THE EFFECT OF CLIMATE IN ARCHITECTURAL DESIGN AND PLANNING-WITH A VIEW OF ACHIEVING PHYSICAL COMFORT IN OUR ENVIRONMENT

BEING

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BY

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DECLARATION

I hereby declare that myself composed this project and that it is the outcome of my findings and personal research effort. It has never been presented in any previous application for a higher degree or diploma. All sources of information have been acknowledged by means of reference.

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ABSTRACT

In an attempt to design and plan any particular environment, the historical background and the climatic elements of that area must be put into consideration. In this aspect, the culture and mode of living of the people and that climatic elements, such as rainfall, wind, temperature should be studied. This study helps the Architect and the planner to design and plan a house that will suit the environment.

It is axiomatic that buildings cannot fill empty stomach, but they can do much to provide a means of creating ambient environment for physical, mental and spiritual comfort. In order to solve this problem, I have proposed that the physiological and psychological comfort of the people must be taken into consideration and therefore factors such as the size, proportion, character and surroundings of rooms, the colour scheme and even the views from windows, extreme heat, dryness, nuisance of flies, sand and dust storms which have great effect on the inhabitants should be incorporated into the Architectural design and planning processes.

DEFINITION OF TERMS

ENVIRONMENT

Means and include the complex, totality of man's surroundings which cover the biogeophysical components (e.g. land, water, air, plant, animals etc)

AMBIENT

Mean the temperature and pressure of the immediate environment.

VENTILATION

To allow fresh air into a room, building or fenestration, either through Natural means or artificial means. (ie Air-conditioning etc.)

ARCHITECT

Someone who is a professional in designing building.

PLANNER

Someone who plans something, especially someone whose job is to plan the way towns grow and develop.

COURTYARD

An open space introduced in design to enhance ventilation within a confined allocated space.

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1.0 INTRODUCTION

1.1 BACKGROUND TO THE RESEARCH

Kano, because of the peculiar nature of its climate, inspired me to choose this topic. After my experience there as a layman and now as an Architect, I decided to undertake the study on how planning and design of external spaces can help to achieve physical comfort in the environment.

To plan and design for an environment, it is paramount to study the climate and the historical background of the people. The nature of the climate has a great influence on the mode of living of the people and therefore this factor should be considered at the planning and design stages. For example, in Kano where rainfall is seasonal and scanty, where vegetation is sparse and where harmattan winds are severe, you find people living in clusters. This type of settlement as is the case in Kano City helps to combat the effect of dust and sandstorms during the dry season. Chapter One deals exclusively with the historical background and the climatic elements.

Human beings form one of the Chief resources in developing regions. Apart from building for industry and commerce, the one areas of responsibility of an architect, builder, or planner lies in satisfying the needs-physiological, psychological and sociological of the people who are to be employed in the actual work of developing these regions and for whose benefit the development is being carried out. Chapter Three which deals with human comfort takes care of this topic.

It is not just enough to understand the needs of the people but also to study the climate and the way it affects materials and structures. This, and many other associated problems, form the basis of Chapters Three and Four.

Because of the hot dry nature of Kano, it is important to know the problems posed to building materials and techniques which in reality require attention from the construction industry. Chapter Six discusses these problems and other problems experienced by the industry.

1.2 STATEMENT OF PROBLEMS

We have seen that in order to be able to plan and design any particular environment properly, the historical background and the climatic elements of that area must be known and well studied. In this aspect, the culture and mode of living of the people and that climatic elements such as rainfall, wind, temperature should be studied. This study helps the architect and the planner to design and plan a building that will suit and conform to the environment.

However, to provide an acceptable environment without air-conditioning in places like the Savannah arid region of Nigeria (e.g Kano), a designer must be primarily concerned with controlling the Micro climate or the climate within the space enclosed by a structural shell; so, when designing, the orientation of the building as regards the solar radiation, I discovered that to arrest the situation, the walls of the building must be thick, bedrooms and living rooms should not be placed on the east-west directions.

Summarily, great effect on the inhabitants should be incorporated in the design proper, so as to achieve a precise and excellent planning and design processes which defines the comfort of the inhabitants in relation to the environment.

1.3 JUSTIFICATION

Looking at the theme from a professional perspective, the effect of climate in Architectural design and planning with a view of achieving physical comfort in our environment can be best justified under the following explanations:-

- The responsibility of the designer in planning the available spaces, taking care of constrains like, size of plot, clients brief and so on

- The relationship of the design and the immediate environment, noting elements like ventilation, orientation in relation to the Micro climate of the environment.
- However, the Bottom line of any well designed building is to achieve maximum comfort for the occupant relating issues like solar radiation, temperature, wind direction, rainfall dust and sand storms etc.

There is absolute need for the designer to study such environment viz-a-viz the design principles and always bear in mind the comfort of the occupants of such building.

1.4 AIMS AND OBJECTIVES OF THE STUDY

The aim of the study is to ascertain that Architectural Design and planner are done with foremost view of achieving physical comfort in our environment.

The objectives include the following:-

(a) Relate the Architectural Design with the environment

(b) Consider the Micro-climate of the environment in the design analysis.

(c) Acquaint and study the effect of climatic elements such as wind, rainfall, temperature etc. on the building.

(d) Provide an acceptable environment without artificial ventilation (comfort) like air conditioning systems/facilities.

(e) Provide a means of creating ambient environment for physical; mental and spiritual comfort.

(f) Great effects, problems and constrains of inhabitants must be incorporated into the planning and design processes as a means of achieving physical comfort in the environment.

1.5 SCOPE AND LIMITATION OF THE STUDY

This study covered the effect of climate in Architectural Design and planning with the view of achieving physical comfort in our environment.

Therefore, the scope of this study is unlimited to a specific period only but should be imbibe as a law, tradition and conditions of achieving human comfort in our buildings and environment.

Inadequate resources, poverty and unaffordability has limited the study to an examination of problems since most Nigerians cannot afford building a descent building not to even say of their ability in consulting an architect to design a building that would be affordable, accommodating and achieve maximum comfort of professional involvement in the design and planning processes.

CHAPTER TWO

HISTORICAL BACKGROUND AND CLIMATIC ELEMENTS:

Kano by the 1990 census was the largest city of the Sudan region and the fourth largest city in Nigeria, with an area of 67843 hactres, and a population of about 2.5million and the surrounding scattered hamlets have a population of 1.260,000.

Kano can boast of playing a long traditional role as trading centre for Northern Africa. Its origin started with a small settlement around Dala hill in the 10th century and later gained importance after the construction of the city walls in the 12th century and especially after the establishment of the city market on its present site in the 15th century.

Kano spatial development was confined to the walled in area until the arrival of the British. The establishment of the British administration in 1903 and the construction of railway from Lagos in 1912 introduced a new focus outside and to the east of the walled city. Commercial development concentrated in township and the residential area; Sabon Gari for Southern Nigerians, with Sabon Gari mark slowly shifting economic activities from the old city to the areas east of the city walls during the following years. Residential development followed and continued to the east with spatially separated areas for different ethnic groups. The main direction has been to the east; only in recent years occurred a trend for further development in southernly directions.

Kano's main characteristics is its compact physical development until today, mainly caused by ethnic segregation. This desire hoods, results in inner growth and increase in density.

However, as densities have reached its upper limits in many areas, there is growing need for development of new residential areas which could induce people to move out from high density areas to low density areas to avoid future increase in density which if unchecked could result in some physical hazard.

CLIMATIC ELEMENTS

TOPOGRAPHY:

Metropolitan Kano is situated on an altitude of 450,500m above sea-level and is bounded on the north by river Taskman, on the west by river Wateri and on the south by river Challau, non of which has permanent water flow. The area has a vegetation that gives a park-like appearance. The plains are broken here and there by weathering processes and also by the wet season rains. Dala and Goron Dutse hills are the two prominent hills which are about 30m and 40m high respectively over the surrounding area.

VEGETATION

The vegetation of Kano is similar to that of Savannah region. This vegetation is typical to places where the total annual rainfall is between 65 and 100 cm and the relative humidity is constantly below 40%. Here, the dominant vegetation is grass with scattered trees.

NATURE OF SOIL

The soil of Kano is the typical sandy loamy type of fine grain which allows an immediate drains and does not easily become water log. It is not subject to marked expansion and contract in volume unlike clay soil area, therefore settlement of a built structure is minimal.

CLIMATE

The climate of Kano is typical of the Northern Nigeria Climate. Kano is one of the areas in the North where the effect of the tropical continental air mass Is felt most. The climate of Kano is mostly influence by the following factors.

TEMPERATURE

Extreme values in temperature occur during the dry season which can range from a low 13^{oc} in January to a high 40^{oc} in April. More moderate temperature value but couples with high humidity occurs during the wet season.

WIND CURRENT

The wind current accuses two climatic seasons namely dry and wet seasons. The dry season (October – April) Is characterised by the tropical dry continental Sahara wind (harmattan from North – east). The wind are dust laden.

The wet season (May – September) is characterised by South Westernly maritime wind which carry warm and humid air.

RAINFALL

The mean annual rainfall amounts to 862mm and occurs mainly between May and September with a peak in August. There is hardly any rainfall from November to February.

CHAPTER THREE

HUMAN COMFORT

The environment of hot dry lands presents problems to those who live and work with them, Temperature are usually high by day, and often at night, with low humidity, dry and dust – laden winds. Vegetation is sparse, the socio-economic are poor, and local resources are limited.

The solution to the socio -economic problems in which the harsh climate an important role lies in the hand of the policy marks, but they are often influenced by circumstances beyond their control - circumstances such as the state of the international market for goods and the absence of political stability in adjoining areas.

It is axiomatic that building can not fill empty stomachs, but they can do more to provide a means of creating ambient environment for physical, mental, and spiritual comfort. I shall therefore briefly examine some of the man needs of people in hot dry environments with special reference to Kano climate so as to arrive at valid basis for planning, design, and construction.

PHYSIOLOGICAL COMFORT

Physiological, uncomfortable condition in arid climates are mainly caused by the extreme heat and dryness and to a lesser extent, by the nuisance of files, sand, and dust storms.

Any study of the requirement of physiological comfort in hot dry environments loses the basic question, what constitutes comfort?. Mactarlane and others have defined comfort as constitutes comfort?. Mactarlane and others have defined comfort as certain thermal conditions in which over 50 percent of the people are unaware of their climatic environment that is, they do not feel the need to adjust to it.

Human thermal comfort is usually found when the mean skin temp. is maintained by various means below 93of (33.9oc) and above 88 of (31.1oc).

In Kano a person is comfortable when his body is able to dissipate to the surroundings all the heat it receives, including hot lost by evaporation from the skin and from the respiratory system. In a building, the heat loss from the body to the Surrounding is mainly related to the air temp, mean radiant temp,. Humidity and air movement, and to a person's clothing, physical activities, and state of health. If some or all of these factors are combined in such a way as to make it difficult for the body to dissipate heat, then the equilibrium necessary for physical comfort is upset, and there is a gradual increase in the tissue temperature until a state of discomfort is reached, which affects work output and efficiency and in extreme cases cause heat stroke or intense fatigue. For example, movement of air reduces the effect humidity, and radiation may increase the air temperature.

The human body is able to lose heat to its surroundings by convection, by evaporation, and by radiation. Loss of heat by convection and radiation can take place only when the air and surrounding are at less temperature . Loss by evaporation depends upon the relative humidity of the surrounding air and the rate of air movement. Air movement will assist in cooling the body only when the air temperature is less than that of the skin and the relative humidity of the atmosphere is not very high. Consequently, up to a point beyond which heat alone becomes a factor of discomfort, hot dry air tends to be more comfortable than hot humid air.

Apart from the problems of physiological comfort generated by adverse climate, by far the most significant irritant in arid lands is air pollution by dust and sand.

The presence of dust and sand particles in the atmosphere is a hazard to human health and they also possess a considerable nuisance value which is most obvious to the people who live in these regions. Apart from the dust storms which periodically limit visibility, particles-polluted air causes discomfort and irritation to the eyes, nose and throat, and it also has a demoralizing effect on people, particularly on the housewife. Her domestic work is considerably increased by extra cleaning and washing, and household equipment and mechanical fixtures require more frequent and often costly repairs.

PSYCHOLOGICAL COMFORT

Here, it is paramount to point out that a comfortable body is no guarantee of a comfortable mind. The design and construction industry should therefore take equally careful account of the factors affecting psychological comfort.

Stimulation is received through sensory receptors and through the action of the different nervous pathway, leading to either stimulation or inhibition of the nervous activity thus affecting the emotional state of the individual. Factors such as the size, proportion, character and surroundings of rooms, the colour scheme, and even the views from windows have a great psychological effect. There is the combined effect of the sun, fresh air, and greenery which impinge on man's higher nervous activity, providing favourable sense impressions during periods of physical activity and rest.

The psychological effect of colour is well known, and various colour standards have been established which are based on ability to soothe, stimulate, cause visual fatigue and/or promote increased physical activity. White and various shades of colours commonly found in nature, such as yellow and green, extert a soothing influence of the visual system by reducing eye fatigue and enhancing the strength of chromatic vision.

The proportions of habitable areas such as rooms and courtyard also possess psychological significance. Courtyard walls must be proportionate in width and height to the area of the ground they enclose, and the height of a ceiling needs to be related to the floor area of the room. A room with a low ceiling appears to be larger than one of the same size with a higher ceiling, but the cramped space of the former can take away the feeling of relaxation and rest and could well exert an unfavourable psychological influence.

In Kano city I discovered that the houses are virtually similar in design and therefore possess monotonous environment. From experiment it has been found that monotony is the main source of boredom and boredom also increases the rate of juvenile delinquence, which in Kano has reached serious proportions. This point to the need for provision of an environment that supplies perceptual stimulation – aural, visual, and tactile. Building can help to provide much of this stimulation by aiming at an architectural and aesthetic standard which avoids monotony and ensures diversity in the surroundings. If these aims can be achieved they will be reflected in the fostering of a community spirit possessing civic pride, integration, and the sense of enjoyment.

CHAPTER FOUR

DESIGN CONSIDERATIONS

To provide an acceptable environment without air– conditioning in place like Kano, a designer must be primarily concerned with controlling the micro– climate or the climate within the space enclosed by a structural shell. This mean dealing with such environmental factors as temperature, humidity, rate of air movement, and radiation from walls, floors, ceiling and other surrounding surfaces, all of which have an effect on human comfort.

ORIENTATION

The orientation of a room is the direction facing by its external elevations. The problem of building orientation is one related primarily to long blocks, where the rows of rooms share either one or two common external walls. The orientation of such a building is the direction faced by these facades, i.e The direction perpendicular to the axis of the block. In a square, or almost square, apartment or house, each of the rooms has a different orientation and the orientation of the whole building should as far as possible be in accordance with the different requirement for these rooms.

The choice of orientation is subject to many considerations, including the view in different directions, the position of the building in relation to roads nearby, the topography of the site, the location of sources of noise, and the nature of the climate. This last is the aspect with which this study is mainly concerned.

Building orientation affects the indoor climate in two respects, by regulation of the influence of two distinct climatic factors.

(a) Solar radiation its heating effect on walls and rooms facing different direction.

(b) Ventilation problems associated with the relation between the direction of the prevailing winds and the orientation of the building.

In humid regions, in order to achieve physiological comfort, orientation is more important with respect to winds than in relation to the patterns of solar irradiation. But in areas (e .g Kano) where ambient temperature has greater physiological influence than ventilation (e.g. where the humidity is low), orientation with respect to the sun is an important consideration for human comfort. Under these circumstances a north– south orientation of the main facades is preferable to one east-west.

As has been stated before that when dealing with a building nearly square on its plan, the term orientation is applicable in effect not the building as a whole but to its different rooms. In every case, the relative advantages and disadvantages of a given orientations for each the individual/rooms in the apartment, e.g. Living room, bedroom, children's room, etc., having to be weighted. In most cases there are specific considerations for various rooms. For example, sun is required more in the morning in bedrooms and children's room, for bathroom and W.C.S. the leeward side of the building is more desirable.

STRUCTURE

With radiation of heat from the surroundings minimized, it remains for the structure itself to reduce heat gained from conduction. The process of conduction can occur through any material and is the only method of heat transfer through solid substance which is opaque to radiation.

In order to elude heat, it is essential to have some knowledge of the properties of building materials, particularly in relation to temperature variations and heat flow. The extent of heat gain through conduction can be controlled by the appropriate selection of materials, which is made possible by assessing the performance of the various materials in terms of their insulation value

(K-value) or their overall thermal transmittance (U-value). The lower the U-value the insulation effect. But the amount of heat transferred through the building fabric under the periodic heat-flow cycle not only depends upon the type of insulation but also on its heat-storage capacity. The larger the heat-storage value, the slower the temperature change that is propagated through the material.

Dense or heavy-weight materials such as mud-brick, and stone have a very high heat storage capacity. They take a considerable time to heat up, once heated take a long time to cool down again (depending, of course upon the temperature differential existing in particular circumstances). Such materials, with their high heat-storage in hot dry regions, where they take a long time to absorb most of the heat received during the day before it is passed on to the inside surfaces. Thus their use ensures a cool interior. For multi-storey buildings where weight critically effects the design of the structure and the cost, a judicious combination of insulation and heavy-weight materials or hollow and perforated masonry construction can be tried with considerable profit.

To understand the effect of structure on indoor climate it is necessary to study the various main components of a building, namely the walls, windows, roofs, ceilings, and floors.

WALLS:

The function of the wall is to control and regulate the passage of heat, light, air, and sound inwards, or both ways. In order to successfully perform its function to maintain comfortable indoor conditions, the wall is further divided into sections consisting of opaque panels, glassed areas (windows) and doors, as well as permanent or controllable vents for the passage of air. The major function of the walls of buildings in hot dry lands is to withstand the onslaught of solar radiation and high day time outdoor temperatures, and to control the inward flow of both heat and hot air for most of the day during the dry season (harmattan).

Provided the openings, in the form of windows and doors, are carefully designed and located, the insulation value and heat storage capacity of opaque material wall panels is considerable.

From tests carried out, it was found that heavy-weight construction would have a greater influence in reducing daily indoor temperature variations than light-weight construction. The overall heat transmission co-efficient and time-lag data for common building materials show that heavy and massive constructions generally offer fairly good U-values and greater time-lag, and able to absorb large quantities of heat without a marked rise in temp hence their controlling influence. As a result, in hot dry regions a properly designed massive building can be relatively cool during the daytime.

