Chapter Four

Shading Devices

1. Introduction.

Windows may contain several elements including shading devices. The design of these elements reflect various functions including thermal control. There are three types of shading devices - vertical, horizontal and egg-crate. The design of sunshading devices for thermal comfort involves four steps: determination of when shading is required; determination of the position of the sun at the times when shading is required; determination of the dimensions and proportions of the required shading device and finally the architectural and structural design of the shading device.

2. Types of Shading Devices.

Openings, especially windows, greatly influence the thermal conditions within a building. Windows usually contain several elements, some of which are adjustable. These elements perform various functions, including the following:

- -ventilation
- -daylighting
- -provision of privacy and security
- -prevention of glare
- -exclusion of rainfall
- -allowing a view out
- -exclusion of dust, noises, pollution and insects
- -exclusion of direct solar radiation.

External shading devices are only one of these elements. Others include curtains, glass, solid or louvered shutters, security bars and mosquito screens. The functions of external shading devices include:

- -allowing a view out
- -protection from rain
- -protection from direct solar radiation
- -protection from sky glare

It can be seen from the above that the design of openings can be very complex indeed. We shall concentrate on the design of external shading devices but it can also be seen that the design of these devices should enable them function in several ways. We shall therefore narrow down our aim to the design of external shading devices for thermal comfort.

In warm -humid areas, such as Lagos and Calabar, it is often desirable to exclude the sun throughout the year. There are however, other regions with composite climates, with distinct hot and cold seasons. The design of external shading devices in such areas must exclude solar radiation in the hot season and allow progressively greater quantities of solar radiation to enter as the season becomes colder.

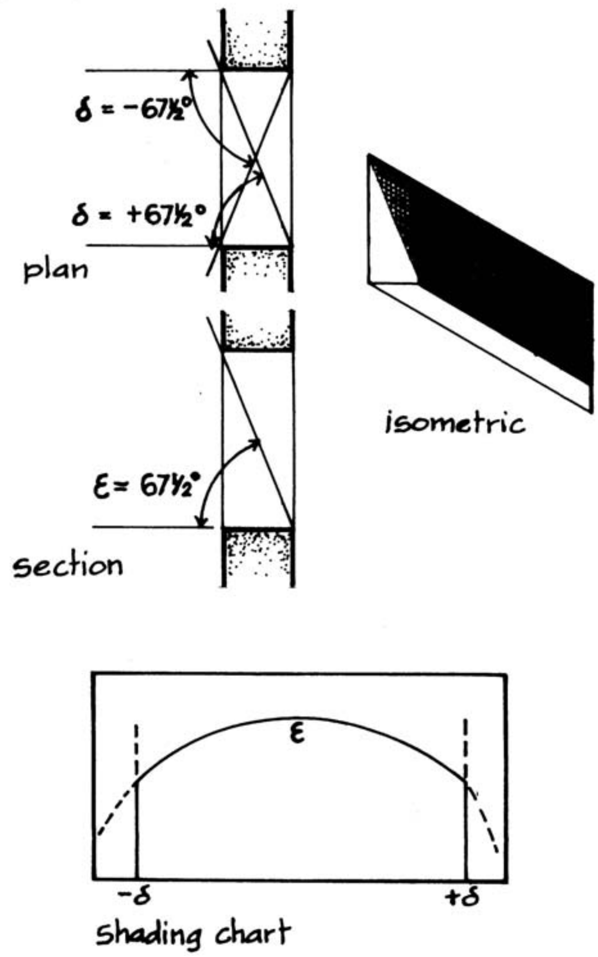

Figure 1: Shading characteristics of a simple window. Shading chart indicating the areas of the sky which are shaded by the thickness of the wall.

3. Various Shading Devices and Their Geometries.

There are three types of sun-shading devices. They are:

Vertical devices.
Horizontal devices.
Egg-crate devices.

Windows without shading devices have some shading characteristics measured by their horizontal and vertical shading angles. See figure 1. In describing the characteristics of shading devices it should be noted that the window and the shading device are considered as one unit.

Vertical Shading Devices.

Vertical Shading Devices consist of pilasters, louvre blades or projecting fins in a vertical position. Their performance is measured by the horizontal shadow angle (delta). They are commonly referred to as fins and are most effective on western and eastern elevations. See figure 2.

Horizontal Shading Devices.

Horizontal Shading Devices are usually in the form of canopies, long verandas, movable horizontal louvre blades or roof overhangs. They are best suited to southern and northern elevations and their performance is measured by the vertical shadow angle (epsilon). See figure 3.

Egg-Crate Devices.

Are combinations of vertical and horizontal devices. They are usually in the form of grill blocks or decorative screens. Their performance is determined by both the horizontal and vertical shadow angles and (delta and epsilon). See figure 4.

4. Design of Shading Devices.

There are certain steps to be followed in the design of shading devices.

Step One:

It is necessary to determine when shading is required, that is at what times of the year and during what hours of the day. This is usually done by defining the overheated and underheated

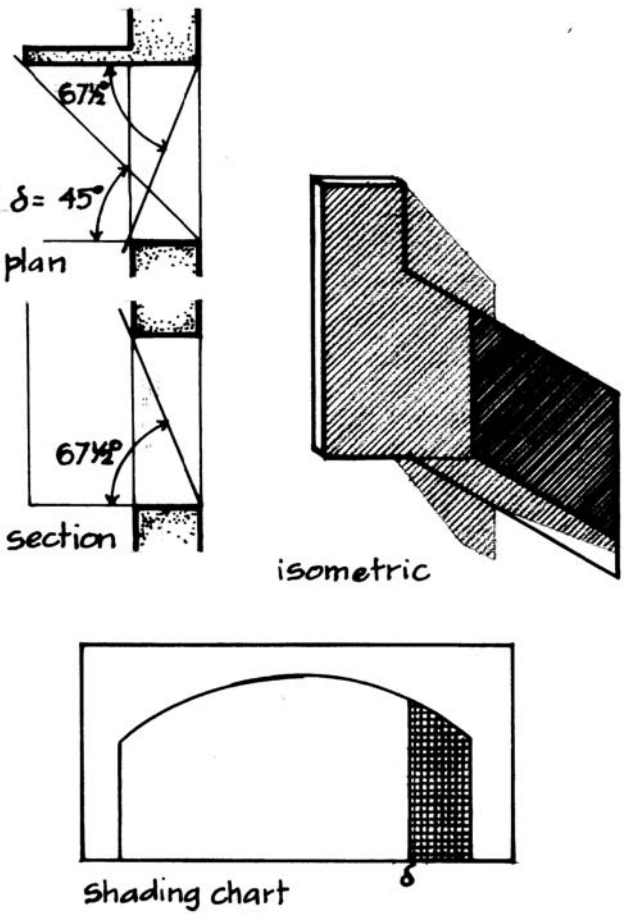

Figure 2: A vertical shading device. Shading chart indicating the additional areas of the sky which are shaded by a vertical shading device on one side of the window only.

periods.

Step Two:
The position of the sun at the times when shading is required must be established. This is usually done with the aid of a sun-path diagram.

Step Three:
The dimensions and proportions of the shading device that will provide shading during the period earlier defined is found. This is done with the aid of a shadow angle protractor.

Step Four:
The choice of prefabricated devices or the design of new ones. The design of shading devices takes not only the required geometry into consideration but also aesthetic and structural factors.

