measuring time are discussed. The way the distribution of solar radiation affects climate and the genesis of the global wind pattern are explained. The spatial and time scales used to delineate categories of climate are also given. Design with climate emphasises compatibility of housing form with climatic requirements.

2. MOVEMENT OF THE EARTH AROUND THE SUN.

The sun is the main source of energy on earth. The sensation of day and night is caused by the rotation of the Earth about its north- south axis. See figure 1. The earth makes one such rotation in 24 hours. At the same time earth is on a closed elliptical orbit around the sun. The Earth's north-south axis is inclined to the plane of orbit at 23 degrees and 27 minutes. The Earth completes one revolution in one year of 365 days, 5 hours, 48 minutes and 46 seconds. This inclination and orbiting give rise to the seasons. See figure 2.

The sun can be said to move between the tropic of Cancer (23.5 degrees North) and the tropic of Capricorn (23.5 degrees South). In June the Earth is tilted towards the sun and the tropic of Cancer receives the maximum intensity of solar radiation. This is the summer solstice, with summer in the northern hemisphere. During the winter solstice the situation is reversed with the tropic of Capricorn receiving maximum solar radiation and the northern hemisphere experiencing winter. The day is longer than the night during the summer with the reverse in winter. The sun crosses the equator in March (vernal equinox) and September (autumnal equinox). At this time the day and the night have equal length for all places on Earth.

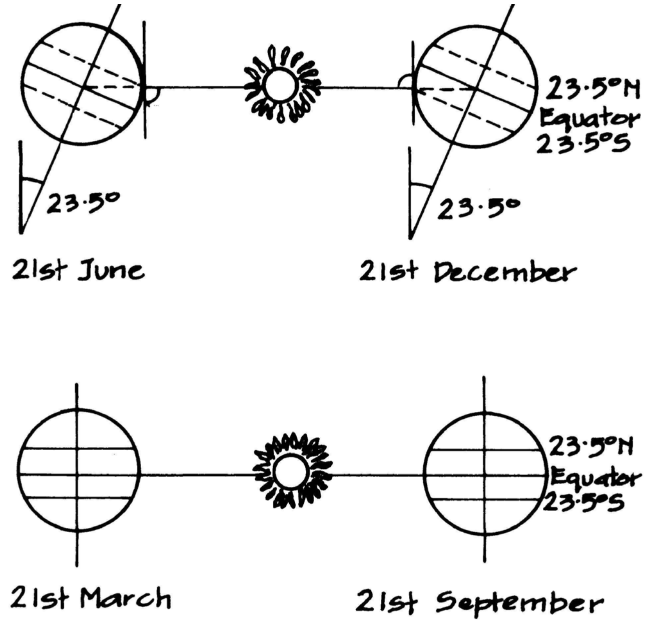


Figure 1: A section through the sun, the ecliptic plane and the earth in two directions.

3. SOLAR TIME.

There are four terms usually used in discussions on solar time:

- clock time.
- mean solar time.
- true solar time.
- local apparent time (LAT).