If the selection of materials is depended on their heat-storage capacity and consequent time-lag, then the question arises as to what is the most appropriate time-lag for a building. This would obviously depend upon the type of use the building is likely to have. For rooms to be occupied during the day, a time-lag of the order of 8 to 10 hours will be required; for night-time living areas the time should be short so that they may cool off quickly at night.

Other significant ways in which heat capacity affects the rise or indoor temp is the mass of internal elements such as partitions, furniture, and furnishings, which may receive direct radiant energy to the rays of the sun coming through unshaded windows. The radiant interchange at the indoor surfaces of the various building components could also be affected by the internal masses.

GLASS

The primary function of a window is to admit light and provide ventilation and view while limiting the entry of undesirable elements of the out-door environment. A special function of a window in hot dry lands, where the dry season heat is the main source of discomfort, is to admit light without admitting direct sunshine. It should also exclude hot, dry, and dusty winds. Glass has little insulation value and heat will flow through it whenever there is a temp gradient from one side to the other. This is a good case for limiting the size of glazing, but too much reduction is likely to conflict with the needs for natural light inside the building. For conditions in hot dry lands, the Building Research Station in the United Kingdom suggests that a minimum glass area as low as one-sixteenth of the floor area of the room to be lit should be adequate for normal residential buildings.

By incorporating certain iron compounds during manufacture, glass can be made to absorb some of the short-wave energy falling on it, thus reducing the incoming radiation intensity. The range of heat-absorbent glasses available in the market is wide and they transmit anything between 10 and 70 percent of the incoming solar heat. Most of them are limited in their effectiveness because their own temperature is raised, which in turn causes an increase in the heat convected and re-radiated into the room. The total heat flow is, however, much less (about 50 percent) than that through the regular plate glass.

Better effectiveness can be obtained, however, if the glass is used independently of the structure itself and set away from the wall in a free-standing position. These observations seem to indicate that, apart from minimum use of glass, there is also a need to provide effective shading devices. I shall later in this chapter discuss how we can use canopies to minimise heat radiation through the building fabric into the interior of the building. An alternative way to reduce solar energy entering the building is to use heat-absorbent glass in conjunction with regular plate as a form of double glazing. The reduction in total heat transfer from sunlit single glazing to normal heat-absorbent glass if it replaces regular plate glass, is about 25 percent. Hence the efficiency of the heat-absorbing lass when used above is rather limited. If double glazing is used, the reduction is about 45 percent. The inner pave of regular plate is not only a protection from the layer of warm air immediately behind the outer one, but it also acts as a radiation filter to the long-wave energy emitted by heat-absorbent glass. If the space in between double glazing can be freely ventilated so as to remove the warm air as quickly as possible, the efficiency of the window can be even further increased.

Another method of reduction of heat transfer and the entry of solar radiation through glass is by using the reflection principle. Heat-reflecting glass is obtained by depositing fine semi-transparent metallic coatings on the surface of glass during manufacture, or by application of reflecting films to ordinary clear to ordinary clear glass.

GLARE:

Apart from high temperatures, large glazed window areas also create problems of glare. Large windows make it possible to see a great part of sky from most parts of the room, and since Sky brightness is much higher than the brightness within the room, the human eye requires considerable effort to adjust from one to the other. The simplest way to control Sky glare is by reduction of window size, though it limits the entry of light, it does not necessary solve the glare problem in all cases.

Le Corbusier once partially solved this glare problem by providing a small opening outside and a wide one inside so that not only the bearest minimum opening is shown, but also it helps to disperse light around the edges of the inside opening. Another method successfully used by Le

Corbusier provides long, vertical floor-to-ceiling slit windows located towards the end of the walls. Although the amount of light entering the building is considerably reduced, this method achieves a deeper penetration of light inside the rooms, the walls of which are literally bathed in the reflected glow, which avoids the contrast usually responsible for glare.

Architect Louis I. Kahn during this research work on glare came to the realization that every window should have a free wall to face. This wall, receiving the light of day, would have a bold opening to the Sky. The glare is modified by the lighted wall and the view is not shut off.

SHADING DEVICES:

When shading devices are applied in combination with the glass they can modify the thermal effect of windows to a very great extent. Another way of controlling the thermal effect of windows is by the use of special glasses or glass treatments, as discussed previously.

Shading devices can be applied either externally, internally or between double glazing. They may be fixed, adjustable or retractable and of a variety of architectural shapes and geometrical configurations. Internal shading devices include venetian blinds, roller blinds, curtains, etc. Usually they are retractable, i.e. can be lifted, rolled or drawn back from the window, but some are only adjustable in their angle. External shading devices include shutters, ownings, overhangs and a variety of louvres:

Vertical, horizontal and a combination of both (eggcrate). Shading between double glazing includes venetian blinds, pleated paper and roller shades. They are adjustable or retractable from the inside.

When discussing with Architect Ella, one of the Principal Partners of Ella, Waziri Associate, he pointed out that almost all the houses in Kano City are without over hangs. This has in no small measure contributed to the constant harassment of solar heat on the inhabitants. Even in Sabon Gari, where there are a lot of modern houses, overhangs are not adequately incorporated into design. In Kano, according Architect Ella, the problem is Solar radiation rather than ventilation. It is therefore pertinent to design the building with deep overhang to protect the walls from Solar radiation rather than having large openings to receive hot dry winds which effect the physiological comfort of the occupants.

The performance of external devices is further improved if they are white or light in colour. Once the sunlight is excluded the ground and surrounding buildings are the main source of reflected light and radiant heat. This can only be countered by grass and vegetation cover, which helps create shade in the immediate vicinity of buildings.

ROOF AND CEILINGS

Because of its orientation and comparatively large area, the roof can be a major source of heat gain in a building. Intense solar radiation generates considerable heat during the day and, after transmission, raises the temperature of under-roof surfaces. The main effect of this is that the temperature of the ceiling surface is raised which in turn, radiates heat to the other surfaces and occupants and thus accentuates bodily discomfort.

There are many ways by which heat flow can be reduced, but most important of these include reduction of absorption of these Solar radiation at roof surface, thereby decreasing its temp gradient in the roof structure, and by incorporating materials of low thermal conductivity in the roof, thus minimising the inward flow of heat.

The use of white or light colours on the upper surface to reflect heat is a wall-known method of improving the performance of roofs. White is the most effective colour for limiting the temperature of a roof surface, although its absorptivity for solar radiation is slightly higher than that of bright metal.

The good thermal resistance of reflective insulation is due not only to its high reflectivity of its indoor facing surfaces. Probably the greatest advantage of the white coloured surfaces is evidenced at night when their high emissivity enables them to cool far more rapidly than a corresponding shiny surface.

A major drawback of white paints and light-coloured finishes such as whitewashes is that they do not retain their reflective or low absorptive abilities as when they are new. For instance it has been found that the absorptivity of asbestos cement roofing is 0.5 when new and 0.7 after twelve months exposure. In hot dry lands ever-present dust in the atmosphere greatly contributes to the dulling of reflective surfaces. This means frequent painting to maintain reflectivity, an uneconomical proposition. Another disadvantage of light colours on a sheeted pitch roof is that they can create a glare problem in the vicinity.

Massive and heavy-weight roofs are usually flat and are particularly useful for buildings such as offices or schools which are not used during the night. Owing to its high heat-storage capacity and thermal resistance this type of roof introduces a time-lag and a diminution in the rate of heat transfer, so that after sunset it takes a considerable time to cool down. The extent of the time-lag depends upon the thickness of the slab. The table below indicates that the time-lag between the upper and lower surface temperatures for a 5.1 cm concrete slab is 1 hour 25 minutes and for a 20.3 slab 6 hours, but in the case of a 20.3cm hollow tiles the time-lag is only 5 hours. To increase this time-lag flat roofs are often provided with extra layers of light-weight insulating materials.

A traditional method commonly used in the Middle East is to cover the slab with a layer of earth, a material with a considerable capacity for heat storage, 10.2cm of mud when used on a 102cm thick concrete slab can reduce the ceiling temperatures by 10.°C. There are further possibilities where grass or some other form of vegetations may be grown on the roof. Apart from cooling the air above the roof, the roots of such growth preserve a certain amount of moisture which not only helps to keep the temperature down but also prolongs the life of the concrete by minimizing cracking in extreme temperature variations.

The use of a double roof systems with an air space between appears to be the most effective means to reduce the heat load. The reason offered is that the upper layer of the roof has a reflective surface which throws off a high proportion of the sun's heat. The hot air which might accumulate between the upper and lower levels is allowed to escape at the open ends, a process which is often helped by the air flow. This system is used in a number of buildings in West Africa, particularly those in the University College at Ibadan. It has been discovered that ventilating the air space alone cannot solve the problem of heat transmission since convection plays a subordinate role. Therefore, for the double roof system to effectively achieve the desired result, it has to be insulated so as to contain the heat being emitted by the roof members.

ROOF SPRAYS:

Evaporative cooling may be used to prevent heating of the roof, using either stationary water ponds above the roof, or by spraying. Sutton reports experiments in which the surface temperature of a light wooden roof deck was reduced from 150 °F by water spraying, and to 108 °F and 103 °F by water pools 5.1cm deep respectively. In addition to the roof, some reduction in surface temperature of the walls of the building is also produced by the spillage of cooled air.

Cooling by spraying can be applied not only to flat but also to pitched roofs. From the practical point of view this method suffers many draw backs; Structural requirements to support pools of water, evaporative cooling is most effective in arid conditions, but such regions usually have restricted and costly water supplies; water ponds may provides a breeding ground for mosquitoes, etc.

CEILING HEIGHT:

The thermal performance of roofs is closely associated with the problem of ceiling height. It is generally believed that high ceilings are more effective in providing cool interiors in building in hot dry lands than lower ceilings. To what extent this is so, is debatable.

The question is particularly important since lower ceilings permit considerable economics in materials, labour, and cost of buildings. When applied to multi-storey buildings, lower ceiling height can often mean savings or provision of additional storeys, thus helping in reducing the overall site development costs by providing increased accommodation on a given site. In view of this, the only possible reason for building high ceiling is their contribution to indoor comfort and the psychological needs of people, ensuring generous space over their heads.

Observations made in a number of countries in hot dry lands indicate that lower ceiling height improves day-lighting and does not cause a temperature difference at head level of more than 0.83 °C corresponding to a reduction of 1.22 metres of ceiling height. The headroom clearance for ceiling fans where used may become the decisive factor in determining ceiling height. Experience indicates that for reasons of safety 2.74 metre ceilings are the absolute minimum in case where fans are used.

FLOORS:

Floors can be constructed in timber or concrete. They may be on the ground, just above the ground, or raised higher as is done in many tropical countries where they virtually doubled the covered area in what would normally be a single-storey building. In hot dry climatic regions it is advisable to enclose the under-space of suspended floors so as to stop the entry of hot winds, which if not obstructed will heat up the floor itself. Concrete floors laid directly on the ground, or on fill, are known to exert certain stabilizing influences on indoor temperature conditions in dry season.

DESIGN FOR DUST AND SAND CONTROL:

The need for building design to combat dust and sand varies according to climatic factors and project demands. Knowledge of variations in wind velocities and directions, month of occurrence and critical periods throughout the day, as well as the nature of the terrain itself, is of considerable assistance in determining the orientation and siting of buildings. The cooling effects of natural wind movement assist greatly in promoting bodily comfort, and are a major influence in determining the setting out and orientation of building. Such winds that are prone to raise dust and create sand disturbances may deter the planner from developing natural ventilation of its fullest extent. At all events, a careful gauging of the circumstances is essential, and in no way should the problem of polluted air be minimized in favour of what initially appears to be more attractive design solutions.

A zone of minimum air pollution is formed on the leeward side of a building exposed to wind currents. The zone remains constant for a wind of given speed and direction.

Its variation depends upon the changes in the proportion of the building (see fig. A) and change in Direction or increase in the speed of the wind. It has a tendency to disappear if the main airstream becomes turbulent during flow. There are advantages to be gained, therefore, by including centrally located courtyards within structures. An outdoor space adjacent to a building can remain relatively free of dust provided the outer perimeter walls are completely sealed. In such cases it is possible to transmit both light and air into the surrounding interior through the internal courtyard wall.

The critical factors to be observed in planning for maximum efficiency in this instance have been noted in Fig. B. Fig. C indicates a method of protecting a building face by using barrier screens or walls located not more than 6.1 metres away. The use of adjustable or demountables screens to seal off the space to be protected in dusty and sandy wind conditions is one that could find great practical use (Fig. Dd).

Because of its tendency to bounce along the ground and the fact that it rises to the heights achieved by dust particles, sand is comparatively easy to deal with. The tendency for sand particles to rise into the air can be minimised by using soft ground cover around the building precincts. When sand deposition occurs on the wind-ward side of the barrier, resulting mound formation allows the wind to change its direction without loss of velocity at the base of the barrier. Thus many of the sand grains bouncing back from the face of wall are carried up and over in a continuous streaming effect. Although sand travels generally at heights or up to 1.07 metres, the walls or barriers, if they are to be effective, need to be higher than 1.68 metres. Walls lower than this have been found to be inadequate and unable to afford protection because of the increased height of travel of sand grains brought about by build-up of wind pressure at the base of an obstacle.

CHAPTER FIVE

PLANNING AND DESIGN OF EXTERNAL SPACES:

Apart from the effect of construction elements and the kind of treatment and flow of air within the building, physical comfort is also substantially influenced by such external factors as vegetation, water, and the nature of surrounding spaces. These external factors assume importance in a hot dry setting, where the environment presents extreme conditions and where the land-scape is drab and monotonous.

WATER:

Water is perhaps the key ingredient of all the gardens in hot dry lands. It is used as a still pool, as a falling stream and as a jet or fountain. Helped by sunlight and breeze, it is capable of creating a variety of moods. Essentially, water improves physical comfort by the evaporative process, which by increasing the relative humidity, decreases the dry bulb temperature of the surrounding air. It is a process which is greatly assisted by air movement, irrespective of whether it is naturally or artificially induced.

Before it is allowed to enter the habitable areas, wind can be made to pass over wet barriers, still water pools, or water sprays. The rate of heat loss from the moving air depends upon the area of water in contact with the air, the relative velocities of the water and the air during contact, the difference between the wet bulb temperature of the air and the initial temperature of the water, and the time of contact between air and water. In view of the greater vertical cross-section of air, a spray pond is more effective than a still pond of the same size. The former, however is likely to consume more water . To achieve the same efficiency in a still pond, it will have to expose a considerable large surface, as compared to a spray pond.

From the discussion above, we can see that water as a cooling medium can be used to effect a harmonious physical comfort in our environment if it is strategical placed in unprotected areas around the structures. However, judging by most of the new buildings in Kano, present-day architects do not seem to incorporate water into their design as a cooling medium.

VEGETATION:

Intelligent and judicious use of vegetation, whether in the form of trees, shrubs and grasses or merely creepers and vines, is known not only to help the micro-climate of a building but to improve the environment of a town as a whole. Researches by scholars show how plants and grasses reduce the heat load on expose surfaces by obstructing the passage of solar radiation. In a very thick forests, less than one percent of the incident solar radiation manages to reach the ground. According to Trapp nearly 80 percent of the incident solar radiation is checked within the foliage itself, and out of the rest only 5 percent penetrates through and reaches the ground. Areas under denser and larger foliage cover take more time to get heated and comparatively less to cool. The cooling effect is achieved with vegetation by using a high percentage of energy through the process of photosynthesis and also by employing the reflective properties of some foliage. Vegetation helps lower the surrounding air temperature by evaporative cooling as a result of transpiration. In an arid setting, it further provides advantages as a windbreak, thus arresting the flow of dust and sand into built-up areas.

Tall trees shade the buildings and generally protect outdoor living and assembly areas. In public spaces they can act as a substitute for bicycle, car and bus shelters. If carefully ordered, vegetation can provide a pleasant foil against the flat and harsh building surfaces. Al these qualities underline the importance of vegetation, in a hot dry, environment, but their achievement is not easy in areas where water is perpetually short and where the range of trees, shrubs, and grasses suitable for use in specific locations is fairly limited.

In the arid zone it is not always possible to grow trees sufficient in height to shade roofs. If planted too close to the building the water requirements of some trees tend to accentuate the natural seasonal changes in the moisture content of the ground, and accordingly the dimensional changes in the soils can adversely affect building foundations. But there are shrubs and plants which do not present this problem.

To achieve maximum efficiency, trees have to be strategically placed.

In the Northern latitudes, their best performance positions are on the east, South-west sides. In Southern latitudes, the best locations are east, North-East, and West and North-West.

Low sun rays cast long shadows which can be utilized effectively on those sides normally difficult to protect from sun's heat.

Architect K. L. Datta, who was my lecturer in the University, has classified trees into the three major forms. Firstly, those with a round shape where the spread and the height is normally the same. A-shaped, these trees may be used for roof shading and should be located on the South-East, South, and South-West sides in Northern latitudes and the reverse in Southern latitudes. In the second type, which are regarded as oval-shaped trees, the spread is nearly half the height and the foliage takes an oval shape. These trees may be used for general shading on East and West at a distance ranging between 6.1 and 9.15 metres from the building to intercept the low rays of the summer sun in the later mornings and early evenings. The third type of trees are vertical and their spread is not very wide. They are known as columnar trees and it is recommended that they be used for shelter belts and screens, both for shade and for protection from dust storms.

The selection of trees is guided by their functional and landscape qualities. The functional qualities depend upon their shape, height, and spread, and their rate of growth to maturity, trunk characteristics, root system, and their capacity to resist wind and give shade. Dense foliage, for instance, will provide solid shade while open foliage will give dappled shade.

The landscape qualities of trees depend upon their form, shape, texture, and colour of foliage as well as their floral and fragrance characteristics. The choice is also dictated by soil and water requirements, heat tolerance and pruning requirements. With a large variety of forms, stem clearances dimensions, and foliage characteristics to choose from, and after functional and landscape requirements are assessed, it is relatively simple to select the right type of tree for a specific purpose.

LANDFORMS:

Surfaces surrounding the buildings in a town also need very careful attention. It is a well known fact that ground surfaces exposed solar rays for a considerable period will in turn become heated and re-radiate to the micro-climate. As a result the heat load creates extra discomfort particularly from about mid-day onwards and through the evening. Solar load varies considerably according to topographical and physical characteristics of the land.

The greater the thermal conductivity of the ground, the more effective is its rate as a heat reservoir. Bare earth, asphalt, concrete and other types of paving have a high abortive capacity and thus become excessively heated during the days exposure to solar radiation. As a result, the air near the ground is heated beyond the normal. When carried into the building, it raises the temperature level inside. External surfaces made up of sand, polished proving, or even water in some instances, can often direct the radiation onto the buildings, thus producing discomfort due to glare and additional radiation.