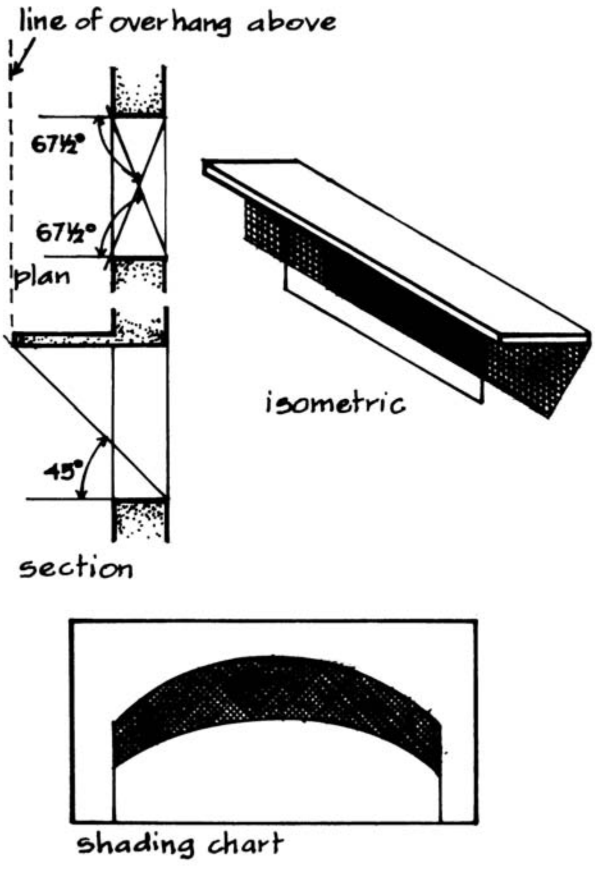

Figure 3: A horizontal shading device. Note that it projects beyond the window on plan to prevent the sun reaching the window from the ends of the shading device. Shading chart indicating the additional areas of the sky which are shaded by a horizontal shading device.

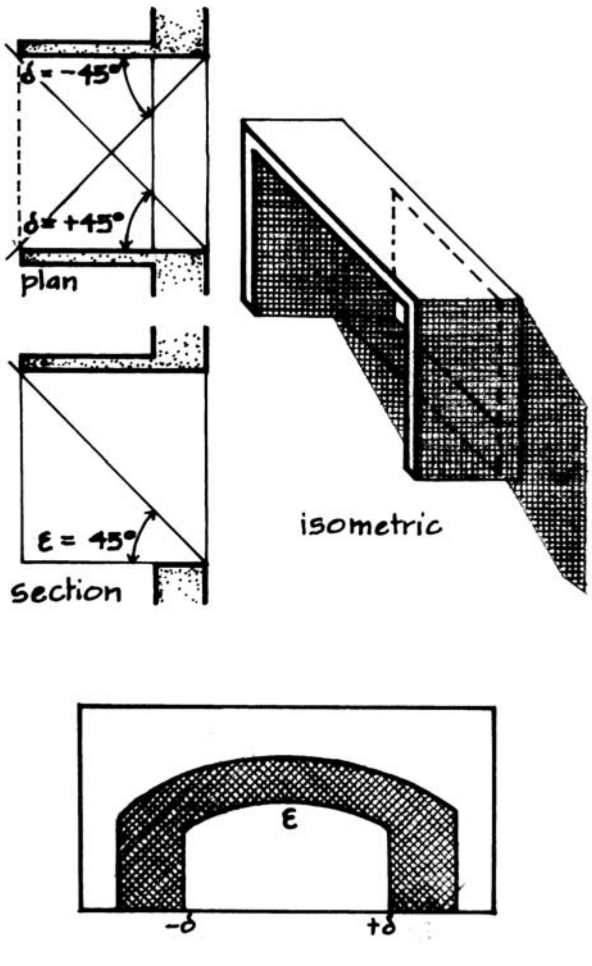

Figure 4: A shading device with vertical and horizontal elements. Shading chart indicating the additional areas of the sky shaded by a combination of horizontal and vertical projections.

5. Overheated and Underheated Periods.

The thermal stress experienced in a particular city is characterised by the duration of the overheated, the comfortable and the underheated periods. The overheated period is that period when there is hot discomfort while the underheated period represents cold discomfort. In composite climates, there are certain periods of the year, especially during the harmattan months of November to February, when there is underheating characterised by low temperatures in the nights and early mornings. The use of solar radiation during this period is welcome. On the other hand, there is serious overheating for a few weeks in March/April and exclusion of sunlight is desirable at this period. The same shading device is used to allow solar heating during the underheated period and block out the sun during the overheated period. The geometry of the shading device must therefore be determined on the basis of the duration of the overheated and underheated periods and when they occur during the year.

The overheated and underheated periods are determined with the aid of a thermal index. Such an index should be able to indicate for given climatic conditions whether there is cold discomfort, comfort or hot discomfort. This process is explained with the aid of the

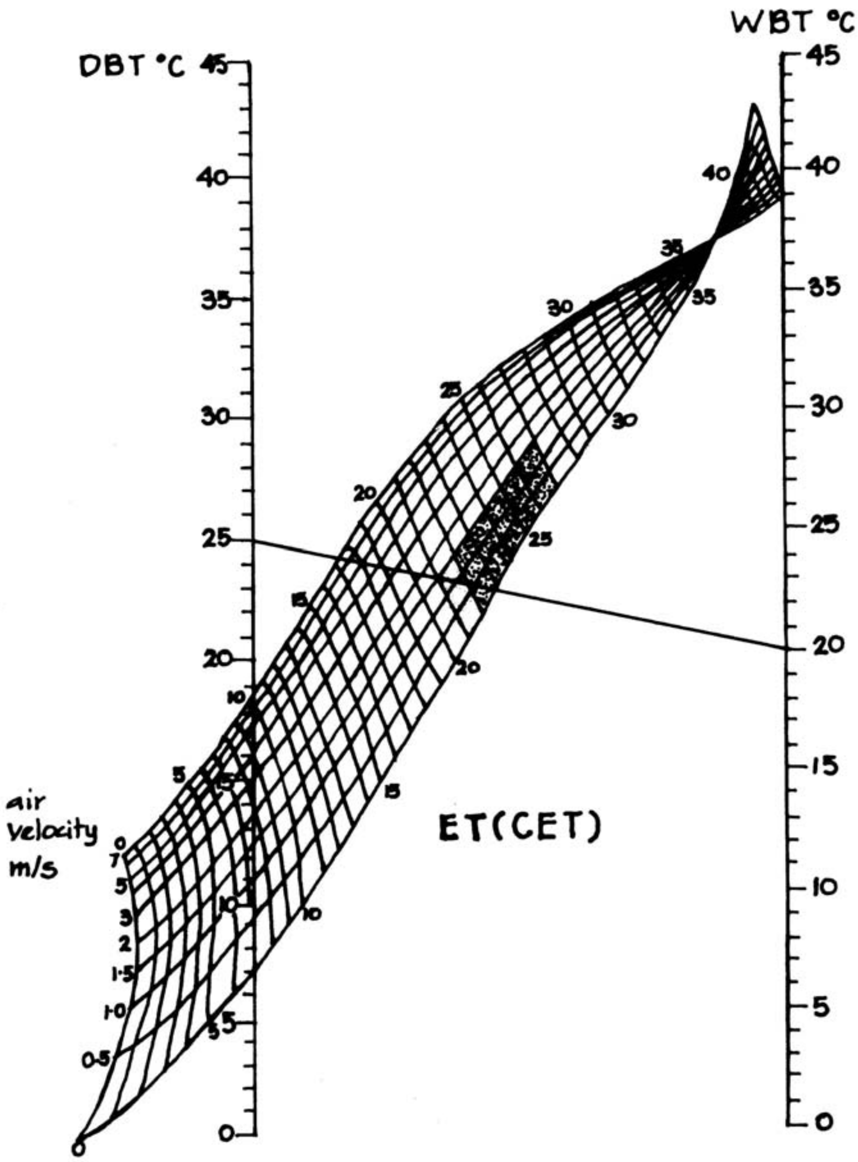

Figure 5: The Effective Temperature nomogram for persons wearing normal clothes.