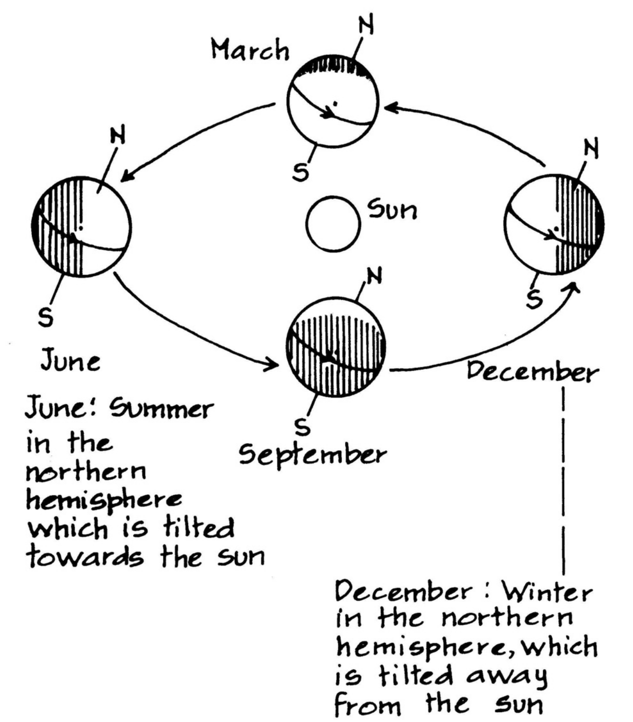


Figure 2: Relationship between the earth and the sun at different times of the year.

Clock Time.

This is the time indicated by a time piece. The world is divided into time zones; each time zone usually covers 15 degrees of longitude. This means there is a time zone for each of the 24 hours of the day. The clock time in any part of a particular time zone is the same, irrespective of the longitude. Nigerian time is based on longitude 15 degrees East and is therefore 1 hour ahead of Greenwich Mean Time (GMT) which is based on longitude 0 degree.

Mean Solar Time:

The mean solar time is a uniform time indicated by a clock which does not take the equation of time into consideration. In a particular time zone, the mean solar time and the clock time are the same on the reference longitude. Locations to the west of the reference longitude will have a mean solar time earlier than the clock time, while locations to the east of the reference longitude will have a mean solar time later than the clock time. The correction factor to be added or subtracted is equal to 4 minutes for every degree of longitude. The reference longitude for Nigeria is 15 degrees East. As an example, let us determine the mean solar time for Lagos (3:24 degrees East), given a clock time of 12 noon and a reference longitude of 15 degrees East.

The correction factor:

= 4 (15 - 3:24) minutes.

= 4 x 11:36 minutes.

= 46:24 minutes.

Lagos is to the West of the reference longitude, therefore mean solar time:

= 12:00 - 00:46:24.

= 11:13:36.

True Solar Time.

This is that time in which noon occurs when the sun is due South, as shown by a sundial. It varies from mean solar time as a result of variation of the angle of declination with date and slight variation of the orbital velocity of the earth. The correction applied to the mean solar time to obtain the true solar time is known as the equation of time. The equation of time may have a positive or negative value. As an example, let us obtain the true solar time for Maiduguri (13:05 degrees East) on January 15th given a clock time of 12 noon.

To obtain the mean solar time, time difference:

= 4 (15 - 13:05) minutes.

= 4 (1:55).

= 7:40 minutes.

Mean solar time:

= 12:00 - 00:07:40.

= 11:52:20.

The equation of time on January 15 is +9 minutes:

True solar time is therefore:

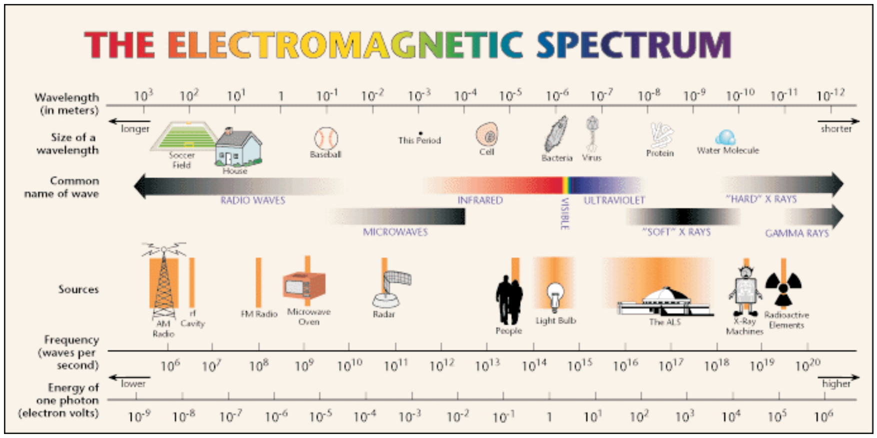
= 11:52:20 + 00:09:00 = 12:01:20.

Local Apparent Time.