In all cases, vegetation, particularly stretches of grass, is a useful element in reducing the incidence of the heat as well as the glare. Grass reduces heat transfer. It creates a thick heat, absorbing layer and gives shade to the soil below. Glare is reduced by planting trees or shrubs in such a way that on looking out of windows, only foliage is seen instead of the sky. This of course involves the proper selection and correct placing of trees in relation to window and other were opening of a building.

DUST AND SAND CONTROL

Apart from encouraging heat and glare, bare earth and hard ground surface also act as a source, and generate the flow of dust and sand into buildings. Loose soil and the absence of vegetation in hot dry lands further aggravate the problem.

A number of temporary soil stabilizers have proved useful. Lime cement, and bitumen are typically conventional stabilizers, all of which are reasonably affective in yielding a dust fee surface. At the moment only bitumen surface coating offers any prospect of economical control of wind erosion and dusting. As an emulsion, which may be combine with latex (natural or synthetic and applied in a thin surface spray, it provides temporary surface stabilization against wind erosion, but not against traffic loads) which will permit establishment of vegetative cover and thus permanent, wherever an adequate subsoil moisture condition exists cable of sustaining plant growth. In hot dry climates it should be recognized that a black top will lead to an appreciable rise in temperature on the surface soil.

The role of plants as nature's soil protectors is well understood by most people in hot dry lands. They help stabilization and assist in binding loose earth, plants and trees are of inestimable value in generally lowering the dust and sand particle pollute. They act as wind break and filtering systems, particularly when carefully planted with siting of buildings, roads, footpaths, and open spaces generally and not as later haphazard visual fill-ins.

COMPACT PLANNING

The control of heat, dust and sand by using vegetation, water, and soil stabilization opens up the whole question of the role which opens spaces play in modifying the micro-climate. The need to design, plan, and maintain open spaces in hot dry areas where water is in short supply and vegetation hard to grow, emphasizes the importance of keeping them to manageable proportions.

This need is well understood by people in Kano city and people in traditional desert settlements. A typical city in North Africa, middle East, or Kano city presents a very compact picture of house and other buildings huddled together so that they not only shade each other but also considerably reduce the exposed open spaces around them. In cases where normal low-level dust swirls within the settlements, the interiors of buildings are protected by almost blank walls with very small openings. The streets are narrow and winding; therefore there is less tendency for wind velocity to increase as a result of tunnelling effects. The public spaces, such as market squares, are well sheltered from the impact of desert winds by adjoining house and high walls. House are built around pleasant well shaded courtyards.

These extend to the outskirts of the city proper where a high perimeter wall act as a safeguard against hostile neighbours, and also provides an excellent barrier against the flow of dust and sand.

Too much open space requires large areas of grass and these need constant maintenance and abundant watering. Even where growth can be encouraged and maintained, the great expanse of dust background, the roads themselves, and the further extension out into micro-climate spaces make it important to provide tolerably dust-free and cool spaces within the buildings. With the absence of controlled external space, the four walls of the buildings themselves are the only barriers against hot, dust-laden winds and direct solar radiation.

This approach of compact planing in traditional settlements in the tropical region is rarely evident in most of the newly developed areas, where designers seem to be bent on following layouts and subdivision more suited to the temperate or cooler areas of Europe and North America. Most of these are based on a gridiron pattern which primarily caters for the interests of the motor car rather than the people who live there.

<u>COURTYARD HOUSING</u>

The courtyard concept seems to offer a valid basis for design of houses in hot dry lands. Essentially horizontal in character, the courtyard concept represents perhaps the simplest and easiest form of shelter of people who are closely associated with rural desert traditions. It is worthwhile to look at the application of this concept of urban housing, particularly where problems of psychological and sociological adaptation are paramount. This form of housing, whether individual or collective retains some of the important elements of life of the desert communities.

The courtyard concept modifies the micro-climate by helping to maintain air circulation through convection currents. At night, cool damp air is formed at ground-level slowly seeps into the rooms, thus making them cool to last for a good part of the next day. In addition, courtyards also act as a buffer against the noise from the street and stop the entry of dust and sand into habitable rooms.

In addition to its value as modifier of climate, the courtyard offers many other advantages in hot dry lands.

Firstly, all or most rooms open into it; consequently, apart from security, it ensures absolute privacy. The later is further guarantee by the traditional house practice of locating entrance door in such a way as to open into a blank wall which obstructs all the view inside whenever the door is opened. As we have said, the courtyard acts as a buffer against street noises, and this can often be further helped by placing secondary service rooms such as bathroom and kitchen near the street. The courtyard also provides a safe play area for small children where mothers while continuing with normal household chores can directly supervise their activities. For adults, the courtyard provides a useful living and sleeping area at times when the weather permits such activities. In winter it is normally used for day activities while in summer it is used mainly in the evenings and for sleeping purposes. In short the courtyard virtually becomes an extension of house proper, thus adding to the total space available to the dwellers.

CHAPTER SIX:

BUILDING MATERIALS

Earth and Masonry constitute the basic construction materials for most buildings in hot dry lands. They are obviously ideal for a region where rainfall is low, timber is scarce, and the climate dictates the use of heavy-weight materials with high heat-storage capacity.

Light-weight materials such as metal, timber, asbestos, plastics, rubber, glass and asphalt are finding increasing use, particularly in sophisticated building in urban areas and in very remote locations where traditional local materials are not available and where building labour is either non-existent or very expensive. It is proposed to discuss the performance of these materials under the special conditions which prevail in hot dry areas.

MATERIALS:

METALS, TIMBERS AND ASBESTOS

Most metals and their alloys perform well in hot dry climates. Corrosion of iron, steel, zinc, aluminium, or copper is negligible unless the local atmosphere is heavily polluted by industrial gases such as sulphur dioxide, especially when associated with particles of carbon as is often the cases.

Fatigue cracking of lead in exposed situations, such as roof flashings, can be a serious problem. The trouble is intensified by the condition produced by the relatively high temperatures of hot dry lands and by the high purity of the metal ordinarily marketed,. Fatigue cracking can of course, be reduced by employing low-alloy leads such as silver-copper-lead alloys and antimonial lead, and by using heavy-weight sheets.

Owing to the absence of water, timber is relatively scarce in hot dry lands, but when it is available its deterioration is not as server as in hot humid areas, where moulds and fungi cause additional problems. Whatever deterioration there is, usually caused by extremes of climates conditions. Continual dimensional change produce checks, splits, warping, and raised grain and reduce the point-holding properties of timber. Where the climate condition is too severe, steel framing is used to replace timber framing in most structures. The greatest hazard to timber, however, is attack by subterranean termites. Asbestos cement is not typical of building materials used hot dry lands. When used, it certainly performs better, in one respect, than in hot wet regions where algae growth on damp sheets leads to considerable blackening. There is evidence that climatic variations in hot dry lands affect the quality of some grades asbestos. Expansion and contraction of supporting structures can cause cracks in asbestos cement roof sheets. In remote location, where building materials have to be transported long distances, the breakage rate of asbestos sheets is extremely high.

PAINTS

It has been suggested that light-weight materials require paint on their exposed surfaces to prolong their performance. Paint tends to break down more frequently in hot climatic areas, probably because of exposure to radiation, which intensifies physical, chemical, and photochemical deterioration. In monsoonal area the performance of paints is further affected by frequent alternations of rain and sunshine. This particularly apparent on wooden surfaces, where scaling and flaking is caused by the combined of photo-chemical action and the expansion and contraction of the surface of the timber. Paints intended for use in hot climate are improved by the use of fillers such as asbestos, which help prevent settling. Alight-weight structure requires painting approximately every three years, and this fact should be taken into account when comparing the cost off erecting a similar building of masonry materials, which would require little or no exterior painting and hence little if any maintenance expenditure.

PLASTIC, BITUMEN, AND GLASS:

In building, plastic are normally used for electrical fittings, floor covering, and in certain cases, as roof sheeting. Linoleum and plastic floor tiles have a tendency to become brittle, lift off the floor and, where kicked or trodden, get broken off. Exposure of thermoplastic materials to sunlight causes warping and cracking because of loss of plasticizer. The addition of small quantities of phenyl-salicylate and ultraviolet radiation inhibitor to plastics helps to reduce deterioration.

Bituminous materials are known to have shorter life in hot climatic regions in the cooler parts of the world. Intense solar radiation is known to promote chemical reactions which result in embrittlement, cracking, and crumbing. Provision of highly reflective surface treatment has been suggested as a solution to the problem, but the need for continual maintenance has almost eliminated the use of bituminous materials for roofs in hot climates.

There is no evidence of deterioration in clear glass under the high temperate conditions normally experienced in hot dry lands. Any cracking which may occur is usually confined to coloured or tinted glass and is caused by tensile failure, due to the periphery of the glass being shaded by the edge of the frame while the centre part is exposed to solar radiation, which it absorbs: the difference in temperature within the same sheet of glass is often as 19.4^{oc}, hence the disintegration. A common from of deterioration of glass in hot dry area is etching or abrasion, caused by send particles blown by high wind.

EARTH CONSTRUCTION

Earth is probably one of the most widely used of all building materials in hot dry lands. For one thing it is the most economical and the most generally available material. The superior thermal performance of earth structures, owing to their density and thickness, has particularly appealed to the people of hot dry lands. In some countries earth is also used in building as a mortar for bonding and rendering rubble walls, and is mixed with lime, cow dung, straw, or other appreciate materials for specific purpose.

The use of earth construction continues in area where labour is cheap and abundant, where transported materials are either too expensive or unobtainable, and where self-help methods are available. in Kano city, the economies of earth construction are appreciated: it is the cheapest material available on site and is widely used for floors and roofs in addition to walls, all of which amount to a substantial percentage of the total building operation.

A major disadvantage of earth construction in lands that have any appreciable rainfall is that frequent repair work to the external wall surface is needed. This is particularly the case in monsoonal areas of semi-arid zones where periods of continuous rain cause the surfaces to crumble. Earth walls are vulnerable to moisture and require maintenance after each rainy season. Although some waterproofing is achieved by oil coating and cement or lime rendering none of these is entirely satisfactory. Good design can considerably help to minimize these problems, with such devices as deep roof overhangs and verandahs to protect the external wall surfaces.

<u>CLAY PRODUCTS AND MASONRY:</u>

Next to raw earth construction, clay bricks baked in a kiln are the most important, and by and large one of the cheapest, building materials in hot dry lands. What is more, they are likely to remain so far many years to come. The Burt brick industry is gradually becoming well established in Nigeria.

Building have always been aware of the limitations imposed by the use of Burt-brick work, but its long life and infrequent need of repair is also well appreciated. The demand for better quality products continues, however, and research work is being done in Burt-brick manufacture in areas where soil is inferior. New types of bricks are continuously being developed, and it is now possible to choose from a wide variety of products, ranging from acid-resistant bricks, kiln brick, and heavy-duty engineering brick to face bricks, all with a considerable range of colours.

Except in very primitive circumstances, use of building stone is largely limited to decorative areas as a relief from brick and concrete work. The material is cheap, but the labour cost is so high as to make building stone uneconomical when compared to brickwork. When chosen with reasonable care, stone is known to weather quite well in hot dry climates, but the erosive influence of dust and sand and high temperatures may produce stresses and cracking.

CONCRETE AND CONCRETE BLOCK

Concrete product are widely used in hot countries and in most cases, are subject to little deterioration. The chief problem lies in the supply of ingredients, particularly cement, which in some areas is imported at an exorbitant cost. Sand and gravel, unless available locally, may have to be transported over long distances. But the most important need is the availability of reasonably clean water. Saline salty water and water with phosphate content and organic matter is considered unsuitable for concrete work. Large amount of water are needed for washing aggregate and for mixing concrete. Water is also necessary for continuous wetting of the surface of concrete work for at least two weeks.

This is particularly so in hot dry lands where rapid evaporation and resulting dehydration is known to result in low strength, cracking, and excessive permeability of the concrete.

Because of its high cost, concrete work in most of the industrially less advanced countries is largely confined to public and commercial building. For low-cost building in areas where Burt clay brick-making is not indigenous, concrete block is increasingly being used for wall and floor construction. It is now possible to install simple, economically run machines to compress and vibrate hollow concrete blocks which use a minimum amount of cement. In really remote locations, very low costs can be achieved by using hand-operated machines similar to those employed for the manufacture of stabilized earth blocks. The hollow block require sand and aggregate of good quality, with reasonably controlled condition for washing and grading. Controlled condition are also essential when it comes to mixing cement and water. Concrete block building requires more careful attention to design and construction than is normally necessary for burnt-clay products.

A major problem posed by block construction is cracking due to shrinkage caused by temperature fluctuations. Given adequate care during construction-and by employing such design precautions as use of lime-rich mortar, control joint, and incorporation of joint reinforcement when necessary.

SUMMARY: (Findings, Conclusions and Recommendations)

We have seen that in order to be able to plan and design for any particular environment, the historical background and the climatic element of that area must be known. In this aspect, the culture and mode of living of the people and that climatic elements such as rainfall, wind, temperature should be studied. The study help the architect and the planner to design and plan a house that will suit the environment.

It is axiomatic that buildings cannot fill empty stomachs, but they can do much to provide a means of creating ambient environment for physical, mental, and spiritual comfort. In order to solve this problem, I've proposed that the physiological and psychological comfort of the people must be taken into consideration and therefore factor such as the size, proportion, character and surroundings of rooms, the colour scheme, and even the views from windows, extreme heat, dryness, nuisance of files, sand and dust storms which have great effect on the inhabitants should be incorporated into the planning and design processes.

To provide an acceptable environment without air-conditioning in a place like Kano, a designer must be primarily concerned with controlling the micro-climate or the climate within the space enclosed by a structural shell. So, when designing, the orientation of the building as regards solar radiation and ventilation should not be overlooked. As regards solar radiation, I discovered that to arrest the situation, the walls of the building must be thick, bedrooms and living rooms should not be placed on the east-west direction, canopies should be used to provide shade and double roof system with vents can be employed to diffuse solar radiation.

In Kano, ventilation is not a big problem because of the hot dry wind and so the window size should not be too wide and fenestrations should be kept at the minimum level.

Apart from the effect of construction elements and the kind of treatment and flow of air within the building, physical comfort is also substantially influenced by such external factors as vegetation, water, and the nature of surrounding spaces. These external factors assume importance in a hot dry setting, where the environment presents extreme conditions and where the landscape is drab and monotonous. In this write-up, I have canalized how water can be used as a still pool, as a fountain or jet and as a falling stream. Helped by sunlight and breeze, it is capable of creating a variety of moods. Intelligent and judicious use of vegetation, whether in the form of trees, shrubs and grasses or merely creepers and vines, is known not only to help the micro-climate of a building but to improve the environmental of a town as a whole.

The compact planning and courtyard concept seem to offer a valid basis for design of houses in Kano. The need to plan, design and maintain open spaces in Kano where water is in short supply and vegetation hard to grow, emphasizes the importance of keeping them to manageable proportions. This need seems to be well understood by the people living in Kano city. Kano city presents a very compact picture of houses and other buildings huddled together so that they not only shade each but also considerably reduce the exposed open spaces around them.

The courtyard concept modifies the micro-climate by helping to maintain air circulation through convection currents. It also acts as a buffer against the noise from the street and stop the entry of dust and sand into habitable rooms. Courtyard provides security and also offers absolute privacy. The later is further guarantee by the traditional Hausa practice of locating entrance door in such away as to open into a blank wall which obstructs all the view inside whenever the door is opened.

Finally, for us to comprehend this topic very well, I decided to make a study on the building materials that will suit the climatic environment of Kano. Earth and masonry constitute the basic construction materials for most building in Kano city. They are obviously ideal for a region where rainfall is low, timber is scarce, and the climate dictates the use of heavy-weight materials with high heat-storage capacity.

Light-weight materials such as metal, timber, asbestos, plastics rubber, glass and asphalt are finding increasing use, particularly in sophisticated building in Kano metropolis and in very remote locations where traditional local materials are not available and where building labour is either non-existent or very expensive. Most of these light-weight materials perform very well in hot dry climates. For example, corrosion of iron, steel, zinc, aluminium, or copper is negligible unless local atmosphere is heavily polluted by industrial gases such as sulphur dioxide, especially when associated with particles of carbon as is often the case.