Effective Temperature index using Zaria as an example.

The climatic data needed are the monthly minima and maxima of dry-bulb and wet-bulb temperatures as well as the mean monthly wind velocity. The wet-bulb temperatures are not always available and in such a case they should be calculated from the monthly minima and maxima of relative humidity. This was done for Zaria with the aid of the psychometric chart. See table 1. Alternatively, the computer program PSYCHRO may be used. See chapter 12.

6. Using the Effective Temperature Nomogram.

The Effective Temperature nomogram is used to obtain the Effective Temperatures. In the example, the nomogram for persons wearing normal business clothing is used and an air velocity of 1.0 m/s is assumed. The maximum DBT and the maximum WBT are used to obtain the maximum ET while the minimum DBT and the minimum WBT are used to obtain the minimum ET. The computer program EFFECT may be used for this purpose.

We have now obtained the monthly minima and maxima of Effective Temperature. The comfort limits 22 -27 degrees Celsius are provisionally assumed for the Effective Temperature index in Nigeria. The calculated Effective Temperature should be compared with the comfort limits to determine the thermal stress and hence the period when shading is required.

7. The Hourly Temperature Calculator.

The hourly temperature calculator is used to determine the diurnal temperature variation. See figure 6. It is based on the sinusoidal character of temperature variation with the minimum temperature around 6.00 am and the maximum around 2.00 pm. To use the hourly temperature calculator, the minimum and maximum temperatures are marked. These two points are joined by a straight line and results are read off the line. For example, given a minimum temperature of 20 degrees Celsius and a

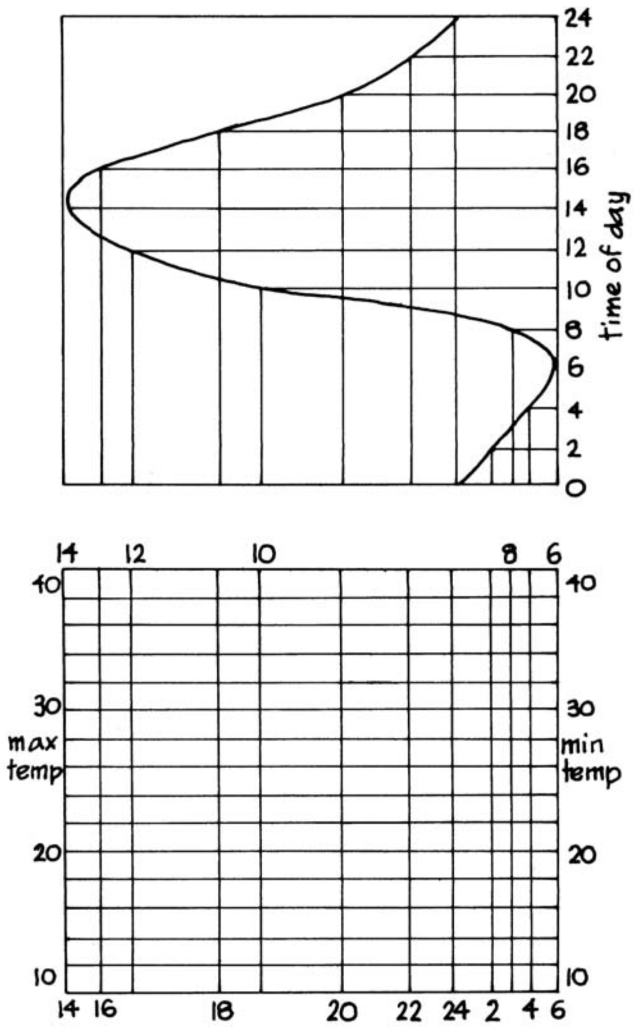

Figure 6: The hourly temperature calculator.

maximum of 30 degrees Celsius, the temperature at 12 noon is about 28.5 degrees Celsius and the temperature rises to 26 degrees Celsius at 10.00 a.m. and falls back to the same 26 degrees Celsius at about 6.40 pm.

It is possible to construct a complete effective temperature isopleth showing the underheated, comfortable and overheated periods using the hourly temperature calculator and the calculated effective temperatures. For our purposes however, it is usually enough to determine when shading should start and when it should stop.

8. When Is Shading Required?

Shading is required both during the overheated period and when conditions are comfortable. The reason for this is that if solar gain is permitted during comfortable periods the excess heat thus gained may cause hot discomfort. Thus the lower limit of comfort is used to establish when

Table 1: Sunshading periods using the Effective Temperature nomogram for Zaria.
Note: F = full shading required, N = no shading required.

Location:	Year:		Lat. & Long.		Nomogram		ET or CET		Comfort limits			
Zaria	1969 - 1975		11 08 N 7 41' E		Normal clothing				Lower: 22 C		Upper: 27 C	
Notes: Air velocity assumed.												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean air velocity (m/s)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Mean maximum DBT (C)	29.7	33.7	36.3	36.5	34.1	31.8	29.0	28.4	29.6	32.1	31.6	30.4
Mean min RH (%)	16	13	16	27	37	52	64	68	62	39	20	19
Mean max WBT(C)	14.4	15.9	18.3	21.5	22.4	23.4	23.6	23.4	23.4	21.3	16.4	15.5
Maximum ET(C)	21.4	23.5	25.4	26.7	26.2	25.7	24.4	24.0	26.6	24.9	22.9	22.0
Mean min DBT(C)	13.6	16.5	20.3	22.8	22.1	21.0	20.1	19.8	19.8	19.0	15.0	13.4
Mean max RH(%)	38	32	44	68	84	90	94	96	94	81	53	46
Mean min WBT(C)	7.0	8.5	13.1	18.1	19.9	19.8	19.3	18.8	18.6	16.8	10.1	7.8
Minimum ET (C)	9.4	12.0	15.6	18.6	18.8	17.9	17.0	16.6	16.6	15.5	10.9	9.3
Shading start	N	12:00	10:30	09:15	09:15	09:45	10:30	11:00	10:30	10:45	13:00	N
Shading stop	N	16:15	18:00	20:00	19:45	19:00	18:00	17:30	18:00	17:45	15:30	N