This term is used in astronomical and nautical calculations and is equivalent to the true solar time.

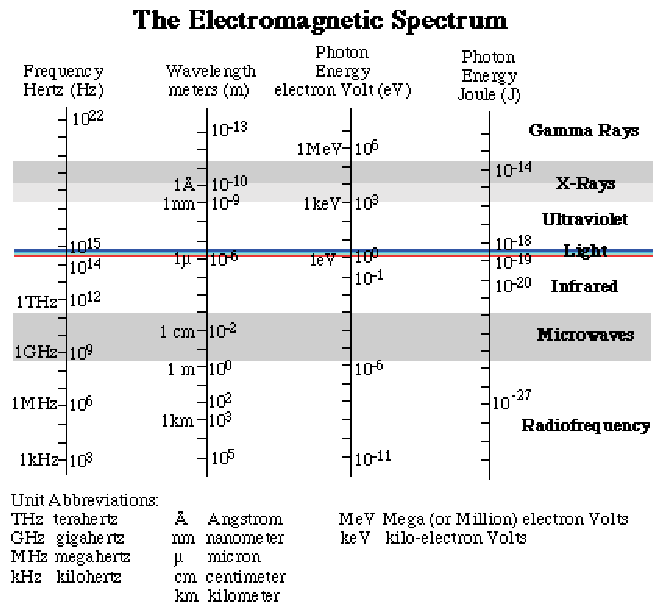
4. SOLAR RADIATION.

The main source of energy on the Earth is the sun. This energy comes in form of electromagnetic radiation. The heat flow rate is measured in Watts (W), that is Joules per second (J/S). The speed of light (c) is the product of its frequency (v) and its wavelength (Lambda), and it is a constant.



Http://www.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html

The frequency is the number of oscillations per second, measured in Hertz and the wavelength is the distance between identical points of two succeeding oscillations, measured in unit length.



Http://science.nasa.gov/newhome/help/glossfig1.htm

Spectrum Of Solar Radiation.

The solar spectrum can be broadly divided into three sections with wavelength extending from 290 to 2300 nanometres:

Ultraviolet radiation	(290-380 nm)
Visible light	(380-700 nm)
Infra-red radiation	(700-2300 nm)

The Solar Constant.

This refers to the intensity of solar radiation reaching the upper surface of the atmosphere and it has a value of 1395 W/m . This value may vary slightly due to changes in the sun and variations in the distance between the earth and the sun, since the earth is in an elliptical orbit. Not all the solar radiation reaching the upper surface of the atmosphere gets to the earth's surface as a result of atmospheric depletion of solar radiation.

Atmospheric depletion of solar radiation refers to the absorption of solar radiation by ozone, vapours and dust particles in the atmosphere. See figure 3. The purity of the atmosphere thus affects the amount of radiation absorbed: the greater the quantity of ozone, dust, smoke, vapours, et cetera in the atmosphere, the less radiation reaches the surface of the Earth. The radiation received at a point on the Earth's surface thereby varies with the path of the solar radiation through the atmosphere. The longer

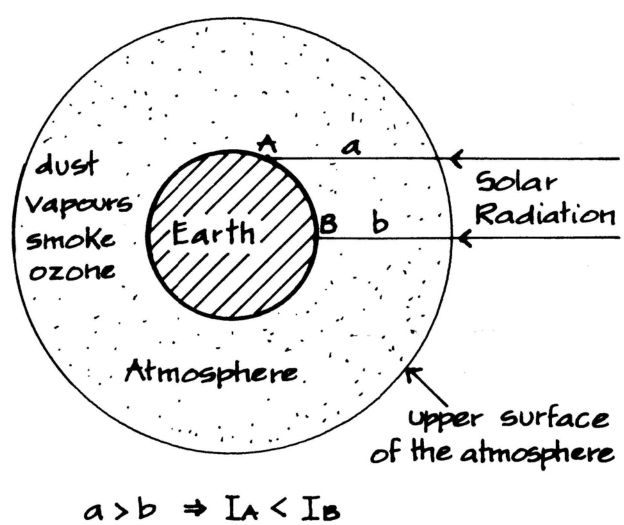


Figure 3: Atmospheric depletion of solar radiation.

the path, the less the radiation received. The intensity of solar radiation incident on a point on the Earth's surface depends on the solar angle, as explained by the cosine law of solar radiation.