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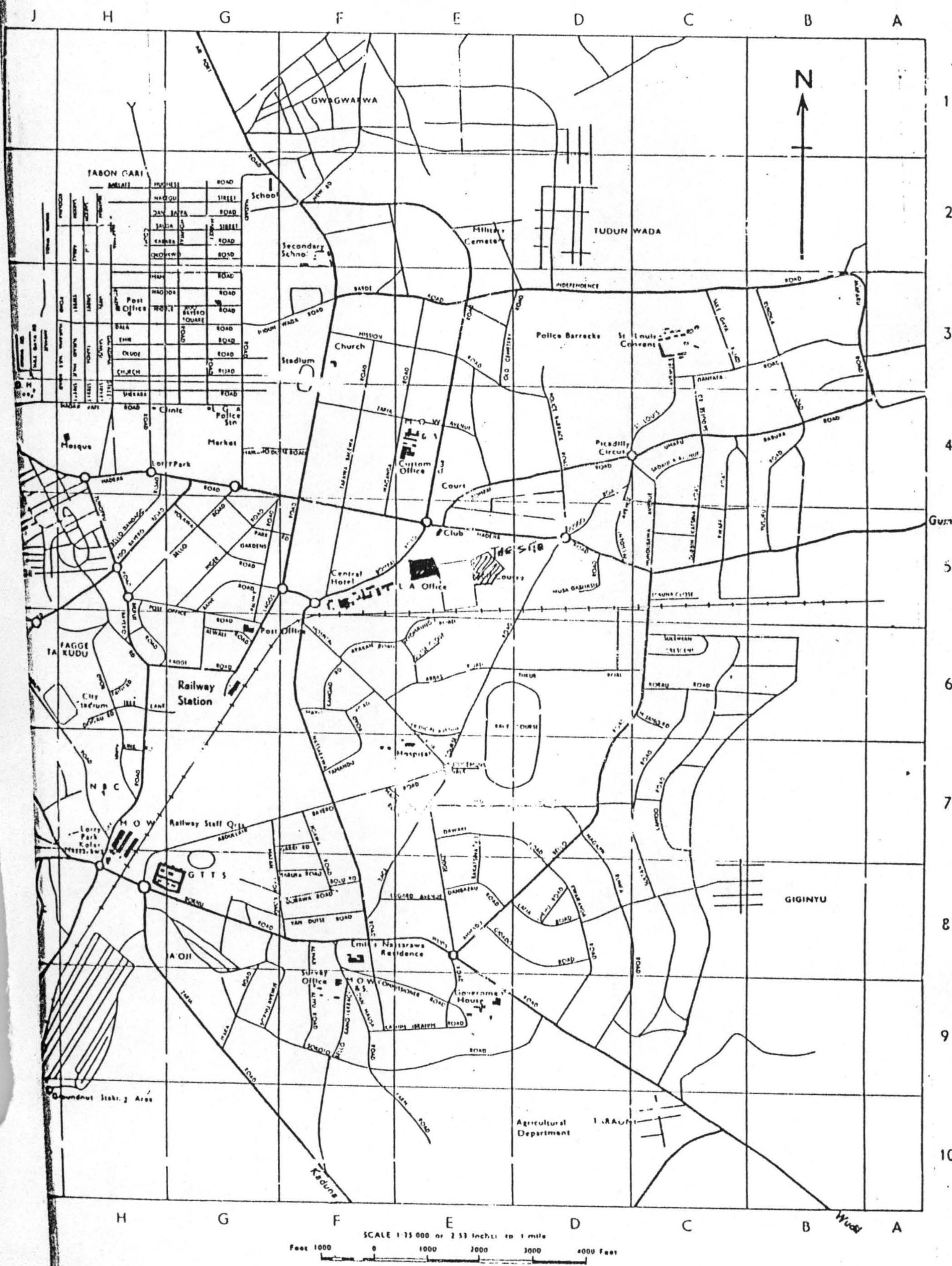
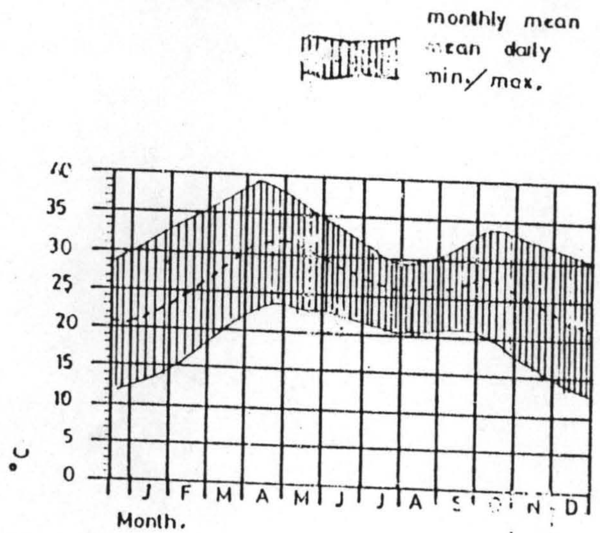
APPENDIXES

1A
KANO TOWNSHIP



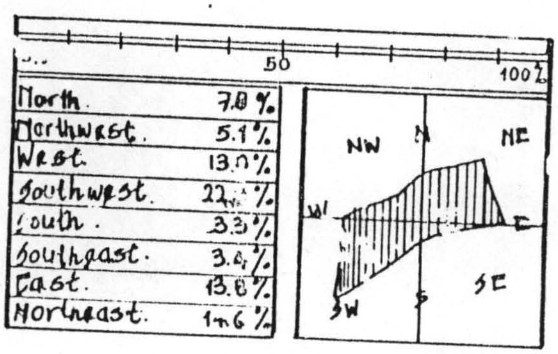
1B

(a) TEMPERATURE



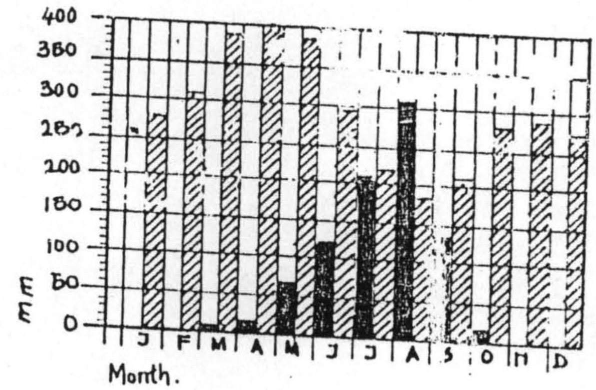
(b) MAIN WIND DIRECTIONS.

North.	7.0 %
Northwest.	5.1 %
West.	13.0 %
Southwest.	22.[illegible] %
South.	3.3 %
Southeast.	3.4 %
East.	13.8 %
Northeast.	1[illegible]6 %

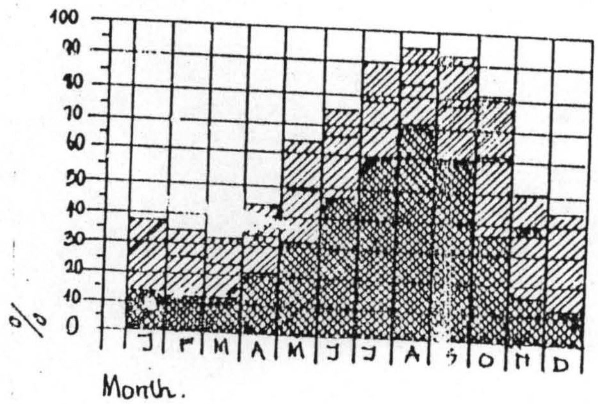


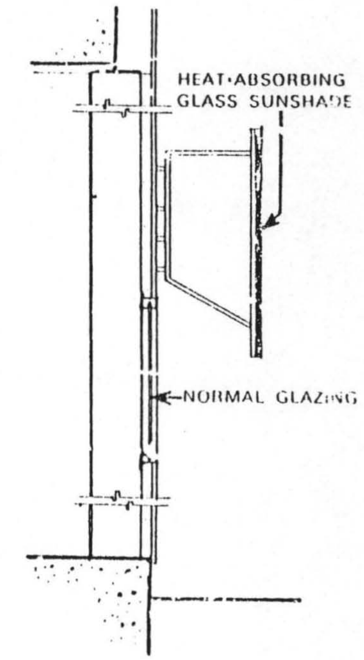
1C

(c) Rain ▮ Evaporation ▨

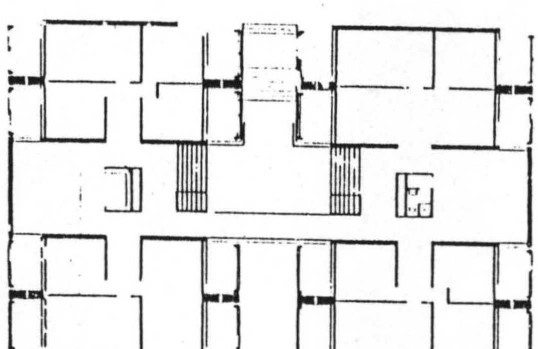


(d) Relative Humidity

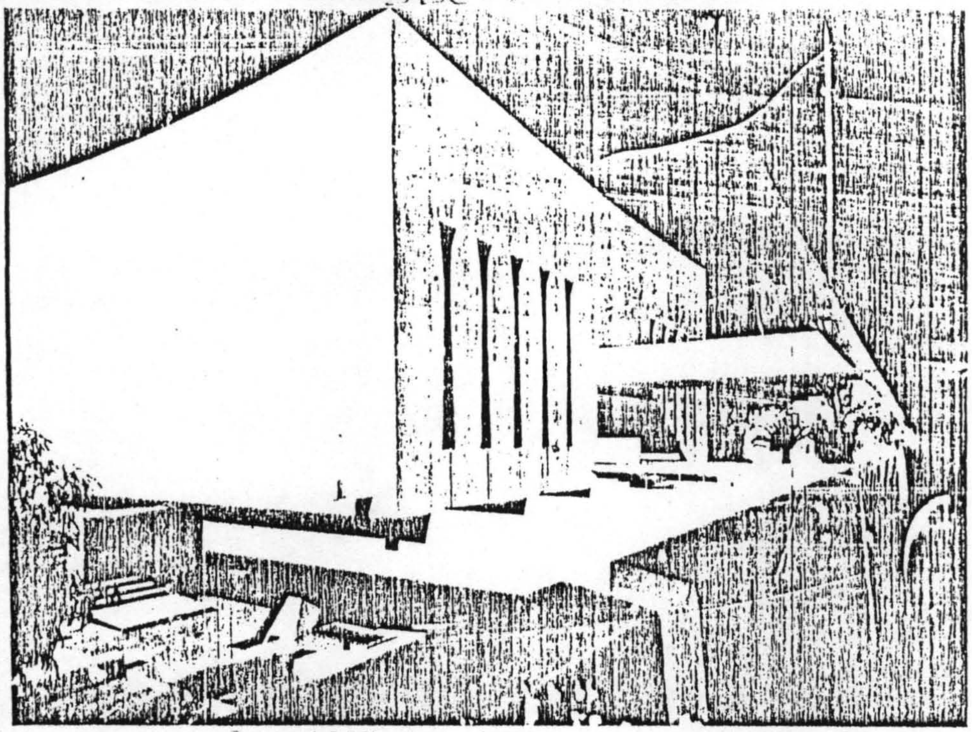




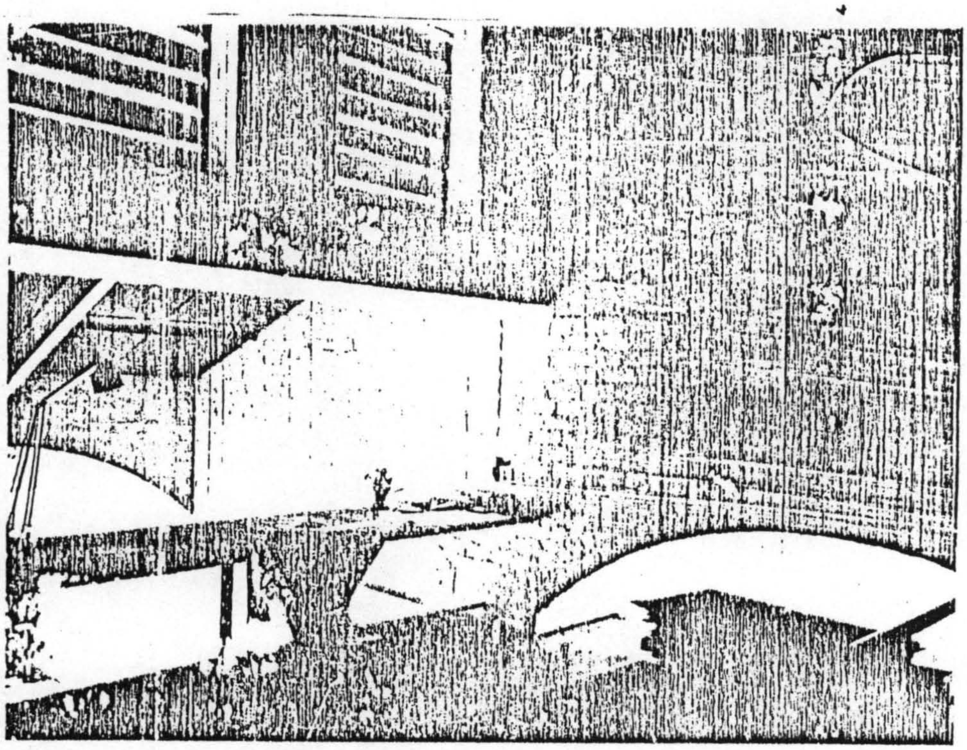
18. *Effective use of heat-absorbing glass in wall glazing.*



19. *Plan of Chancellery building for Luanda, Angola, designed by architect Louis I. Kahn. The glare problem is avoided by placing each office in such a way that it overlooks the small shielded court.*



(aLove right). Façade treatment of this Law Courts building in Morocco by :. itect Jean-Francois Zevaco follows the traditional practice in hot dry climatic regions: the smaller openings have kept glazed areas to the minimum.



(right). Solar radiation and sky glare can be reasonably checked by reducing the size of the openings. To be effective, however, they need to be carefully designed and located as shown in this studio room in a house in Itawa, in Ndola, Zambia, designed by architect Julian Elliott.

3C

. Efficiency of these fixed concrete louvres in the High Court building in Chandigarh, India is considerably reduced because of their high heat-storage capacity. After sunset the louvres steadily warm the cool night air on its way into the building, thus making it difficult for interiors to sufficiently cool down for daytime comfort.

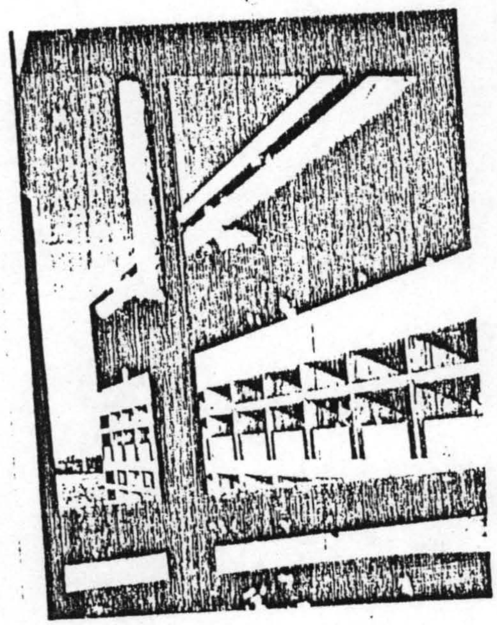


Table . Effect of shading upon instantaneous solar heat gain through a single thickness of common window glass[a]

Type of shade: finish on side exposed to sun	Percentage of heat gain (unshaded window 100 per cent)
Outside slatted shade, slats set to prevent direct sun falling on glass: white, cream	15
Outside commercial bronze shading screen of narrow metal slats; solar altitude above 40° so that no direct sun falls on glass: dark	15
Outside canvas awning, sides open: dark or medium colour	25
Inside venetian blinds, slats set to prevent direct sunshine passing through: diffuse reflecting aluminium	45
Ditto: white, cream	55
Inside roller shutter fully drawn: dark	80

[a]Based on data in the *American Society of Heating and Air-conditioning Engineer's Guide*, 1955.

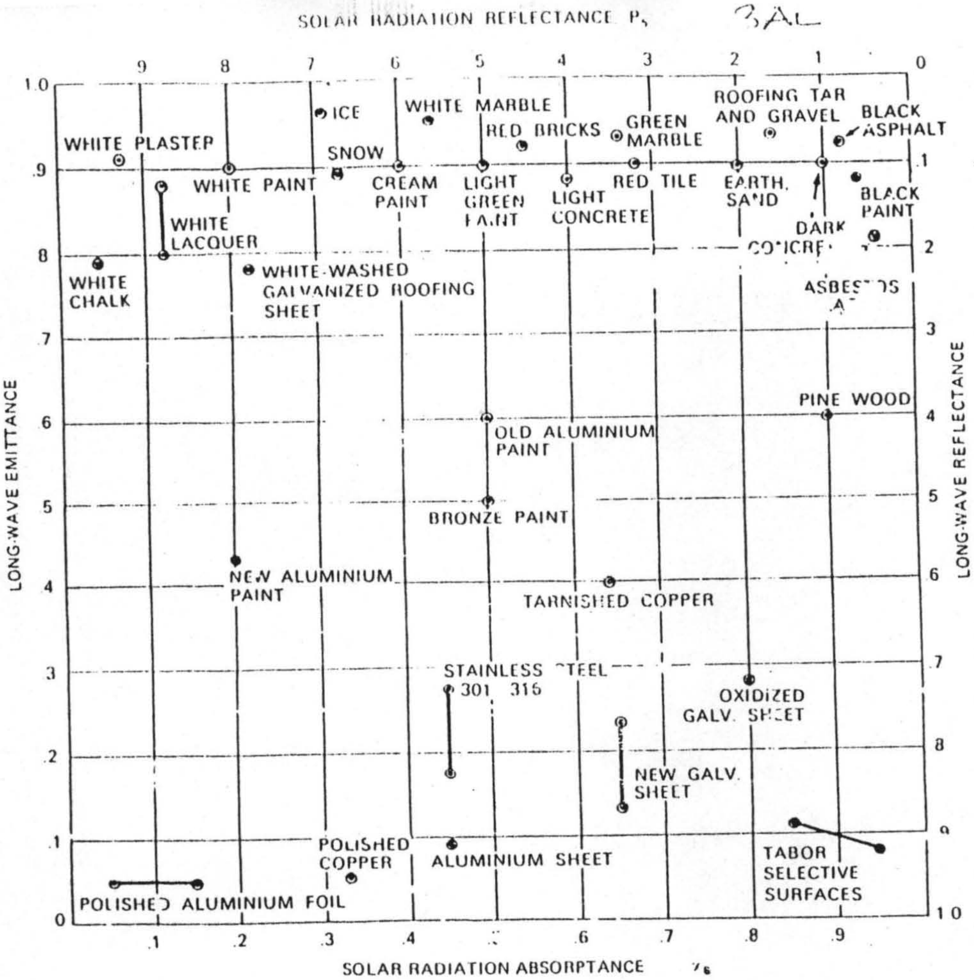


Table ■ Temperatures attained by concrete roof slabs

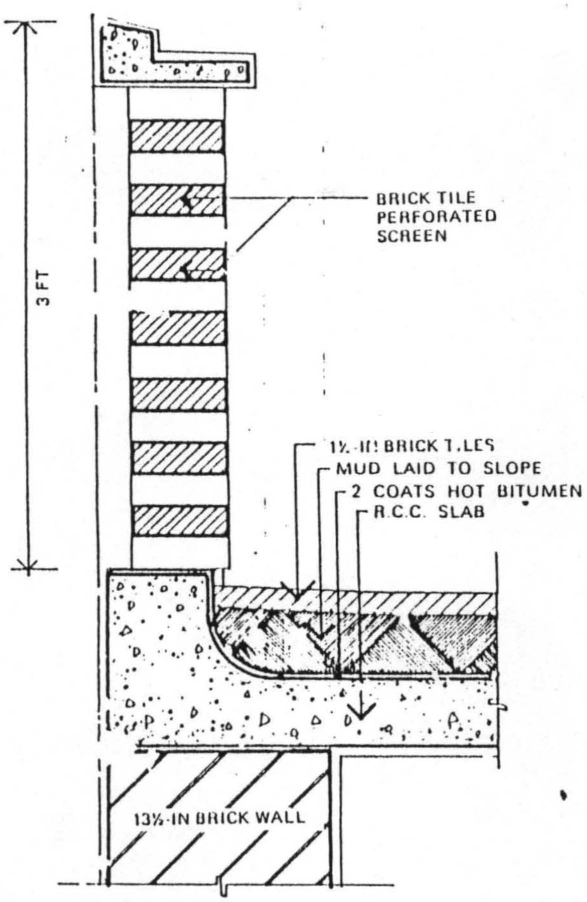
	2-in (5.1 cm) concrete		4-in (10.2 cm) concrete		8-in (20.3 cm) concrete		8-in (20.3 cm) hollow tile[a]	
	Maximum temperature							
Position	°F	°C	°F	°C	°F	°C	°F	°C
Upper surface	121	49.4	104	40.0	101	38.3	99.5	37.5
Lower surface	115	46.1	97.5	36.4	84	28.9	88.0	31.1
Mean temp.	116	46.7	89.5	36.9	88	31.1	90.0	32.2
Time lag	1 hr 25 min		2 hr 30 min		6 hr 0 min		5 hr 0 min	

Maximum shade temperature 80 °F (26.7 °C).
[a] 4¾-in (12.07 cm) clay tile, with 3¼-in (8.26 cm) concrete screed.