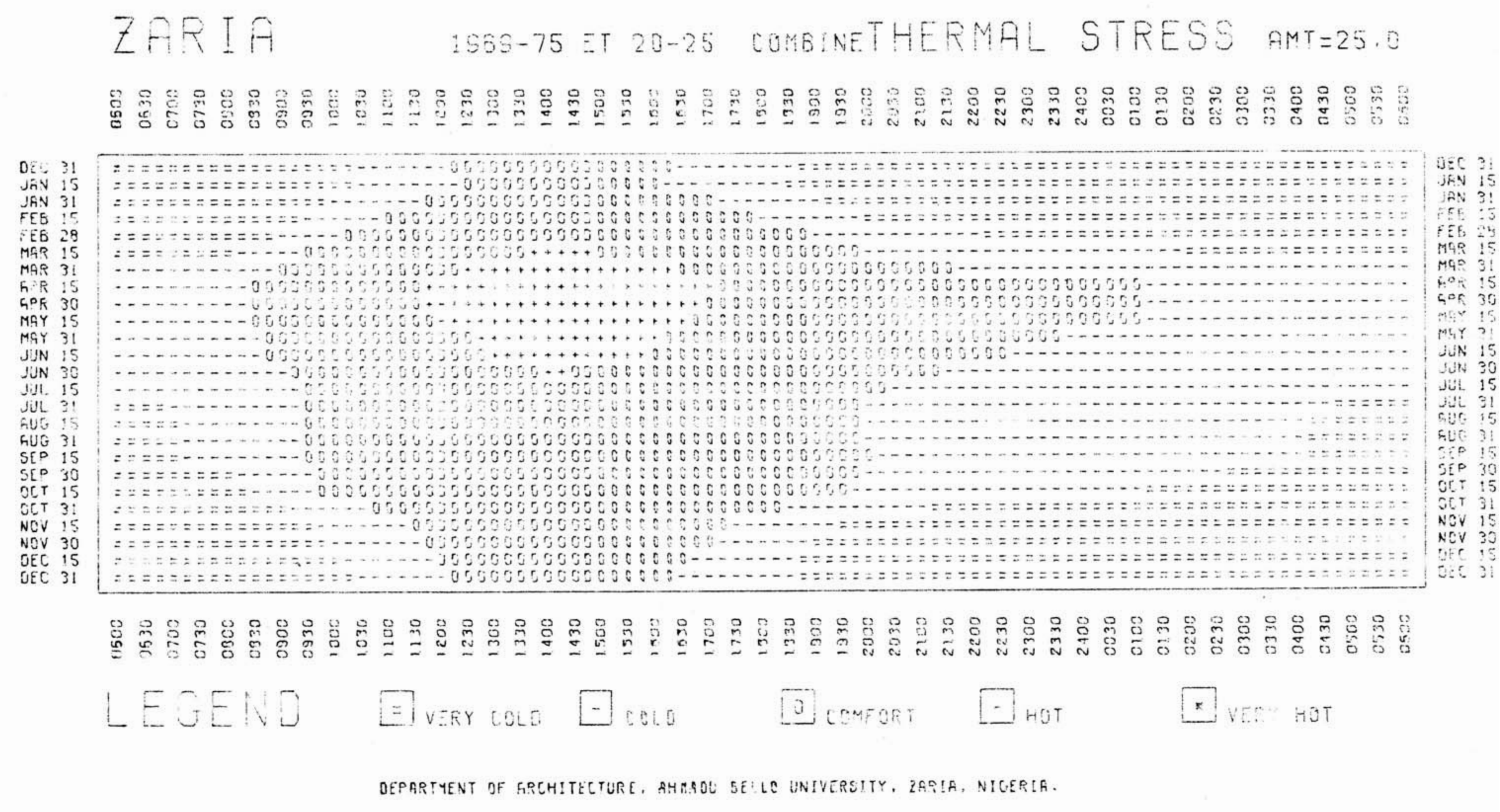

Figure 7: Plot of the thermal stress for Zaria by the computer program COLDHOT.

shading should start.

9. Sun-Shading Periods.

Take the minimum and maximum Effective Temperatures for January. Using a lower comfort limit of 22 degrees Celsius, determine the time of the day when the temperature rises to 22 degrees Celsius. This represents when shading should start. Shading should stop when the temperature falls back to 22 degrees Celsius. When the temperature is always above the lower comfort limit then full shading is required throughout. Consequently, when the temperature is always below the lower comfort limit no shading is required. See table 1. Repeat the process for the remaining months of the year and tabulate the data. If required, plot the sunshading periods thus obtained on a graph.

The sunshading periods can be obtained from basic climatic data using the computer program SHADE. Plots of the thermal stress (overheated and underheated periods) are made by the computer program COLDHOT. An example of such a plot is presented in figure 7.

10. Determination of the sun's position.

The next step in the design of sun-shading devices is to determine the position of the sun at the times when shading is required. The position of the sun is defined by two angles -the solar altitude ß (beta, measured from 0 to 90 degrees above the horizon) and the solar azimuth □ (theta). The solar azimuth is measured from the south and is measured from 0 to -180 degrees (westward) and 0 to +180 degrees (eastward). See figure 8. The position of the sun can be determined in five ways:

10.1 By Calculation.

The solar azimuth and altitude can be calculated given the latitude, date and time from mathematical formulae. In fact the vertical and horizontal shading angles can be calculated directly for various orientations. This method is usually too tedious for architectural purposes.

10.2 By a computer program.

There are various computer programs that can

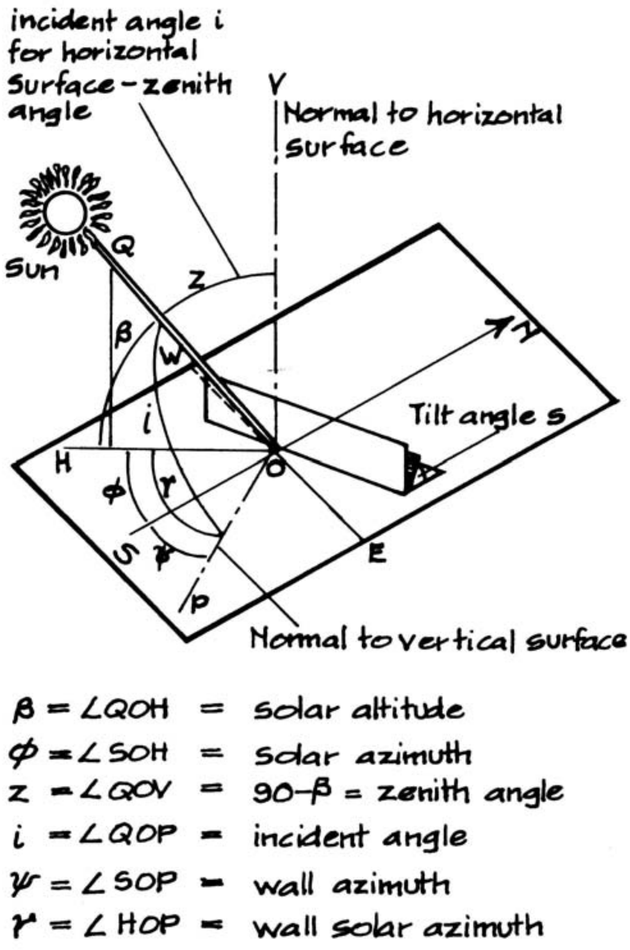

Figure 8: Solar angles for vertical, sloping and horizontal surfaces.

make the necessary calculations and present the results graphically, sometimes even in the form of plots. Such programs are now available on microcomputers and are becoming more popular.

10.3 From tables:

A good alternative is the use of almanacs where the necessary solar angles are tabled. These tables undergo minor revisions yearly.

10.4 Experimental methods:

Complex and lengthy research on the sun-earth relationship is often carried out experimentally using the heliodon, the solarscope or some other device. See figure 9. These studies are carried out on models and are very popular in teaching.