The Cosine Law of solar radiation states that the intensity of solar radiation on a tilted surface equals the normal intensity times the cosine of the angle of incidence. See figure 4. In the illustration, the same radiation is distributed over surfaces BC and AB. Since surface AB has a greater area, the intensity on it is less. This accounts for the greater intensity of solar radiation at the equator when compared to the poles.

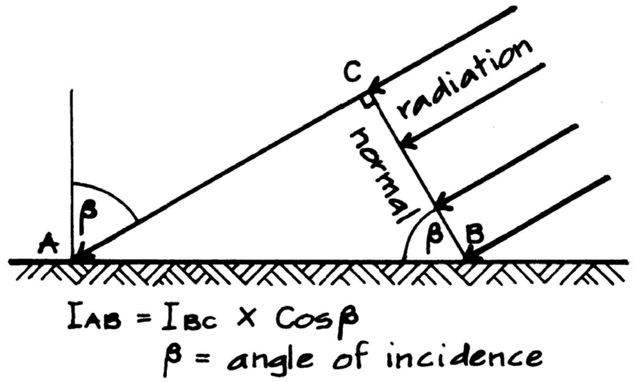


Figure 4: Cosine law of solar radiation.

To maintain the thermal balance of the Earth, the equivalent amount of the radiation absorbed is lost back to outer space. Without this regulatory system the temperature of the Earth would constantly be on the increase.

Incoming Radiation:

If we take the total amount of solar radiation reaching the outer surface of the earth as 100%, then 20% is reflected from clouds, 25% is absorbed in the atmosphere and 5% is reflected from the ground. Only 50% of the total radiation is thus absorbed by the Earth's surface with 23% of this being in the form of diffuse radiation and the remaining 27% as direct solar radiation. This energy is absorbed by the hydrosphere to raise water temperature, by the bare soil and by land and marine vegetation. See figure 5.

Outgoing Radiation:

The Earth loses the heat absorbed through long-wave radiation (40%), evaporation (40%) and convection (20%).

4. GLOBAL WIND PATTERN.

The global wind pattern is the result of three basic forces. The thermal force, the Coriolis force and a force explained by the law of conservation of angular momentum.

The thermal force is a result of the differential radiation balance on the surface of the earth. The difference in temperature between the equator and the poles gives rise to convection currents. The hot air at the equator rises and flows to the poles where it falls. The area where the hot air rises, between the tropics of Cancer and