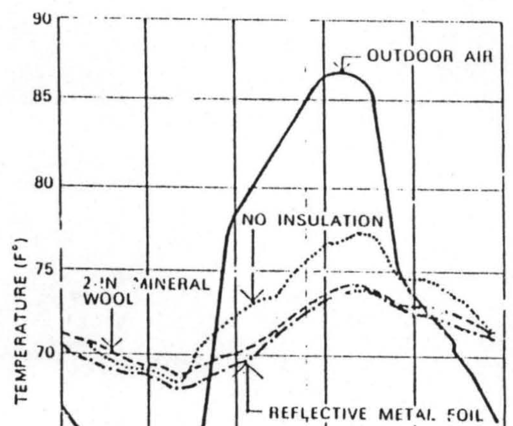
■. Materials in the upper left-hand corner of this diagram are considered to be 'cool'—they do not absorb very much of the solar heat that strikes them, and they are good radiators of the heat that is absorbed. But materials in the lower right-hand corner are 'hot'—they absorb a considerable amount of the sun's heat but they do not re-radiate much of that absorbed. Some materials in the upper right-hand corner (when the construction is not massive) may experience wide temperature swings (roofing more than [illegible] F in 24 hours).

3D

5

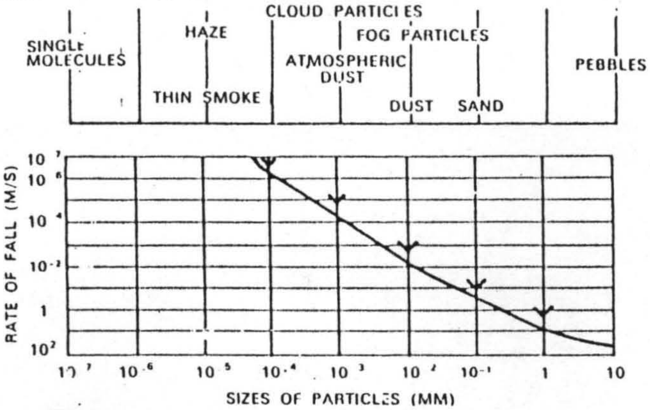


. Standard detail of parapet which affords privacy but allows air to pass through for sleepers on the roof. Note the use of a layer of mud for insulation.

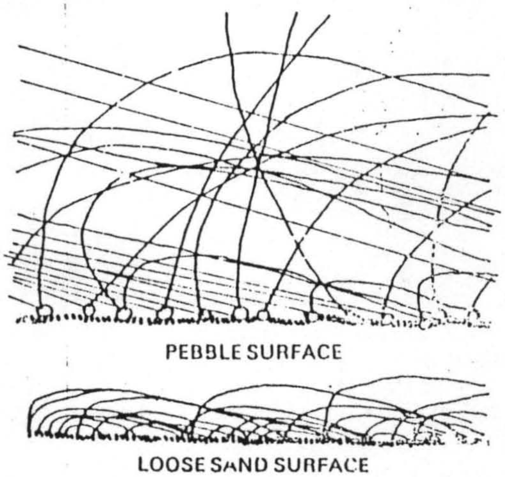


. Effect of ceiling insulation on indoor air temperature under typical summer conditions.

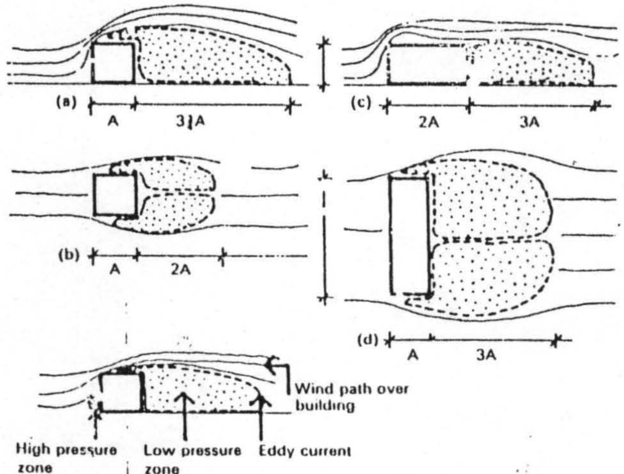
3BL



. Size and rate of fall of particles.



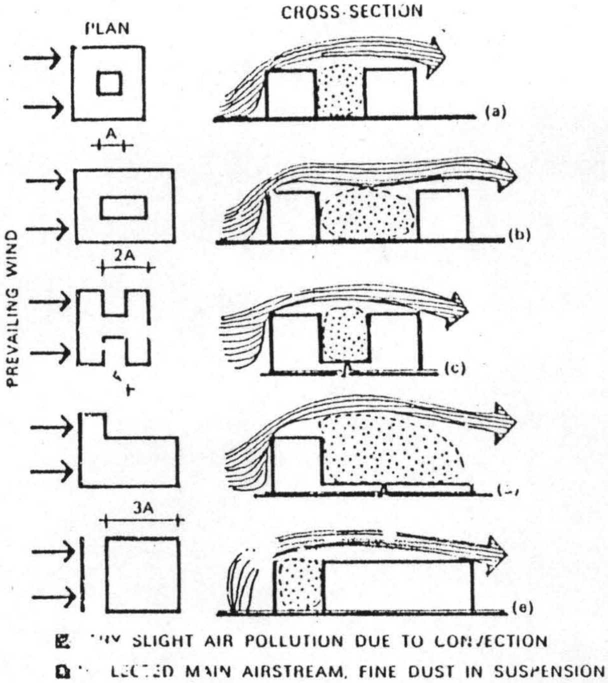
Effect of surface on motion of grains of similar diameter and moving with same wind speed; angle of impact at ground surface is between 10° and 16° in both cases.



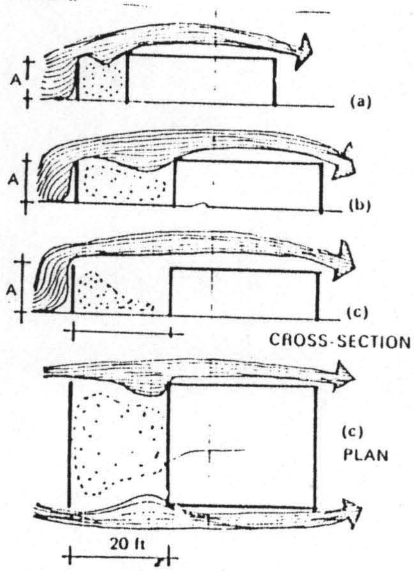
Distribution of low pressure zone in the lee of a building for a laminar surface wind of constant speed and direction: (a) *Low pressure zone [illegible] passage over building (elevation).* (b) *Low pressure zone due to sideslip of air round building (plan): depth of zone is less than in* (a). (c) *Depth of low pressure zone decreases as depth of building increases (elevation: cf.* (a)*).* (d) *Depth of low pressure zone increases with increase in length of the building (plan,*

3BL

S



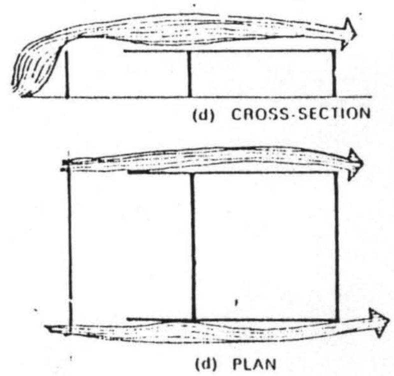
. *Air pollution in courtyards:* (a) *Central square court giving protection from sand and most of the wind-borne dust; orientation unimportant.* (b) *Central rectangular court giving good protection for depth up to 3A; for depths exceeding 3A the building should have long axis perpendicular to the wind direction.* (c) *Perimeter square court gives protection as in* (a) *against overhead dust but eddy whirls caused by sideslip will allow dust to enter from the sides; depth of courts limited to 3A; both receive same protection.* (d) *Perimeter rectangular court provides some protection to maximum depth 3A but would be better situated on lee side of building.* (e) *Fully exposed space requires a barrier to provide protection from overhead dust and side swirls; protection is function of length and height of barrier and distance from face of building.*



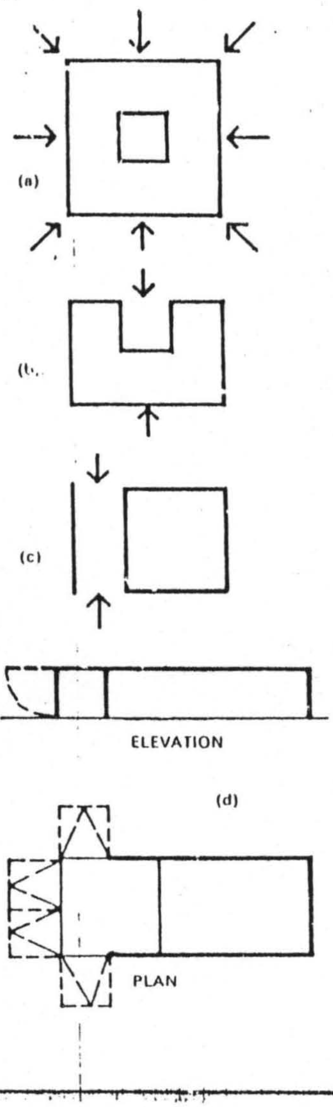
. *Barrier screens:* (a) *Portion of dust stream enters sheltered space if barrier is less than A.* (b) *Amount of dust entering sheltered space increases as distance of screen from building face increases.* (c) *Little dust enters sheltered space if barrier height A is equal to height of building and distance does not exceed 20 ft.*

3BL

[redacted] *(continued).* (d) *Depth of enclosure from which dust is excluded is extended by a combination of fixed side barriers and roof overhead (cf.* (c)*).*

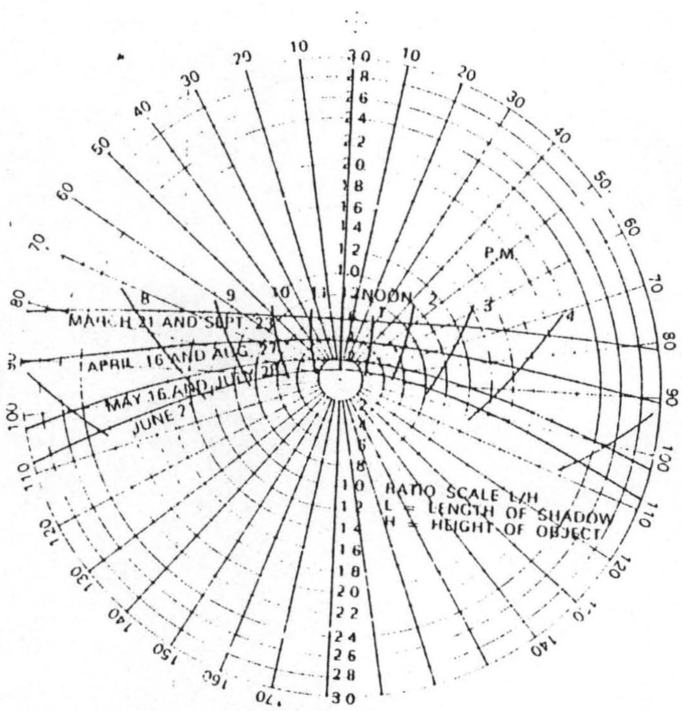


[redacted]. *Integration of protected open spaces into planning:* (a) *Central court gives greatest protection from variable dust whirls.* (b) *Perimeter court may be an adaptable space throughout the year if movable dust barrier is provided.* (c) *Free standing screen provides only limited protection because wind direction is variable; inclusion of barrier side screens is desirable.* (d) *Flexible barrier arrangement to provide protection from sand and dust; barrier may be folded to form a shading device at times when air pollution is not a serious problem.*



4-AL

■. *Shadow charts: . iagrams similar to these can be drawn to suit any specific latitude and in the scale in which the building drawings are prepared. By juxtaposition of the tracings it is possible for a designer to visualize the extent and nature of shading for different locations of a tree.*



Shadow Chart at 29°N

4BL

/ PATTERN
)W LI' 'S FOR MARCH 21 AND SEPT 23 SHOWN —
)W LINES FOR APRIL 16 AND AUG 27 SHOWN —
)W LINES FOR MAY 16 AND JULY 28 SHOWN -
)W 'INES FOR JUNE 21 SHOWN -x-x-
/ I ANGE
21 APRIL 16 (S.R.)
SEPT. 23 (S.A.)

21-APRIL 16 (S.C.)
-MAY 16 (S.R.)
-AUG. 27 (S.A.)
SEPT 23 (S.C.)

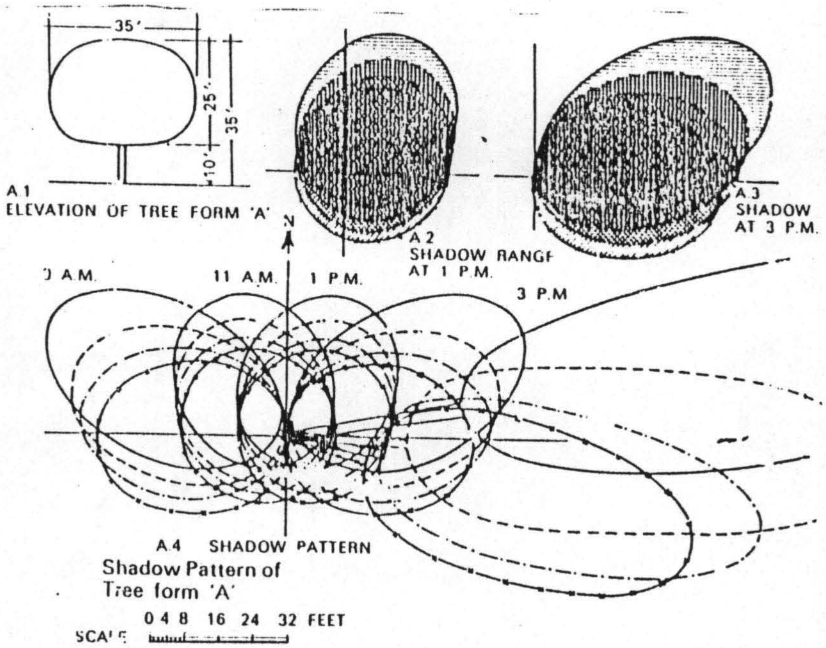
21-MAY 16 (S.C.)
JUNE 21 (S.R.)
-JULY 28 (S.A.)
-SEPT. 23 (S.C.)

2'-JUNE 21 (S.C.)
-SEPT. 23 (S.C.)

21-APRIL 16 (S.A.)
6-AUG. 27 (S.C.)
-SEPT 23 (S.R.)

6-MAY 16 (S.A.)
-JULY 29 (S.C.)
-AUG 27 (S.R.)

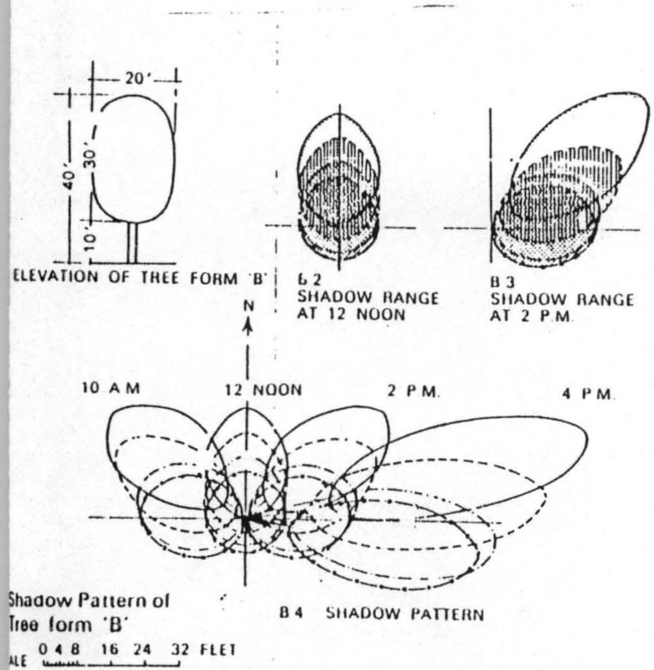
-JUNE 21 (S.A.)
-MAY 16 (S.R.)
ADOW ADVANCING
HADOW CONSTANT
HADOW RECEDING



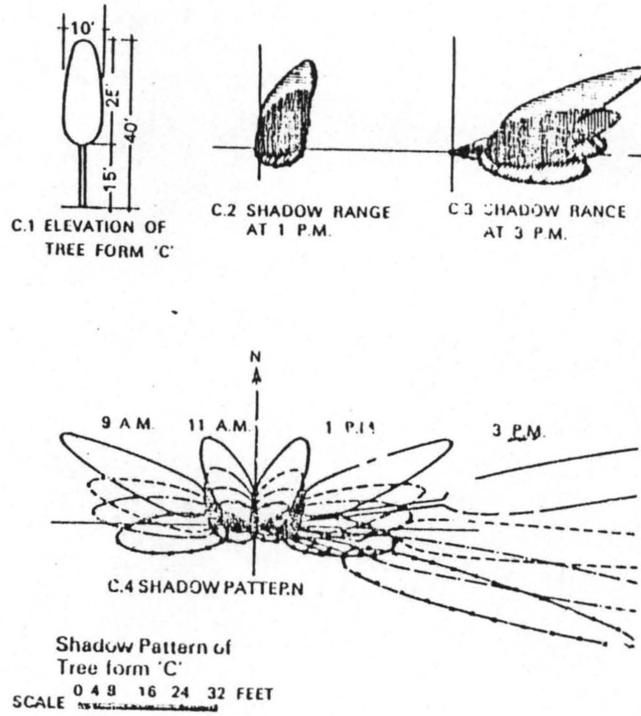
Shadow Pattern of
Tree form 'A'