10.5 Sun-path diagrams:

These are graphical representations of the movement of the sun across the sky throughout the day and the year. They owe their popularity to simplicity. The sun-path diagram is used in this text and is described in more detail.

The sunpath diagram is a projection of the hemisphere of the sky. The observer is assumed to be in the centre of this hemisphere and the sun to travel on the surface of the hemisphere. There are two types of projections used to obtain sun-path diagrams. The first is a stereographic projection of the hemisphere onto a horizontal circle. This is the most common projection and is most useful in visualizing the movement of the sun

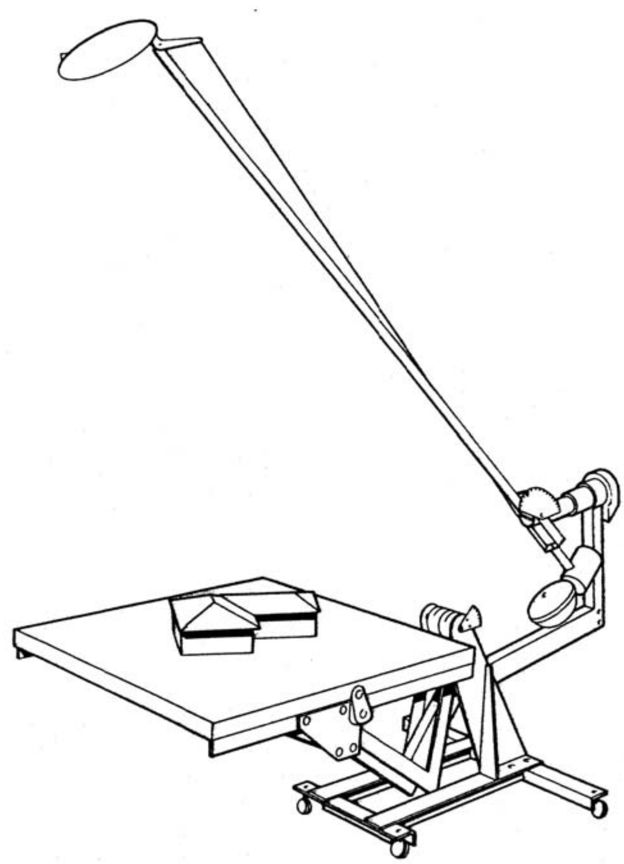

Figure 9: The solarscope.

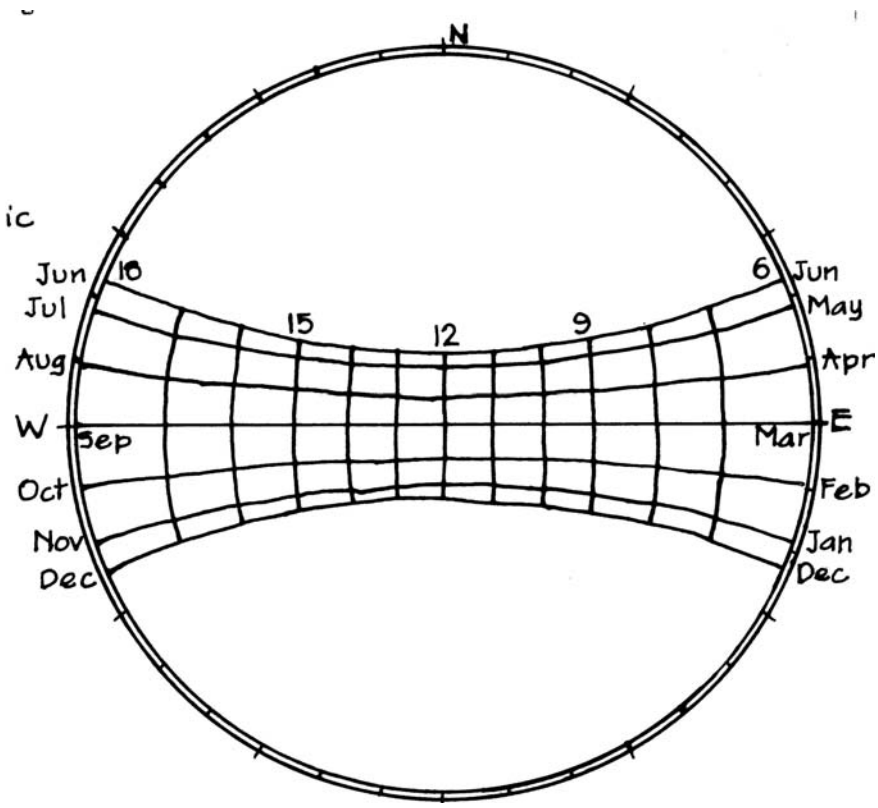

Figure 10: Stereographic sunpath diagram for latitude °0.

across the sky. See figure 10. The hemisphere can also be projected onto a vertical surface. This gives an orthogonal sun-path diagram useful in the analysis of shading angles, glare and diffuse light from the sky. See figure 11.

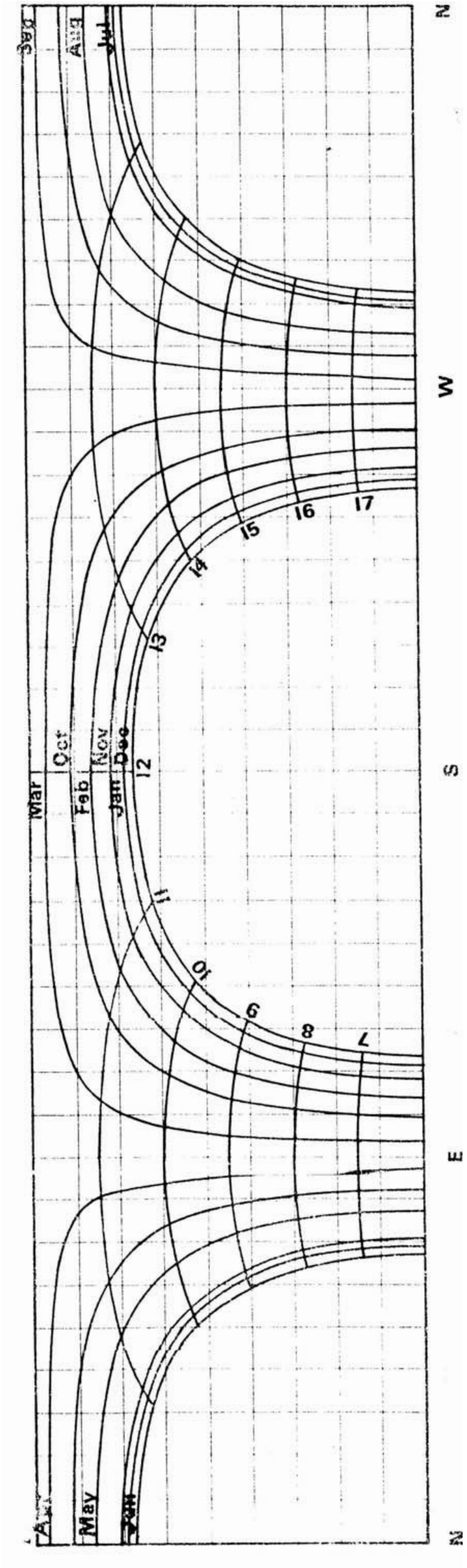

Figure 11: Orthogonal sunpath diagram for latitude °0.