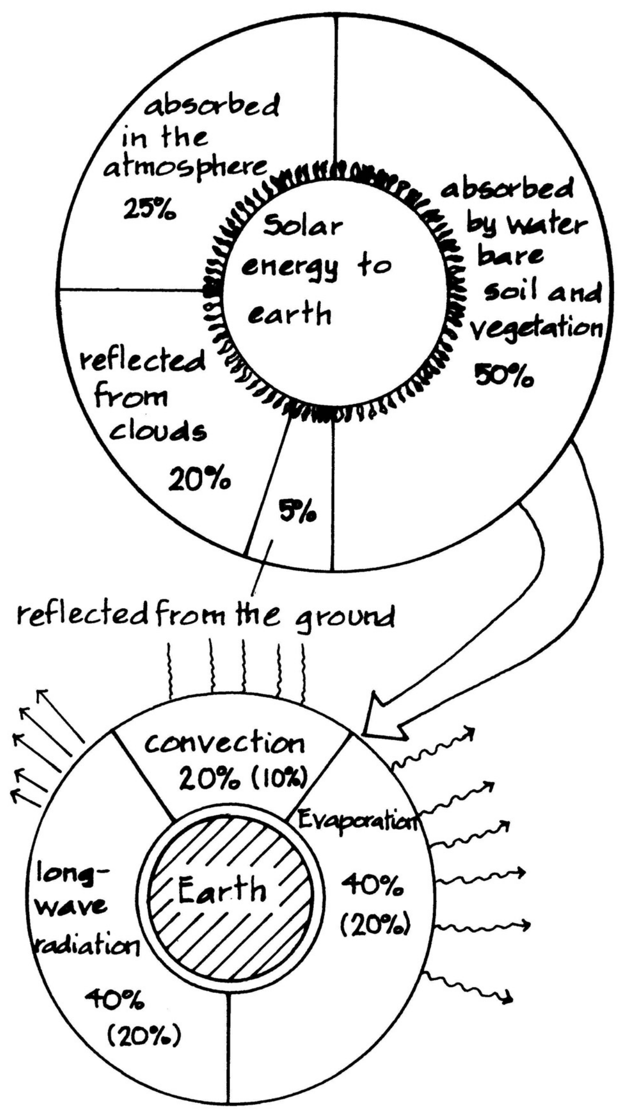


Figure 5: Incoming solar radiation and heat loss to outer space.

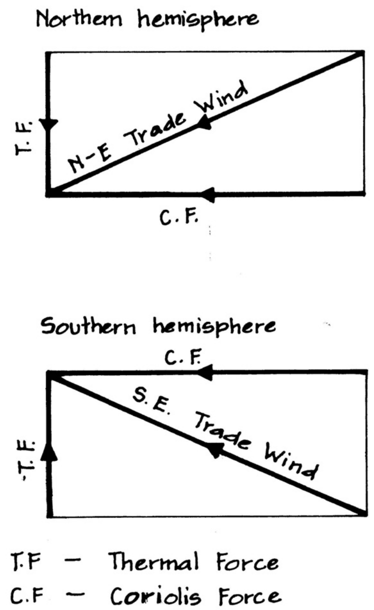


Figure 6: Origin of the North East and South East trade winds.

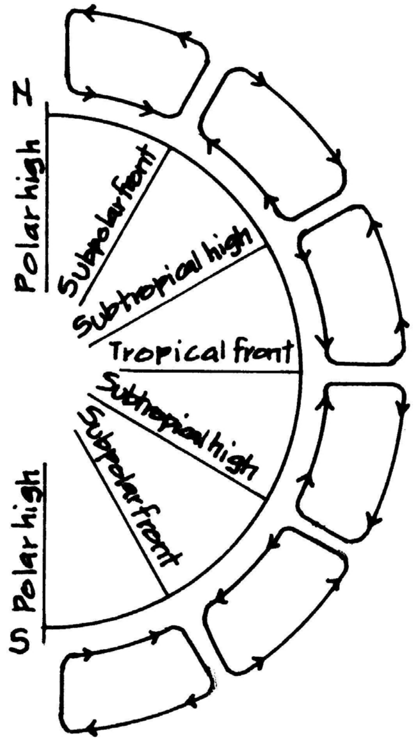
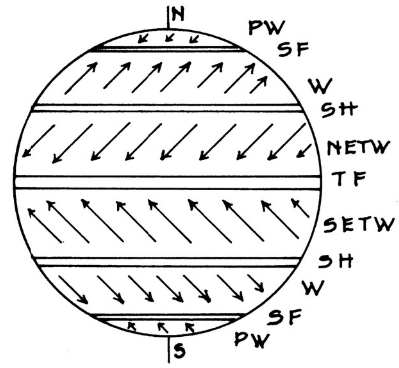


Figure 7: Global wind pattern.



Legend:
PW – Polar winds.
SF – Subtropical front.
W – Westerlies.
SH – Subtropical high.
NETW – North East Trade Winds.
TF – Tropical Front.
SETW – South East Trade Winds.

Figure 8: Global wind pattern.

Capricorn, is called the Inter-Tropical Convergence Zone (ITCZ). This is where the northerly and southerly winds meet, forming the Tropical Front.