VEGETATION

4BL



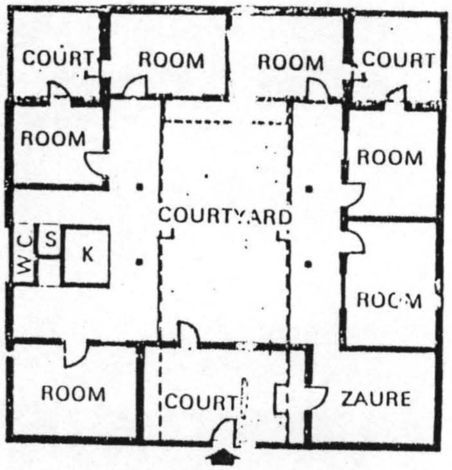
Shadow Pattern of Tree form 'B'



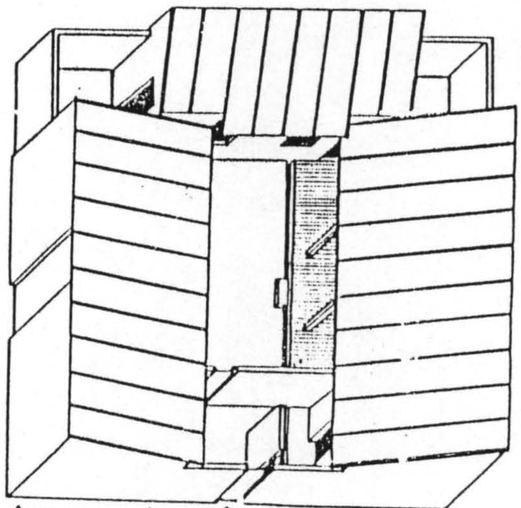
Shadow Pattern of Tree form 'C'

VEGETATION

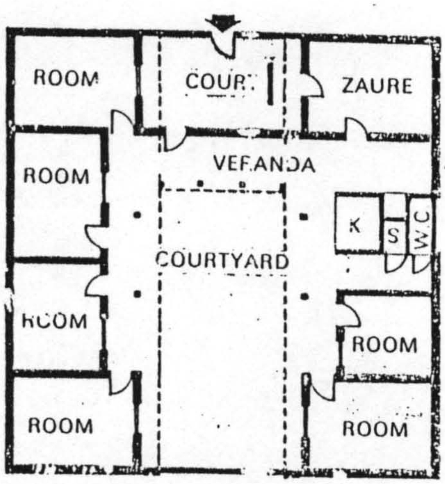
4A



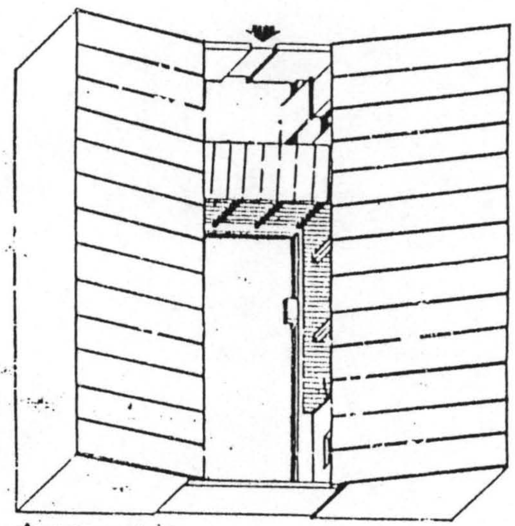
Plan House
NO. 12 N 0 5 10 20 FT



Axonometric



Plan House
NO. 2 0 5 10 20 FT



Axonometric

COURTYARD DESIGN

7 The form of dwellings

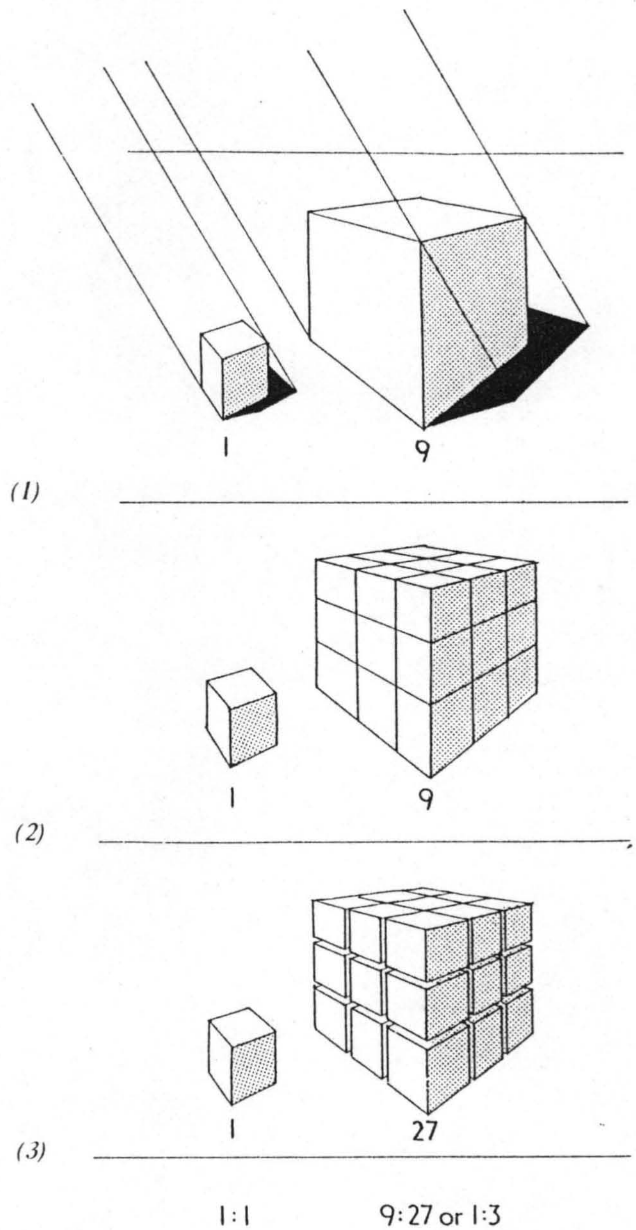
The form of dwellings can be adjusted to take advantage of the beneficial aspects of the climate, and to reduce the impact of unfavourable aspects. The form, layout, orientation and scale of dwellings and dwelling-groups should therefore be controlled in relation to the needs of the climatic zone. The design of dwelling form should not only be related to improvement of the internal environment, but also to the creation of comfortable conditions in the external spaces between and around buildings. This is particularly important in hot climates where outdoor spaces can function as living rooms, kitchens, play spaces, laundry spaces, and even as bedrooms.

Outdoor spaces and semi-enclosed spaces are also cheaper than totally enclosed spaces, and are therefore particularly important in low cost housing where totally enclosed space may be limited. They may furthermore provide a valuable alternative when indoor conditions are uncomfortable. However outdoor spaces must also be designed in relation to climate as the need for solar radiation or for shade, for breeze or for protection against the wind, is as important as for indoor spaces. They should never be considered as 'left-over spaces' remaining after the internal spaces are defined (although the by-laws in many countries, with requirements to set buildings back from the plot boundary, do not help in this respect).

In this chapter a brief summary of the basic variables is provided, including the proportion and depth of buildings; the spacing between buildings; and the ceiling height. This is followed by an outline of the requirements for the form of dwellings in each of the main climatic zones. For intermediate zones some interpolation or compromise between different requirements may be necessary. Many of the factors discussed may be limited by law: spacing angles and ceiling heights are two of the obvious examples. Nothing that is stated in this book can relieve the designer from the obligation of complying with local legislation! Nor should the designer follow the recommendations blindly since each climate will have its own particular requirements and each site will have its own limits.

Proportion and depth

The volume of a building will be very approximately related to its thermal capacity (its ability to store heat energy), while the surface area will be related to the rate at which the building gains or loses heat energy—see figure 7.1. The ratio of volume to surface area is therefore an important indicator of the speed at which the building will heat up by day and cool down at night. (This ratio is roughly related to the time constant which is described in chapter 8.) If the temperature range is high and it is desirable that the building heats up slowly, a high volume to surface ratio is preferable. In hot dry climates or climates



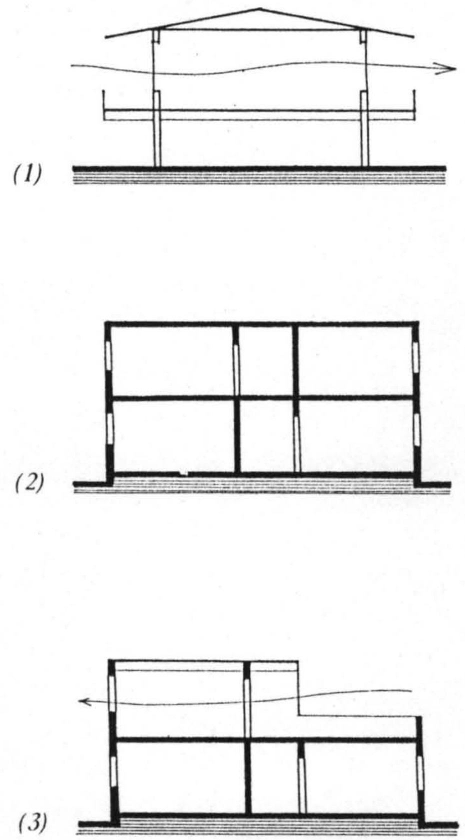
7.1 *The volume effect. The cube with a larger thermal capacity in proportion to its surface area (or rate of heat loss) will cool down more slowly.*

(1) Surface area exposed to direct solar radiation

(2) Surface area across which the cube will gain or lose heat to the air

(3) Volume, proportional to the thermal heat capacity for a homogenous solid

Ratio of surface to volume or rate of heat gain to thermal capacity

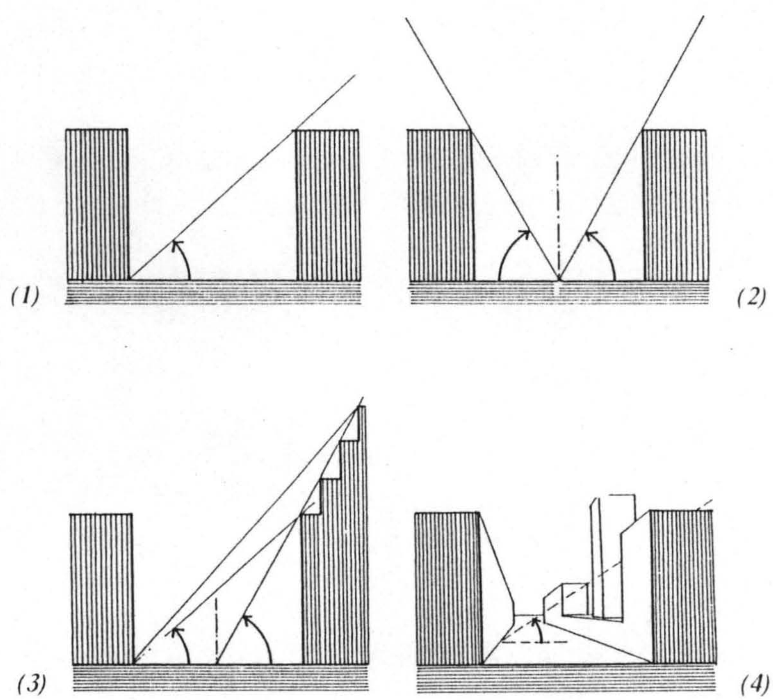


7.2 *Effect of building depth on internal conditions*

(1) Single-banked rooms (buildings which are one room deep in section) should be used when low heat capacity and cross ventilation are required

(2) Double-banked rooms can be used to give a high heat capacity building in climates where air movement is not so important for comfort

(3) A compromise for composite climates: the upper floor can be used in the humid season or at the time of day when air movement is needed; the lower floor, with its higher heat capacity, can be used in the hot dry season



7.3 *Spacing between buildings*

(1) Spacing angle used to control the proportion of streets and external spaces to safeguard environmental standards

(2) The traditional form of building control; angles measured from the central axis of the street

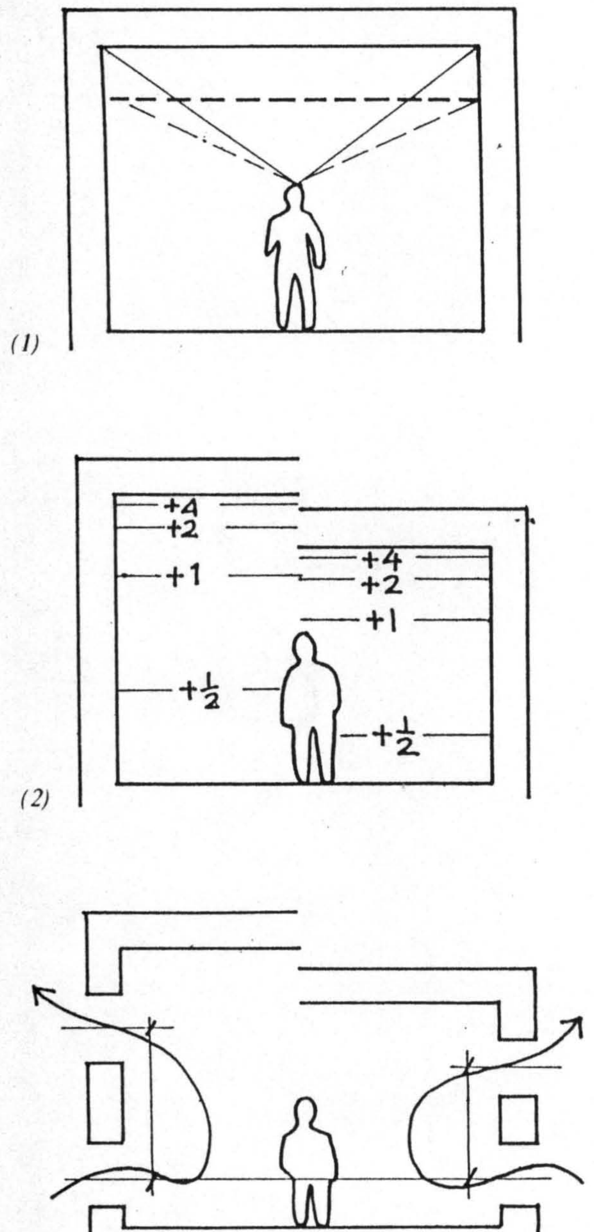
(3) The second method may give lower standards if 'set-backs' are allowed

(4) Buildings may receive sun, light and ventilation around the sides of opposite buildings rather than over the roof

the assumption that there will be high rates of heat gain through the roof. Most of the arguments for high ceilings will only apply to the top floor in multistorey buildings. On other floors, lower ceilings will reduce the external wall area and therefore the heat gain from the exterior. Only when internal heat gains are high can high ceilings be justified, and this is not usually a problem in domestic spaces. The control of internal heat gains is discussed in chapter 16.

The use of ceiling fans in warm humid and composite climates requires ceiling heights of up to 3m to avoid revolving fan blades at heights which are within reach of the occupants. Lower ceiling heights may be possible if portable fans are used, and there are other advantages of using this type of fan in domestic situations. The use of fans to achieve air movement is discussed more fully in chapter 14.

The psychological factor may also affect perception. For those who are accustomed to dwellings with high ceilings, a lower ceiling may appear oppressive and uncomfortable. Over time lower ceilings are likely to become more acceptable, so long as roof construction is adequate to prevent high ceiling temperatures. Lower ceilings are also associated with lower standards, although this association is unfounded as far as thermal comfort is concerned. Conversely high ceilings are associated with higher standards, since often only the rich can afford them. Traditionally high ceilings were often provided in dwellings that also had high standards of roof construction, generous verandahs, and other features, so that a large part of the improvement in comfort conditions under high ceilings in these cases may be due to other factors.



7.4 *The effect of increased ceiling height*

(1) *Lowered ceilings will increase radiation from the ceiling to the body, but the difference is not noticeable*

(2) *The change in temperature gradient will usually be less than ½°C at body level, which is not noticeable*

(3) *Increased ceiling heights will not give 'sensible' air movement due to stack effect under normal conditions*

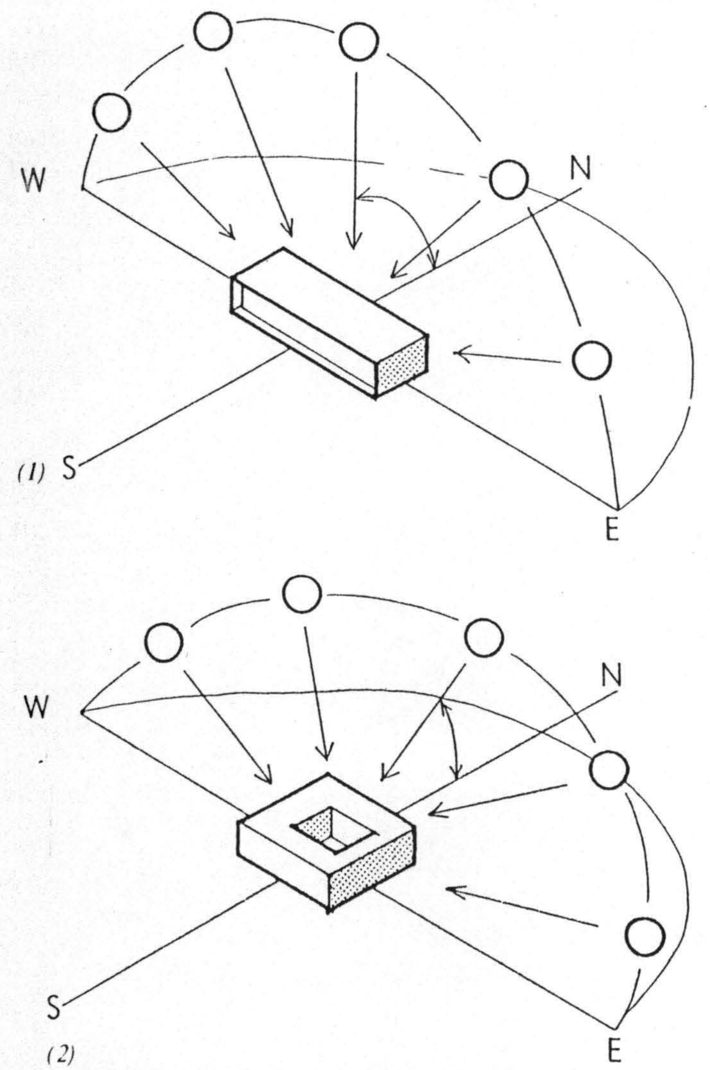
Requirements for dwelling forms

In *warm humid climates close to the equator*, the sun rises in the east, travels up to the zenith or the area of sky close to the zenith, and then sets in the west. The highest intensity of radiation will therefore fall on the roof and west walls, with slightly less on the east wall since morning temperatures are lower, humidities higher, and skies may be more cloudy. To minimise the impact of solar radiation the relative areas of the different building surfaces can be adjusted to minimise heat gain. Little can be done to reduce the roof area unless two-storey dwellings are used. The east and west walls can be reduced and the north and south walls increased to form long thin buildings. With multi-storey construction thin slab blocks facing north and south have advantages in reducing solar radiation impact although the shallow depth of building may not be very economical. (See figure 7.5.)