11. Superimposing the sun-shading periods.

The date and the time when shading should start and stop should be marked on the sun-path diagram: these points should be joined and the enclosed area shaded. In doing this there are usually instances where the sun passes over the same part of the sky at different times requiring different shading. It is left to the designer to choose between overheating, underheating or a little of both. See figure 10.

The shaded area represents the position of the sun in the sky when shading is needed. The sun-shading device should be so designed that it will block this part of the sky. The required geometry is determined using a shadow angle protractor.

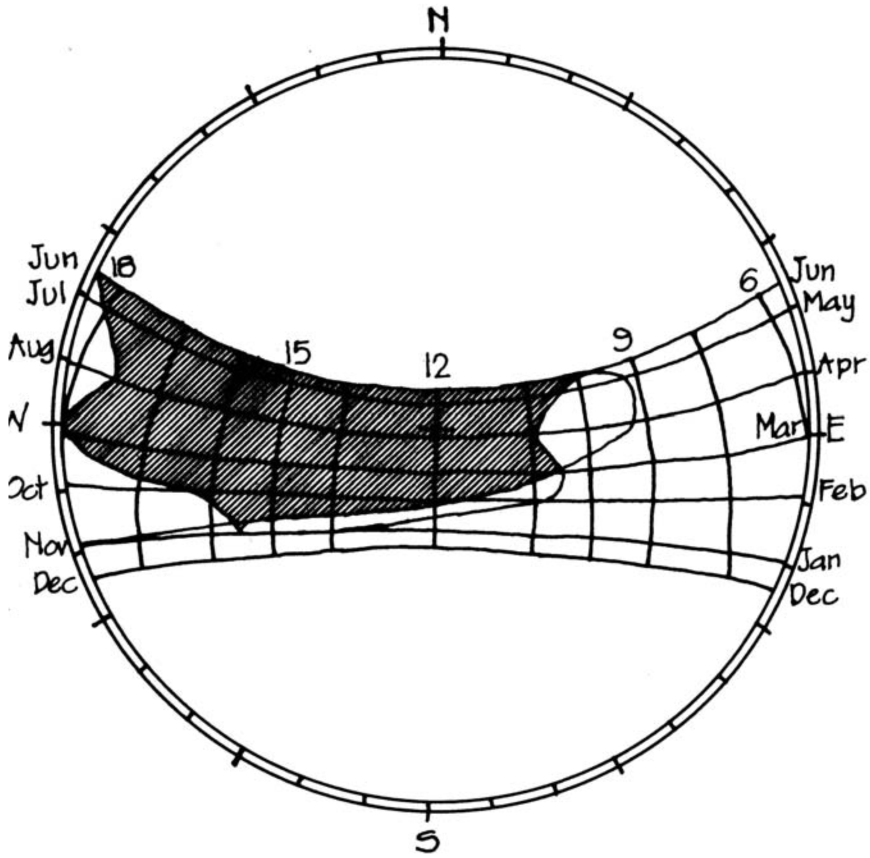

Figure 12: The overheated period for Zaria shown on the sunpath diagram. Shading this part of the sky gives no underheating and partial overheating.

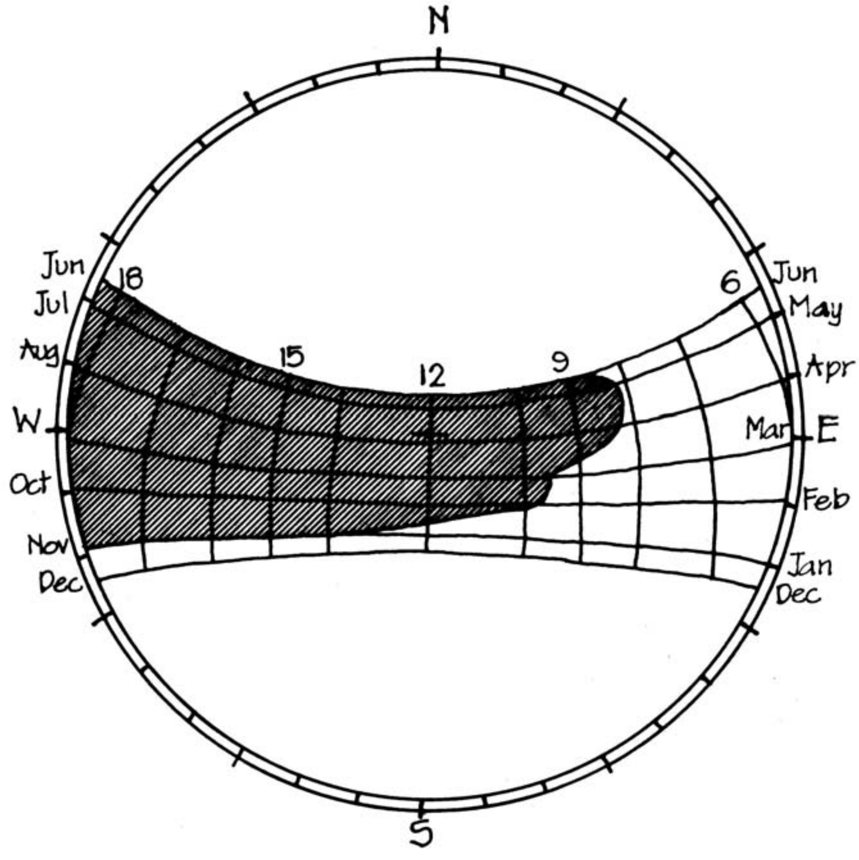

Figure 13: The overheated period for Zaria shown on the sunpath diagram. Shading this part of the sky gives no overheating and partial underheating.

12. The Shadow Angle Protractor.

The shadow angle protractor is used to determine the horizontal and vertical shading angles of the shading device. See appendix A.7 and A.11. There are two types, one for each of the projections of the hemisphere, either onto a horizontal or vertical surface. The shading angles can be determined for only one orientation at a time. Thus if we are designing shading devices for a building with elevations facing N-E, S-E, S-W and N-W, we must take the four orientations one by one and establish the shading angles. This gives us four sets of horizontal and vertical shading angles.

It is common to find that the shading mask defined by these angles do not cover the required portion of the sky. Some areas are left uncovered while other areas are covered unnecessarily. The designer should choose such angles that will be optimal.

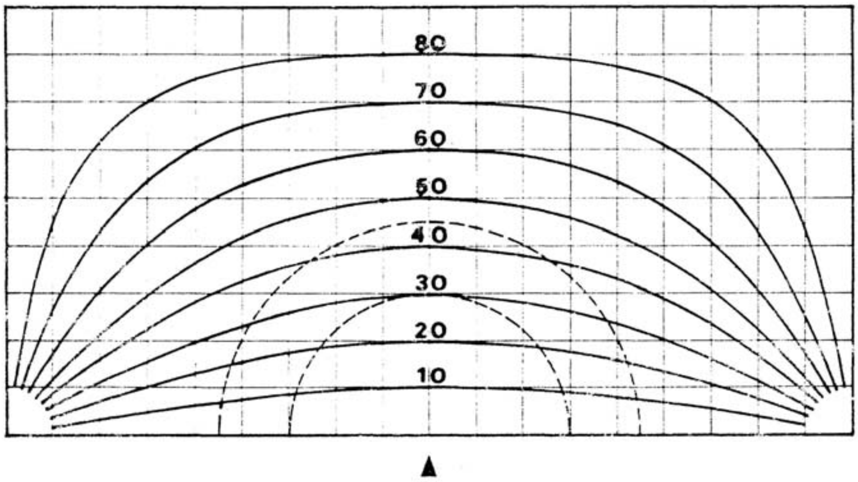

Figure 14: Orthogonal shadow angle protractor.