The Coriolis force is caused by the apparent higher speed of rotation of the equator than the poles. The atmosphere rotates with the earth, but being a fluid held to the earth only by gravity and friction, it tends to lag behind. This creates a force experienced as a wind blowing in the opposite direction to that of the earth's rotation. The Coriolis force and the thermal force create a resultant force in the form of a wind. This is the North-East trade wind in the Northern Hemisphere and the South-East trade wind in the southern hemisphere. See figure 6.

Westerly winds are strong winds blowing between latitudes 30 and 60 degrees. But unlike the trade-winds, they blow in the same direction as that of the earth's rotation. This peculiar behaviour is explained by the law of conservation of angular momentum. The westerly winds are the result of a tendency to keep the earth-atmosphere angular momentum constant. This constant is reduced at the equator by the easterly trade-winds and this is compensated for by the westerlies. The braking effect of the easterlies on the earth is thereby balanced by the accelerating effect of the westerlies. See figures 7 and 8.

The polar winds are created by thermal forces and the lag of air behind the rotating earth. These forces create easterly winds known as the north-easterly and south-easterly polar winds. The sub-polar front is formed where the polar and westerly winds meet

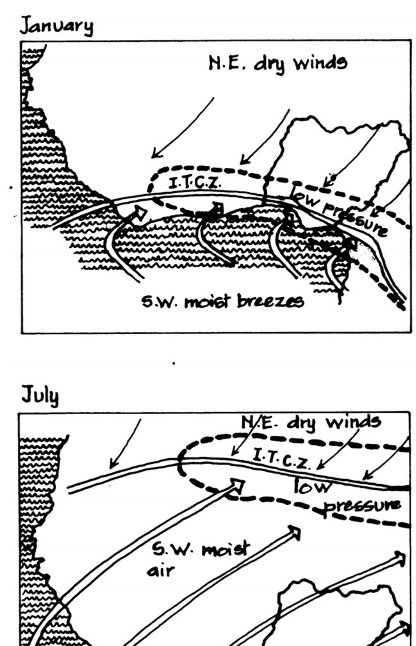


Figure 9: Position of the Inter Tropical Convergence Zone in January and July.

and is characterised by highly variable and strong winds. The position of the Inter Tropical Convergence Zone (ITCZ) changes during the year. This position is equivalent to the region of maximum solar heating, with a delay of about one month. The ITCZ is therefore at an extreme northern position in July and at an extreme southern position in January. See figure 9. This plays an important role in the formation of climatic patterns around Nigeria. In January the country is under the influence of dry winds but by July the moist winds take over.

5 SPATIAL SYSTEMS OF CLIMATE.

The concept of scale is very important in building climatology. There are four generally recognised categories of climate based on spatial and time scales (see table 1):

- The global climate.
- The regional macroclimate.
- The (local) topoclimate.
- The microclimate.

Table 1: Spatial systems of climate.

System	Approximate characteristic dimensions		
	Horizontal scale	Vertical scale	Time scale
Global wind Belts	2000km	3 to 10km	1 to 6 months
Macroclimate	500-1000km	1 to 10km	1 to 6 months
Topoclimate	1-10km	10 to 100m	1 to 24 hours
Microclimate	100m	10m	24 hours

The global climate is a result of the movement of air masses due to temperature and pressure changes. This climate is largely independent of surface topography. These changes in land features and surface change have an effect on the regional macroclimate. At the next scale, the topoclimate or local climate, the effect of the topography and human activity play a very important role. The microclimate refers to a spatial scale of about 1 km horizontally and 100 m vertically. The architect is primarily interested in the microclimate which is affected by trees, buildings and windflow patterns.

6. DESIGN WITH CLIMATE.

The need to design with climate has always been a major consideration in architecture. Vitruvius, in his ***Ten Books On Architecture*** drew attention to the importance of climate in architecture and town planning (Vitruvius, 1960). Since then a lot of research effort has gone into the determination of the relationship between climate and architecture as well as into the formulation of guides for architects in the different climates.