This form of building is also desirable for good air movement. Ideally dwellings should be one room thick with windows on both sides of the building to achieve good cross ventilation. With low wind speeds, windows on only one side of a room will be insufficient to achieve adequate air movement for comfort when conditions are hot and humid. Where rooms are double banked on either side of a corridor, air movement will also be reduced even when internal doors are left open to allow air to blow through the dwelling.

When sun and prevailing wind both come from the west it is difficult to prevent the sun from entering without excluding the wind. Since compromise is not easy, the choice is between both sun and wind, or neither. When solar radiation enters through a west-facing window it may easily increase the internal air temperature by 5 deg C, and it will cause even greater discomfort if direct radiation falls on the occupants. The effect of good air movement will be equivalent to a reduction in temperature of only about 2.5 deg C. It is possible to exclude direct solar radiation from west-facing windows by shading devices but these will be heated by solar radiation, and may heat up the air before it enters the room. Shading devices on west walls which exclude the sun will inevitably severely limit any view out of the window and deflect air movement in directions where it may not be effective. It is therefore clear that west-facing windows should be avoided.

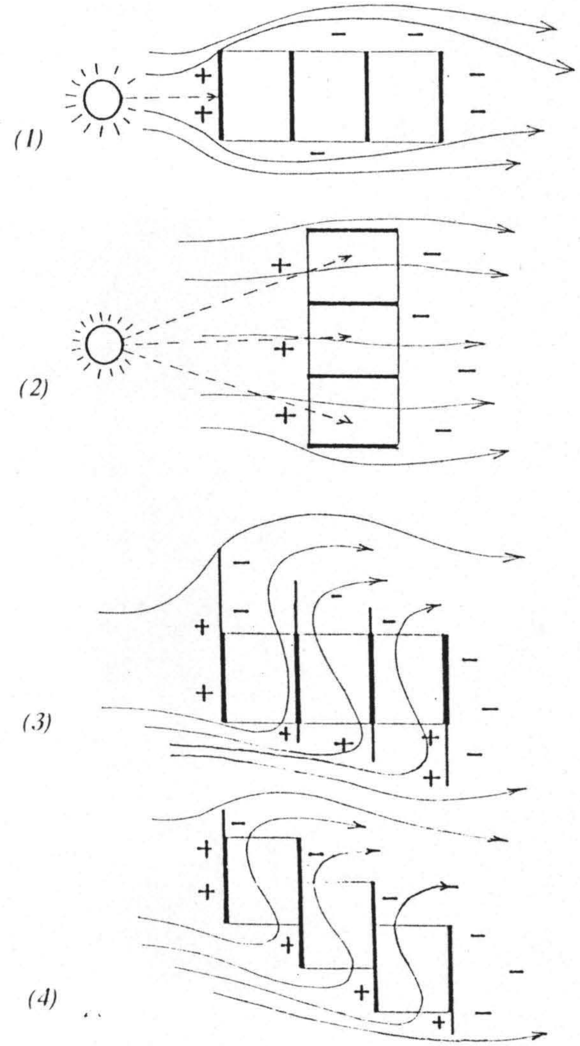
Wind from the west may still be deflected through windows facing north and south, by staggering the building form and using suitably placed external walls to create high and low pressure zones to induce cross ventilation—see figure 7.6. Vegetation may also be used, but will not be so effective or



7.5 *Solar radiation on building surfaces at different latitudes*

(1) On the equator the sun rises in the east, passes overhead (through or close to the zenith) and sets in the west. The east and west walls and the roof will receive most solar radiation; north and south walls can be increased in area without significant increases in heat gain.

(2) At latitudes further north and south from the equator, the sun is correspondingly lower in the sky at midday. The south (or north) walls will therefore receive more solar radiation, and therefore a more compact form is required to minimise heat gains.



7.6 *Alternative solutions to the problem created when sun and wind both come from the west in hot climates where cross ventilation is required for comfort*

(1) With wind and sun from the west, rooms with two external walls facing north and south will have little air movement, but protection from solar radiation

(2) Rooms facing east and west will have breeze and solar radiation, a less desirable combination

(3) The careful placing of external walls can be used to create high and low pressure zones to achieve cross ventilation 'turning' the air movement through 90°

(4) The staggering of rooms can be used to achieve the same result, obtaining the benefit of cross ventilation and protection from solar radiation at the same time

permanent. Vegetation close to buildings may harbour insects or animals, and allow termites to by-pass barriers.

Where winds blow obliquely to the north or south wall, the average wind speed within the room may actually be greater than when the winds blow directly onto the face of the building. When the angle between the face of the wall and the wind is less than 45°, average wind speeds within the room will begin to fall quite sharply. So long as this angle is above 30°, the use of projecting fins will assist in deflecting air flow and achieving a better distribution of air movement in the room.

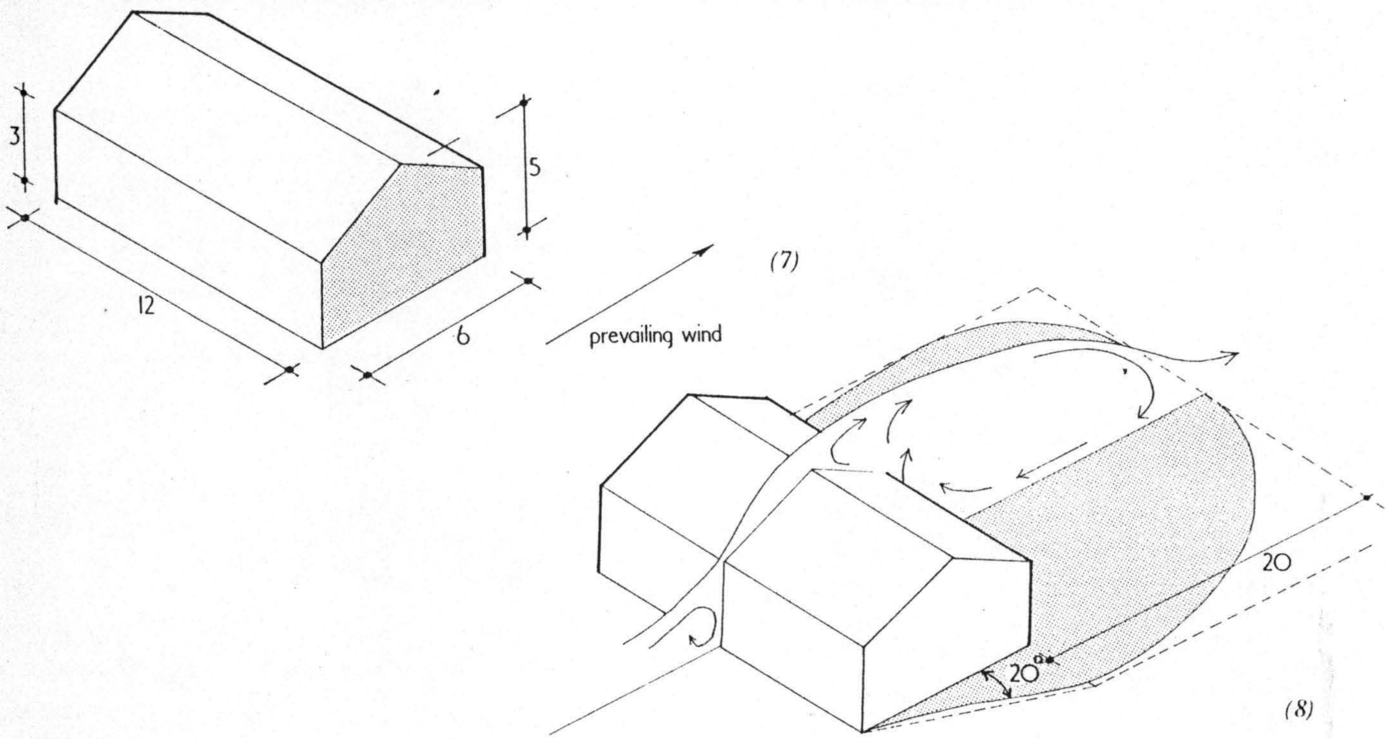
Since air movement is vital for comfort, buildings must be well spaced to allow wind to return to ground level when it has been deflected upwards by buildings to windward. Table 7.1 shows the results of wind tunnel studies[6] to find the size of the 'wind shadow' in the lee of buildings of different proportions. The results, though theoretical, appear to correspond with good spacing which permits adequate air movement in practice—see figure 7.7. It will be seen from the table that for most proportions of building, a space between building of five times the height of the windward building will allow the wind to return to ground level and to blow against the face of the leeward building. Wider spacing is only justified with long slab buildings, whose wind shadows are generally longer than five times their height.

The orientation of buildings in this climate is critical as the shape of the building required for good air movement will cause a very large variation in the solar radiation received as the orientation is changed. The large windows required for good internal air movement will allow direct solar radiation to penetrate into the interior if the orientation is unfavourable, and are difficult to protect with shading devices.

TABLE 7.1 LENGTH OF THE WIND SHADOW OF A BUILDING, IN TERMS OF THE HEIGHT, LENGTH AND WIDTH OF THE BUILDING FORM

Building form Width (W)	Height (H)	Roof pitch	Wind shadow length (×H) Length of the building (L) 2A	4A	8A	16A	24A	Wind direction →
A	A	0°	$2\frac{1}{2}$	$3\frac{3}{4}$	$5\frac{1}{4}$	8	$8\frac{3}{4}$	
2A	A	0°	2	$2\frac{3}{4}$	$3\frac{3}{4}$	6	7	
3A	A	0°	$2\frac{1}{4}$	$3\frac{1}{4}$	$4\frac{1}{2}$	$5\frac{3}{4}$	$5\frac{1}{2}$	
A	2A	0°	$5\frac{1}{4}$	$8\frac{1}{4}$	$11\frac{3}{4}$	$16\frac{1}{4}$	18	
A	3A	0°	$6\frac{3}{4}$	$11\frac{1}{2}$	$16\frac{1}{2}$	$18\frac{3}{4}$	$20\frac{3}{4}$	
2A	2A	45°	$2\frac{3}{4}$	$5\frac{1}{4}$	$9\frac{1}{4}$	$13\frac{1}{4}$	15	
2A	1.6A	30°	3	4	$6\frac{3}{4}$	10	13	
2A	1.5A	15°	3	$5\frac{1}{4}$	$8\frac{1}{4}$	$11\frac{1}{2}$	$14\frac{1}{2}$	
2A	1.5A	15°	$2\frac{1}{2}$	$4\frac{1}{2}$	$6\frac{1}{2}$	11	$13\frac{3}{4}$	

Source: R. H. Evans, 'Natural Air Flow around Buildings', Research Report 59, Texas Engineering Experiment Station, Texas, 1957.



7.7 *Example of the application of table 7.1*

(1) As wind blows against the face of a building a high pressure zone develops

(2) As the wind escapes upwards a low pressure zone is created over the roof

(3) This low pressure zone extends behind the building and draws the wind stream back towards the ground

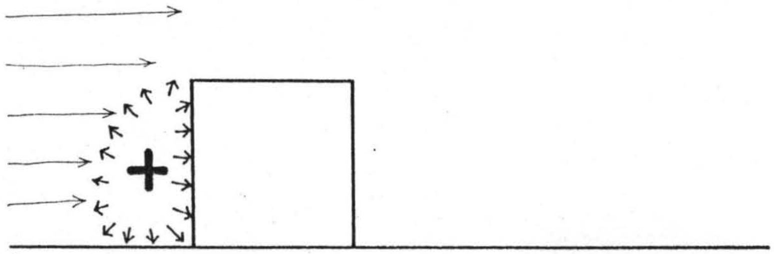
(4) A similar flow and pressure distribution is found in plan

(5) Air movement within a building occurs when air moves from an opening in a high pressure zone to an opening in a low pressure zone

(6) Similar movement occurs in plan

(7) The dimensions of a proposed building can be used to find a shape of similar proportions in table 7.1. In this case A=3, width=2A, H=1.6A, roof pitch=30° and length of building=4A.

(8) From table 7.1 the length of the wind shadow is found to be four times the height of the building, 4×5=20m. The shaded area indicates the approximate shape of the area in which air movement will be poor, and the dotted line shows the limit within which other buildings requiring cross-ventilation are not recommended.



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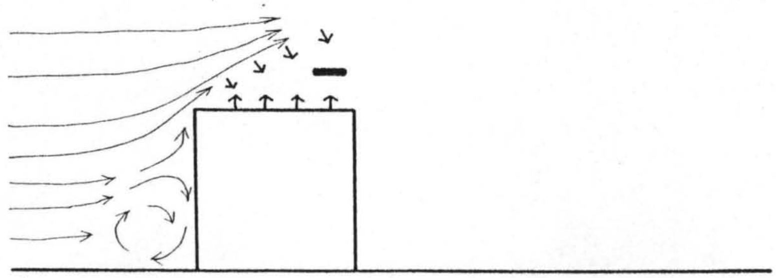

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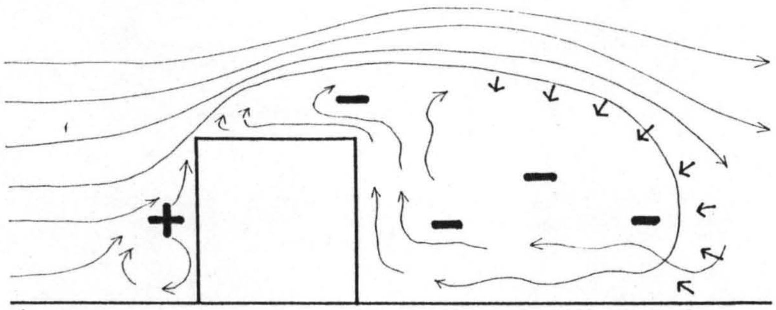

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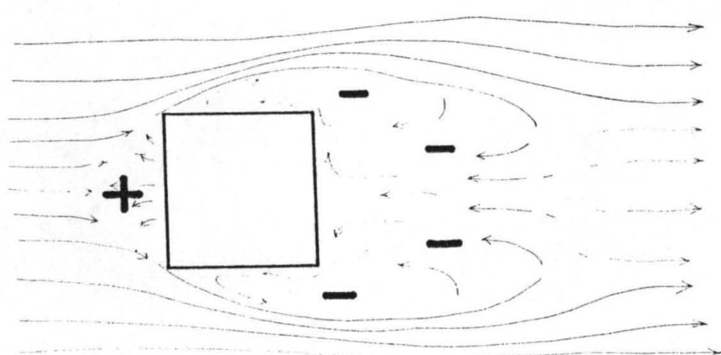

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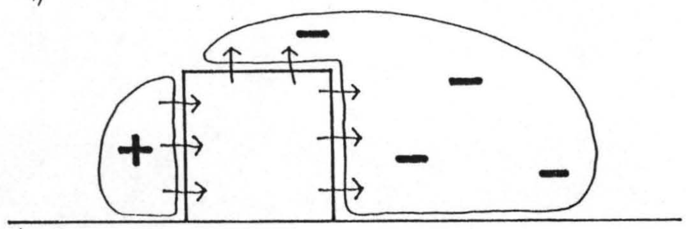

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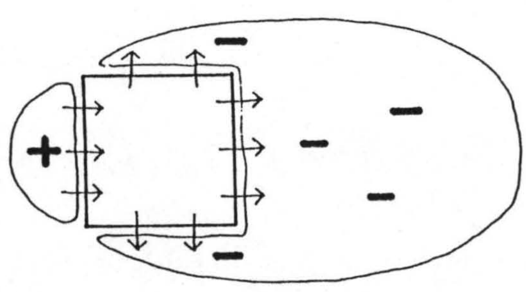


6)

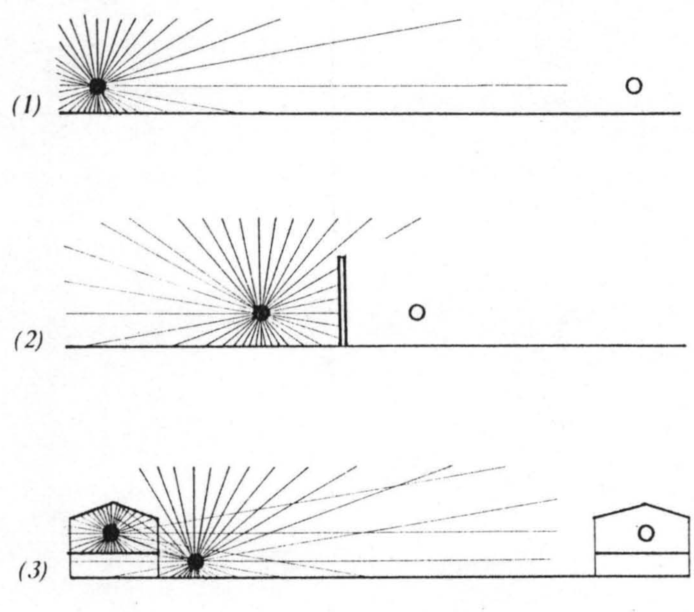
Traditional houses were raised off the ground on stilts to avoid the damp ground, and to catch the breeze. The security and separation from animals offered by this building form was also an advantage. Buildings which are raised off the ground still offer a number of advantages. The surfaces under the building can provide a shaded parking and storage area, and termite protection is easier. The spaces enclosing the indoor living spaces will have a lower heat capacity when the building is raised off the ground, allowing the building to cool more quickly at night (see chapter 10).

The ideal plan form therefore consists of a row of rooms, raised off the ground, with a low pitched roof with an overhang to protect the longer facades which face north and south. Alternatively a two-storey house would consist of a row of bedrooms upstairs, with the living rooms below. Since large windows are required, the indoor living spaces can be closely connected with outdoor living spaces on wide verandahs, with only the inconvenience of a mosquito screen to separate them. When winds are light, it may be more comfortable to carry out such domestic activities as food preparation out of doors. Shade will reduce direct and diffuse solar radiation, and will improve the comfort of outdoor spaces. Mature trees provide ideal shade, but pergolas, spaces under raised buildings, and extended roofs forming verandahs can also be used as they will not interrupt air movement.