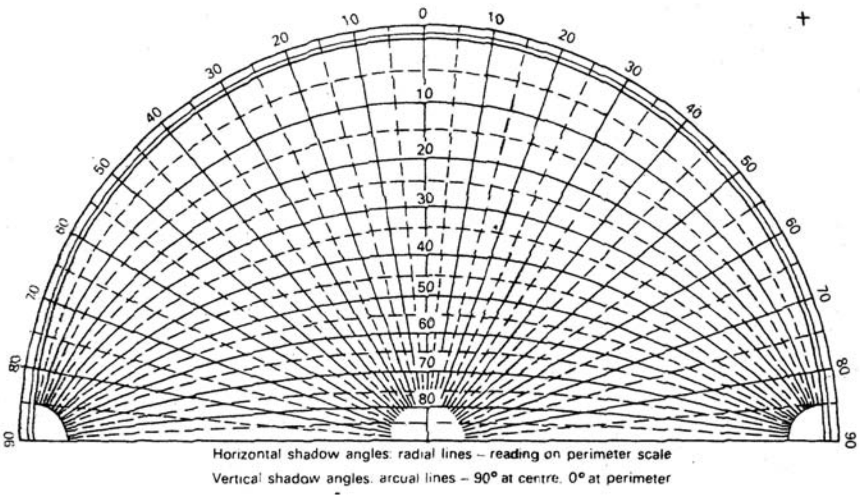

Figure 15: Stereographic shadow angle protractor.

13. Examples of Shading Devices.

The horizontal and vertical shading angles only give an indication of the required geometry of the shading device. The design of the actual shading device is based on structural and aesthetic factors and several designs can be made in conformity with the shading angles. One important decision is whether to use a single large element or several small elements. See figures 18, 17 and 18. Large elements are usually made of concrete while small elements may be made from various metals, plastics and wood. The shading devices may be designed as

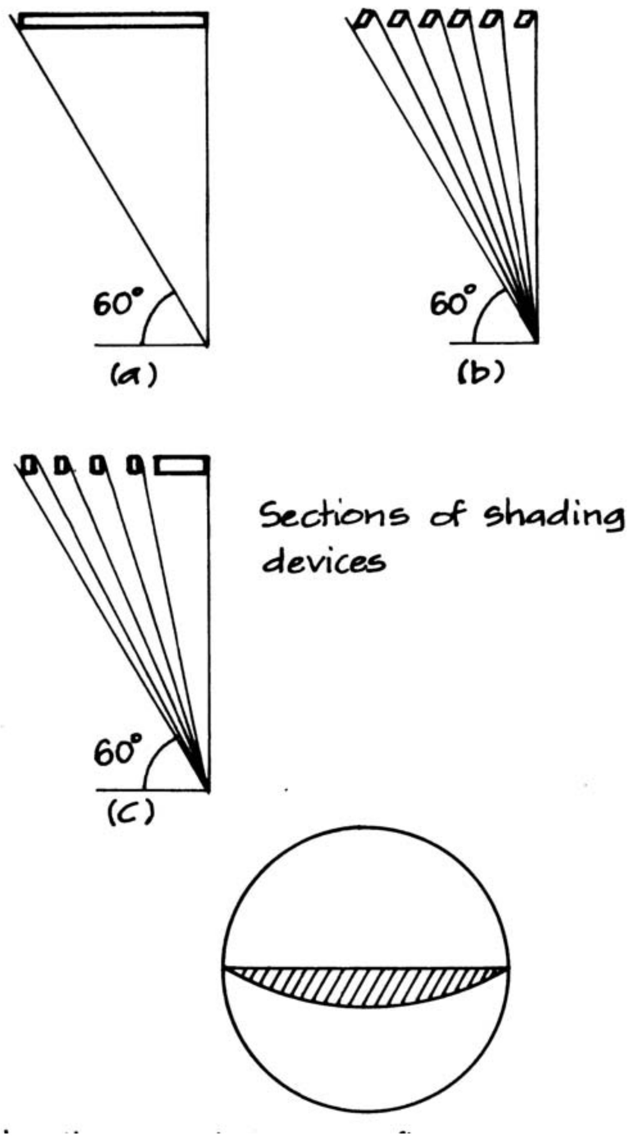

Figure 16: Example of horizontal shading devices with the same shading mask.

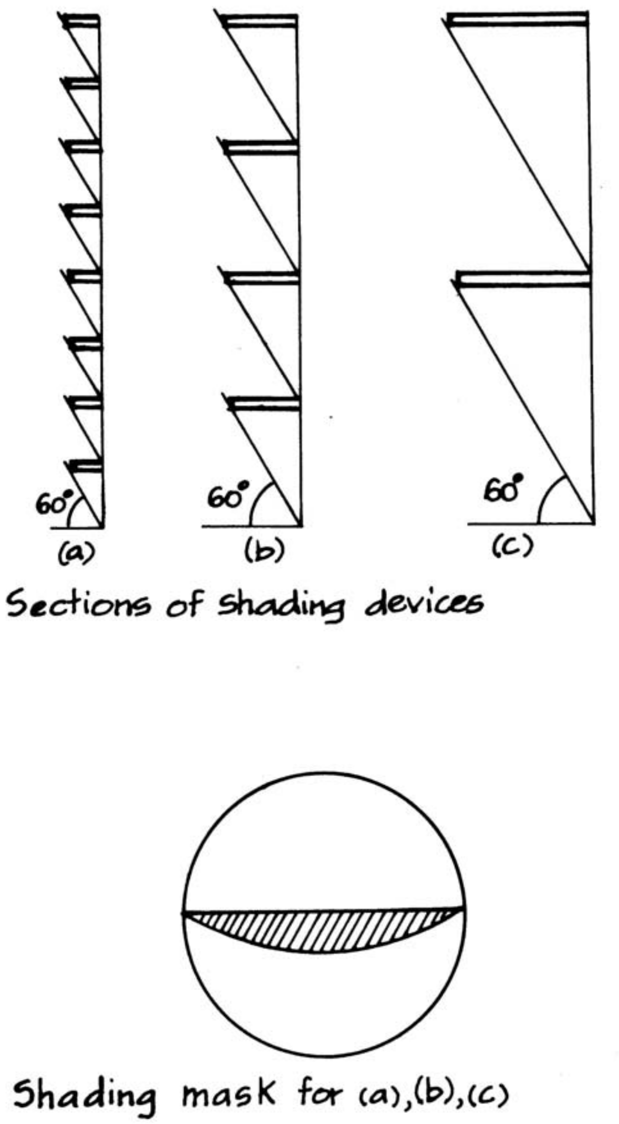

Figure 17: Example of horizontal shading devices with the same shading mask.

adjustable and the need for a view out is often important. A great challenge to an architect is posed by aesthetics. A good design should be functional, structural and reflect our culture. Examples of sunshading devices on existing buildings (located at Ahmadu Bello University, Zaria) are shown in plate 1.