The last few decades witnessed several developments in the field of environmental technologies in heating, cooling and illumination, and according to Fitch, architects and urbanists have tended towards an extravagant reliance upon them and have shown little interest in the systematic exploration of other possibilities (Fitch, 1972). These other possibilities, as recognised by the Building and Road Research Institute, Kumasi, lie in "finding methods of building which will enable the building structure itself effect the desired environmental control" (Essien, 1968).

The complexity of architectural design is a necessary consequence of the quest for that delicate balance of building form that, in an ecological sense, derives from and is compatible with nature. This concept of the environment being the fundamental generator of building form crystallised in primitive architecture. The harsh reality of excessive heat and cold, among others, dictated building fabric and form.

Natural forms undoubtedly acted as a form of inspiration (Olgyay, 1963). Bird nests, termitaries, hibernating mammals, plants reaching up for light, tree branch and root systems and the flowing forms of windswept rock surfaces express with logical clarity the genesis of several building practices. Adapting only one of these solutions, however, cannot solve the architectural problem. The needs of man are wider in scope, more detailed in content and more complex in their inter-relationships.

A popular example of the adaptation of house form to the environment is the igloo. Eskimos were forced to use ice blocks - a consequence of the dearth of other building materials. The tolerable indoor temperatures, the level of lighting achieved and the protection from cold winds are worthy testimonies of adaptation (Fitch, 1972).

The harsh desert climate also dictated interesting architectural solutions. The main problems are high day temperatures accompanied by intense insolation, low night temperatures, dust and strong winds. The use of thick mud walls and mud roofs provides the necessary thermal capacity. This is combined with compact courtyard design and small openings. Half-buried and underground houses are sometimes used.

Examples of adaptation to climate can also be found in Nigeria. The use of verandas in the southern part of the country provides shade from the tropical sun (Akinsemoyin et al, 1976). Roofs, made of thatch, were necessarily steep to allow proper drainage. In the drier parts in the northern part of the country, the roof is made of mud domes that provide thermal capacity.

Contemporary architects stress the need to respond to environmental stimuli as indigenous builders do. Rudolfsky, in his Architecture Without Architects demonstrated the enormous range of beautiful solutions which illiterate craftsmen are able to produce without benefit of any body of formal literary tradition or academic training (Rudolfsky, 1964). Schweibert pointed out the significance of primitive architecture and analysed the derivation of forms in terms of response to climate, materials and techniques (Schweibert, 1965). Ralph Erskine, the Anglo-Swedish architect, has designed a series of buildings which provide novel solutions to the oppressive environmental loads (Erskine, 1960). Ralph Knowles studied the skyscraper and the form it should take in response to environmental forces (Knowles, 1964).

These studies confirm the main thesis of bioclimatic approach to architectural design: that "the solution of experiential problems is the only source of valid form" (Fitch, 1972).

TESTS AND EXERCISES.

1. Explain the meaning of the following:

    a. True solar time.

    b. Atmospheric depletion of solar radiation.

    c. The cosine law of solar radiation.

    d. Coriolis acceleration.

2. Calculate the mean solar time for the following towns given a clock time for the Nigerian Time zone of 10 am.

    a. Kano (08:32 degrees East).

    b. Calabar (08:21 degrees East).

    c. Sokoto (05:15 degrees East).

    d. Zaria (07:41 degrees East).

    e. Ikeja (03:20 degrees East).

3. What is basically responsible for the climate of any particular place? What is meant by solar radiation? With the aid of sketches illustrate:

a. how solar radiation can affect climate.

b. the effect of latitude on climate.

4. Describe the phenomenon of solar radiation on the Earth's surface and mention its effects on some basic human endeavours.

5. How does the earth maintain its thermal balance?

6. Describe quantitatively the concept of radiant heat transfer and thermal balance of the earth.

7. What do you know about electromagnetic short-wave radiation? What is long-wave radiation?

8. Describe the nature and consequence of the three forces that determine the global wind pattern.

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