External walls can be used to channel air movement, but they may also reduce air movement, so that privacy and good air movement may be difficult to achieve simultaneously. Solid boundary walls should be avoided near ground floor windows or outdoor living spaces. Pierced screen walls or 'permeable' fences can be used around outdoor living spaces although they will still reduce air movement.

Noise is another problem in warm humid climates where the open south-facing window of one dwelling is opposite the open north-facing window of the next. Open windows also give no protection against the increased noise from outdoor activities. External walls between dwellings will have little effect on aural privacy, unless they are so high that they block air movement (though they may provide some visual privacy). Distance provides the best remedy with noise as with air movement, and for individual dwellings or low rise developments this implies low densities—see figure 7.8.

For higher densities, balcony access slabs probably provide the most practical building form which minimises solar radiation and maximises air movement. Privacy is still difficult to achieve economically since open windows will face directly onto the access balcony; pairs of walk-up apartments will have improved privacy though walking up more than two flights of stairs will be extremely uncomfortable in such a climate. The internal planning of apartments is likely to be a compromise between the requirements for air movement, and economy, since a shallow building is required for good air movement while deep buildings will be more economical. Habitable rooms should be located on the side of the building facing the prevailing breeze; access balconies or private balconies should be placed on the face of the building orientated towards the equator since this face will receive the greater intensity of radiation. However, for latitudes within a few degrees of the equator this will not be important, since the sun will shine almost equally on both north and south facades.



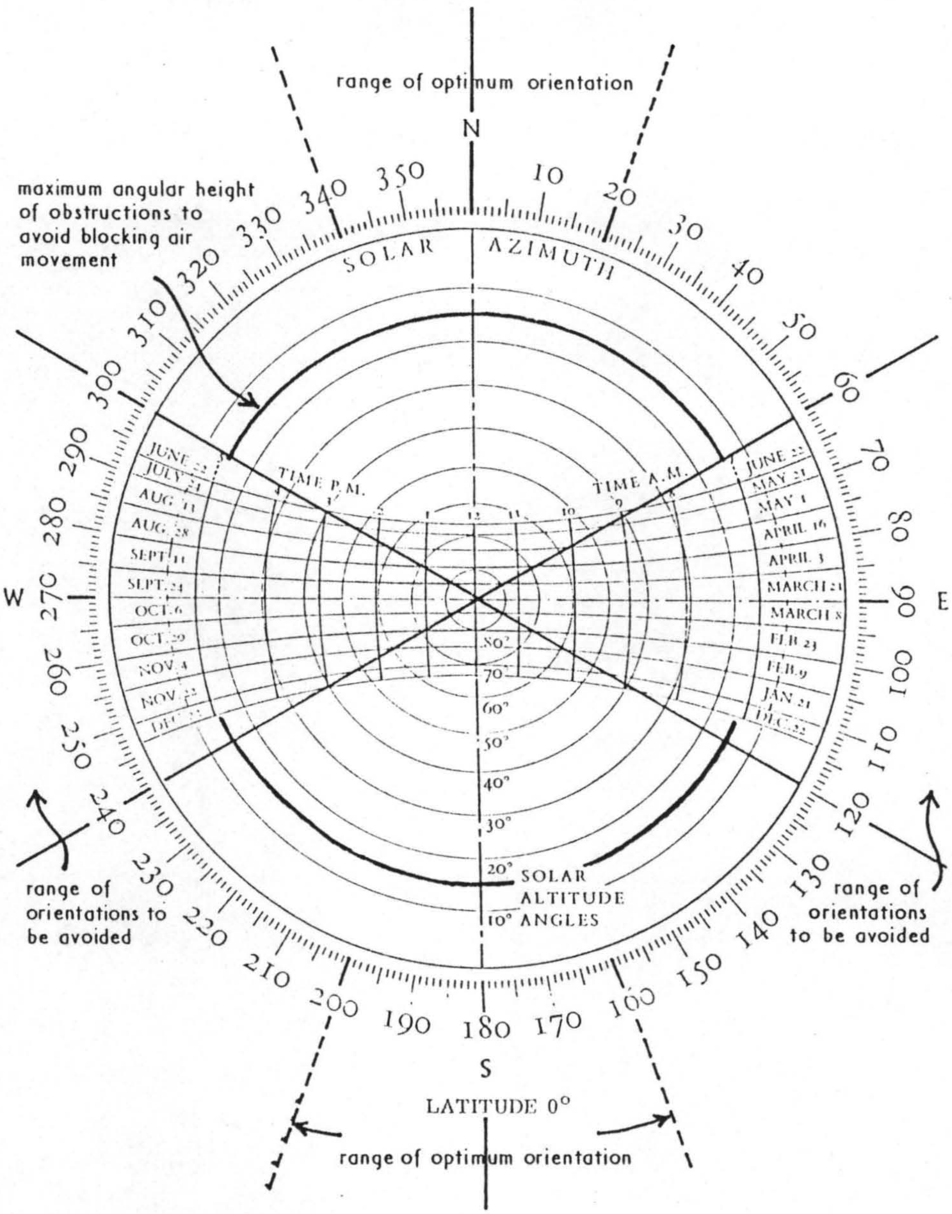
7.8 *Achieving aural privacy in hot climates with open windows*

(1) Increased distance between source and observer will reduce noise levels

(2) Barriers can be used where wide spacing is not possible or desirable

(3) Wide spacing gives aural privacy and good ventilation in warm humid climates

(4) Courtyard houses give aural privacy and protection from dusty winds in hot dry climates



7.9 *Spacing and orientation requirements for a warm humid climate (on the equator)*

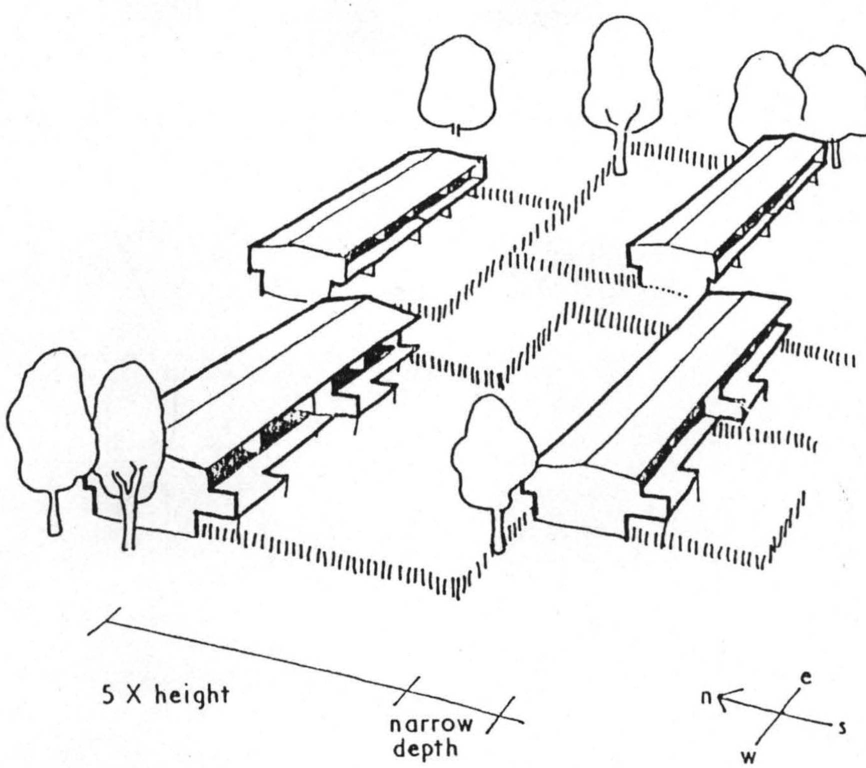
Where dwellings are not designed to benefit from natural air movement and are reliant on fans or air conditioning for comfort, wide spacing for air movement and privacy are no longer so critical. The same form is required to minimise heat gain, though buildings with greater depth may be possible. For single and two-storey dwellings, privacy will probably remain the most important criterion for space between buildings, once the functional space requirements for access and outdoor space are satisfied. Minimum spacing of 35m between windows of living rooms of different houses has been suggested[7] though acceptable standards may vary considerably for different countries.

For multi-storey dwellings the space for daylight may become critical if air movement is ignored. With relatively bright skies, light angles of 40° to 50° will give more than sufficient height for domestic purposes. There are advantages in receiving light from around the sides of buildings opposite the windows, rather than over the roof, since light can more easily penetrate to the back of the room. However, this may increase sky glare. A staggered arrangement of slab blocks will also give better air movement in the external spaces even if it is not required indoors.

Figure 7.9 shows a spacing diagram which indicates the light angle and orientation requirements.

Figure 7.10 shows a typical layout for a warm humid climate, which incorporates the requirements for orientation, spacing and building form.

In *equatorial upland climates* air movement is no longer so essential although it may be desirable at times. Orientation becomes even more critical, since direct radiation is stronger and skies are clearer. Double banked dwellings can be planned when the altitude is such that air movement is only infrequently required. Again shaded external spaces are needed for outdoor living. Solid screen walls may now be advantageous, providing sheltered outdoor space, and at times solar radiation may be desirable. There is considerable scope to design outdoor spaces that are sheltered from sun or wind in some seasons of the year while benefiting from sun or wind at others. This will require careful study of the climate data and sun path diagram.



7.10 *Typical layout in a warm humid climate*
Main design features:
1. *Main habitable rooms facing north-south*
2. *Wide spacing between dwellings to ensure good air movement*
3. *Narrow depth of dwelling to allow good air movement in all rooms*
4. *Overhanging roof to the north and south to provide protection from sun and rain and glare from the bright overcast sky*
5. *Trees to provide shade to the east and west walls without blocking air movement*

In *monsoon climates with long warm humid seasons*, the layout requirements for this season will predominate, so that spacing for breeze and orientation for sun remain important. It may however, be possible to arrange layouts so that buildings catch the prevailing breeze during the warm humid season, while some protection is given against hot dusty winds, which blow from a different direction in the dry season. The change of season will affect a number of layout requirements. Very wide spaces between buildings may become a liability for at least a few months of the year, since vegetation may wither and grass become brown and dusty unless frequently watered. External spaces still require shade, but shelter from air movement can help to maintain comfort in the shorter hot season. Thermal capacity is also an advantage in the dry season so that deep plan dwellings are not so disadvantageous, although on balance, single banked dwellings are still preferable.

In *tropical island climates* which are found further from the equator, the sun will be lower in the sky. The south facing wall in the northern hemisphere (and the northern wall in the southern hemisphere) will receive a greater intensity of radiation than that experienced in warm humid climates closer to the equator. The wall facing away from the equator will receive considerably less. The protection of the exposed wall will be more important and can be achieved by the use of north-facing living-rooms, and circulation and other secondary spaces on the south in the northern hemisphere.

In these climates the wind will be much more reliable than in latitudes closer to the equator. Correct orientation to catch the wind is important as there will be little variation from prevailing wind directions. Many tropical island climates are in the tropical cyclone belt and may experience hurricanes or typhoons. This belt is found north of latitude 8°N (and south of 8°S) in large areas of ocean where water surface temperatures are over 26°C.

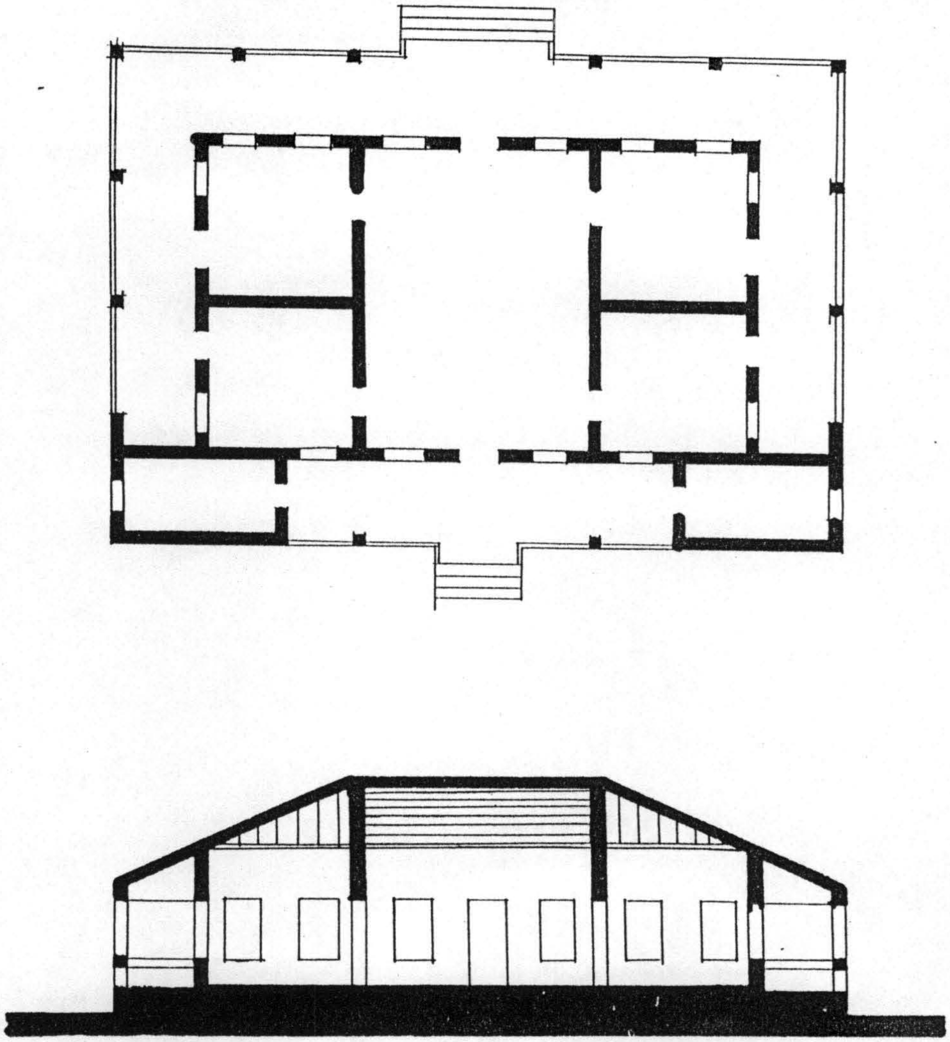
Exposed structural elements such as overhanging roofs and shading devices may be exposed to wind speeds of over 160km/hr (45m/sec). This may limit the size of overhangs and windows and result in buildings with a less open and 'airy' quality than would otherwise be possible.

For tropical island climates with higher annual and diurnal ranges in temperature the increase in thermal capacity resulting from smaller windows, is not too disadvantageous, although windows must always be large enough to provide adequate internal air movement.

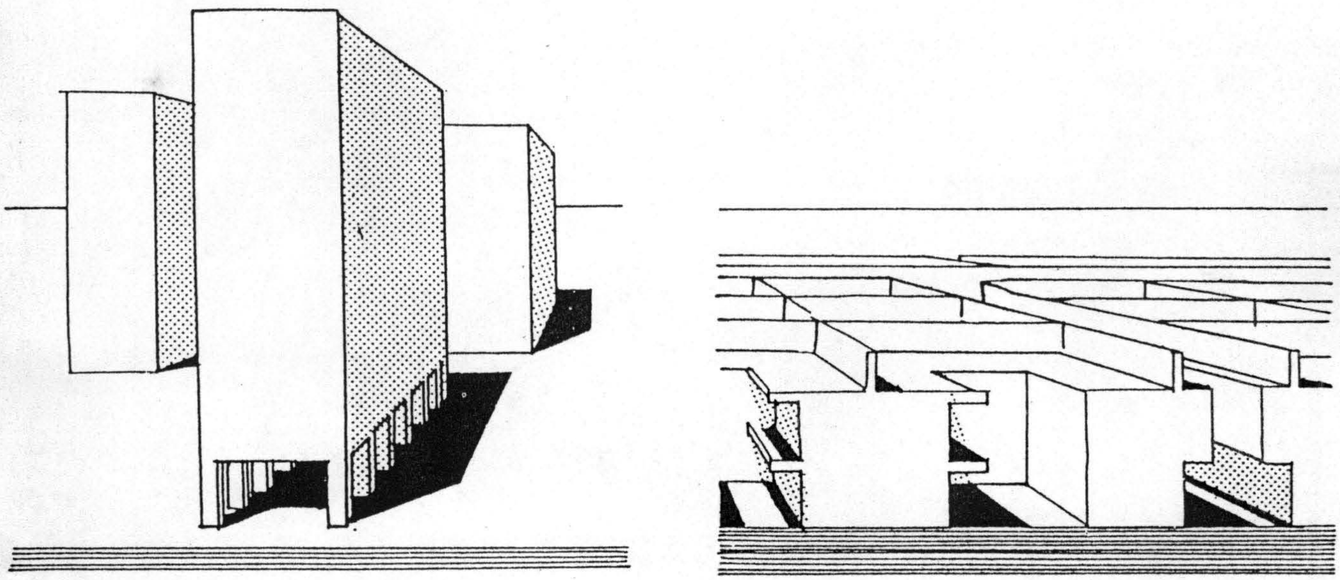
In *monsoon climates (or composite climates)* with longer hot dry seasons, breeze is no longer such a critical factor, and closer spacing can be adopted. This will reduce breeze during the humid season but will also reduce the areas of hot dusty outdoor space which are undesirable in the dry season. Closer spacing of buildings will also create a larger proportion of shaded outdoor space and increase the mutual shading.

Composite climates further from the equator may also have a cold season when some sun is desirable for winter heating, since the sun is still high in the sky for most of the day; no increase in building spacing is required to achieve this. The path of the sun across the sky will be similar to that found in warm humid climates, though slightly further south in the sky in the northern hemisphere, and further north in the southern hemisphere—see figures 7.11 and 7.12.

In *monsoon* climates there will always be conflicting layout requirements and different building solutions may be equally appropriate. Some traditional building forms create



7.13 *Plan and elevation of a traditional Indian bungalow*



(1)

(2)

7.14 *A comparison between the advantages of low-rise and high-se building forms in hot dry climates*

In hot dry climates, isolated slab blocks result in large sunlit spaces which are difficult to maintain or landscape, and a small proportion of external shaded space.

(2) *Closely clustered low courtyard buildings leave less external space at ground level, but it is sheltered from the wind, and a high proportion is shaded. With low buildings the roof space is also more easily used by the occupants.*