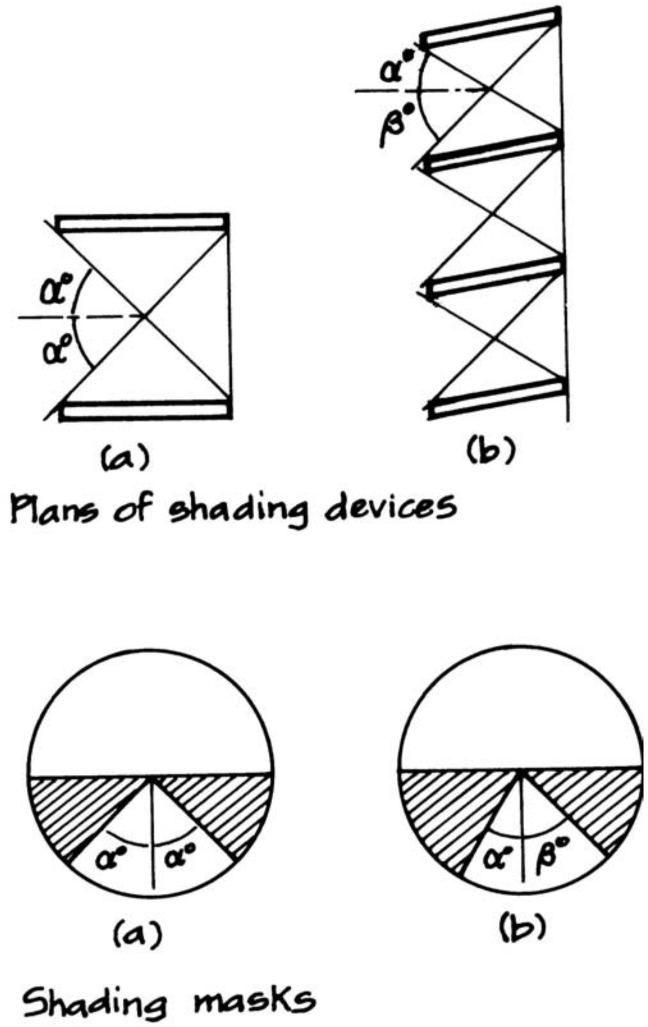

Figure 18: Examples of shading masks for vertical shading devices.

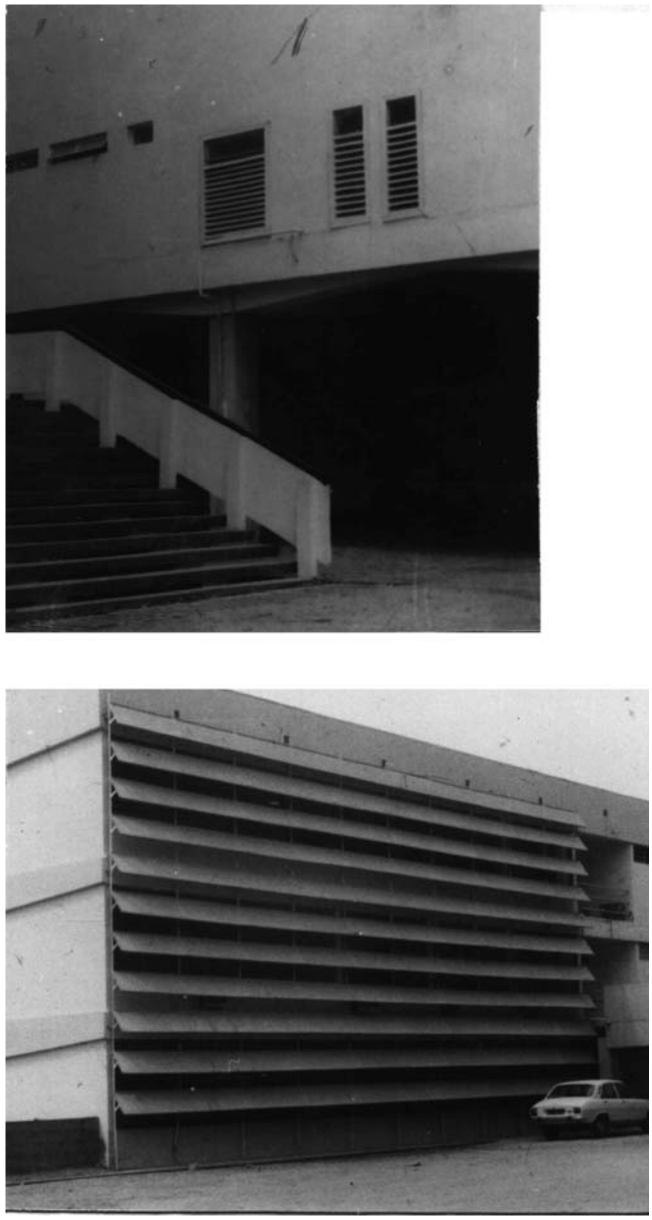

Plate 1: Examples of sunshading devices on existing buildings.

14. Tests and Exercises.

1. Explain how solar heat can be regulated for the purpose of achieving comfort in a tropical house.

2. Describe three types of sun-shading devices.

3. Describe the steps involved in the design of sun-shading devices for composite climates.

4. Describe how sun-shading periods are obtained from basic climatic data.

5. Sketch the details of the shadings devices made of the following materials:

   a. Steel

   b. Concrete

   c. Timber

   d. Plastic

6. Describe the types and geometries of sun-shading devices.

7. Describe how sun-shading periods are super-imposed on sun-path diagrams.

15. References.

Evans, M. (1980). Housing, Climate and Comfort. The Architectural Press, London.

Givoni, B. (1976). Man, Climate And Architecture. Second Edition. Applied Science Publishers Ltd., London.

Harkness, E.L. and Mehta, M.L. (1978). Solar Radiation Control In Buildings. Applied Science Publishers, London.

Koenigsberger, O.H., Ingersoll, T.G., Mayhew, A. and Szokolay, S.V. (1974). Manual of Tropical Housing And Building, Part I, Climatic Design. Longman, London.

Markus, T.A. and Morris, E.N. (1980). Buildings, Climate and Energy. Pitman International, London.

Ogunsote, O.O. (1986). "MOTOLA, STRESS and SHADE -Educational Software for Tropical Countries". Paper Presented at The Seminar On Computer Aids: Computers and Climatic Data Held at British Research Station, Garston, England. 10-11 June.

Olgyay, A. (1953). Shading and Insolation Measurement of Models. University of Texas Press, Austin.

Olgyay, V. (1963). Design With Climate - Bioclimatic Approach To Architectural Regionalism. Princeton University Press, Princeton, New Jersey.

Olgyay, V. and Olgyay, A. (1957). Solar Control and Shading Devices. Princeton University Press, Princeton, New Jersey.

Petherbridge, P. (1969). Sunpath Diagrams and Overlays for Solar Heat Gain Calculations. HMSO, London.

Pleijel, G. (1956). "The Little Sundial". In: Orengrundsgabtan 10, Vol. VI. Stockholm, Sweden.

Prucnal-Ogunsote, B. and Ogunsote, O.O. (1988). "COLDHOT -A Design Aid for Multi-Index Thermal Stress Analysis". In: Architectural Science Review, Vol. 31.3, pp 99-106. Sydney, Australia.

White, B.G. (1962). "Aids to The Design of Shading Devices For Latitudes 4 Degrees North to 12 Degrees North". In: West African Building Research Institute Research Note 6. Accra, Ghana.