Frontispiece

1 *Architecture in the humid tropics is a collaboration with nature to establish a new order in which human beings may live in harmony with their surroundings*

TROPICAL ARCHITECTURE IN THE HUMID ZONE

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Introduction

General outline of factors affecting design in the humid tropics; people and their needs; climate and its attendant ills; materials and the means of building

ARCHITECTURE is a personal art responding directly to what its creator brings to it: feeling, knowledge and experience. Each time a new building is created the process takes place within an individual.

What that individual does is modified by what others have done before him, and by all kinds of influences in the life about him – of many of which he is unconscious – that make up the civilisation of which he is a part.

How well an architect responds to the stimuli of knowledge and experience is entirely a matter of the inner man, the mysteries of which it is not our intention to plumb. What we can do here in treating of architecture in the tropics is to attempt to arrange what knowledge and experience we have, and can collect, upon the subject, that will augment, define and perhaps refine the vocabulary that each reader may bring to the creation of new works of architecture.

It is necessary at the outset to recognise that we, the authors, are not inhabitants of the tropic zone but have come to it from the temperate zone. We have experienced its climate, lived with its people and dealt with its problems as they have affected our work, but we write not only for those who, like ourselves, live outside the tropics and for whom, therefore, designing is something of an intellectual process; but also for the growing number of those who inhabit these regions and who, by their over-familiarity with the conditions, may be stimulated to re-examine them. On these architects and planners falls the major burden of creating an environment in which the tropical peoples may flourish.

One element of the problem they will virtually understand better than ourselves, and that concerns the needs of tropical people. At the moment this may not be true; but just as we may be expected to understand the needs of English people for whom we build, and not only their immediately expressed needs but their subconscious desires, the subtlest social distinctions that satisfy them, the changes which they are prepared for; just as we are able to gauge such things because they form part of our own mental and emotional background; so will the future architects who build for their own tropical people bring to their task emotions, sympathies and knowledge denied to us who come from outside.

It seems proper to mention this, though at the same time we would say how invigorating it has been for us as architects working in England to shake free from the

crippling mental state brought about by too great a reverence for habits and customs which have outlasted their time.

There have been times in history when architecture worked under instructions. The Romans, for instance, appeared to understand so well how to deal with the circumstances by which they were surrounded, and had invented what was necessary to deal with them, and no more, that there was little further left for architecture to do than to multiply the villas, the viaducts and temples, with no further invention, until decay supervened.

The same is true of Moghul architecture in India, a closed circle of repeating motifs exactly satisfying the defensive, domestic and religious needs of a conquering race isolated within the great sub-continent.

The situation today is different, and more resembles that of architecture in the dark ages in Europe, when the overrunning of the Roman Empire by barbarians had removed one sort of order without substituting another.

One need have neither fears nor regrets for the rapid development of modern architecture today, because it corresponds with the rapidly changing state of the world due to the onrush of science and its manifold applications to human use – and human destruction. It proposes a new and more logical and applicable form of order.

Science has added to our knowledge, but it has created more problems than we know how to solve. With the aid of its chief instrument, the machine, we have enormously accelerated the speed of production and construction, of travel and communication, so that the world is enabled to support an expanding population.

Medical science has stamped out diseases and plagues, but by increasing longevity has re-created the problems of want, and over all lie the threats to civilisation inherent in the awful potency of science's destructive weapons.

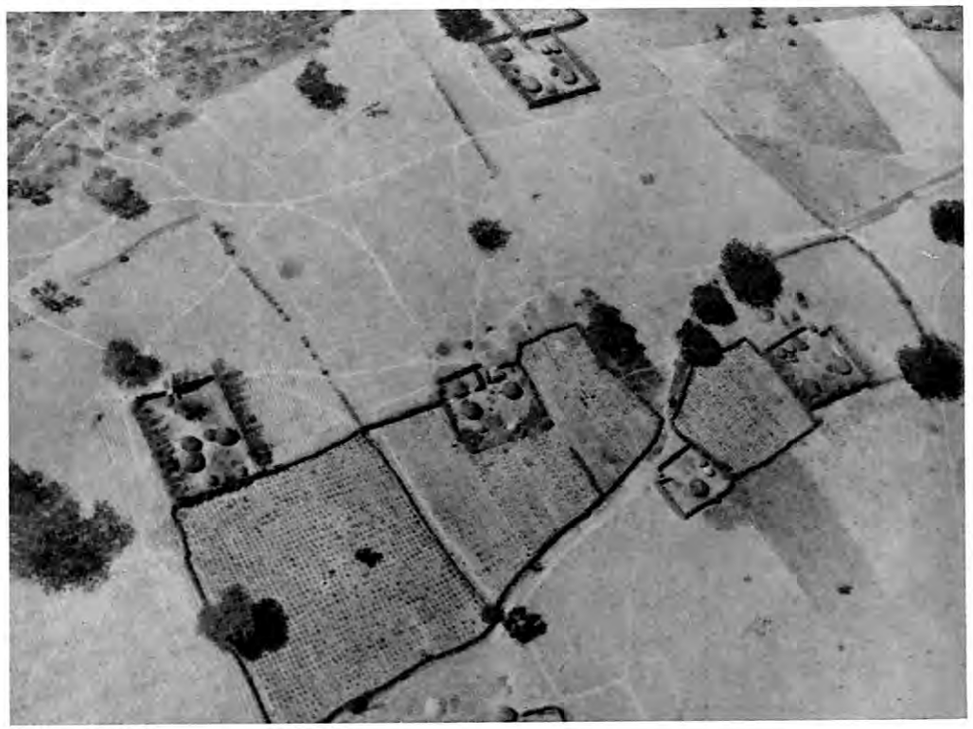
It is in the crowded vulgar cities and the inhuman industrial centres that the failure of applied science is most apparent, and one feels that it is not so much the failure of science itself as of our capacity to assimilate the consequences of using science that is to blame for the disorder and miseries that ensue.

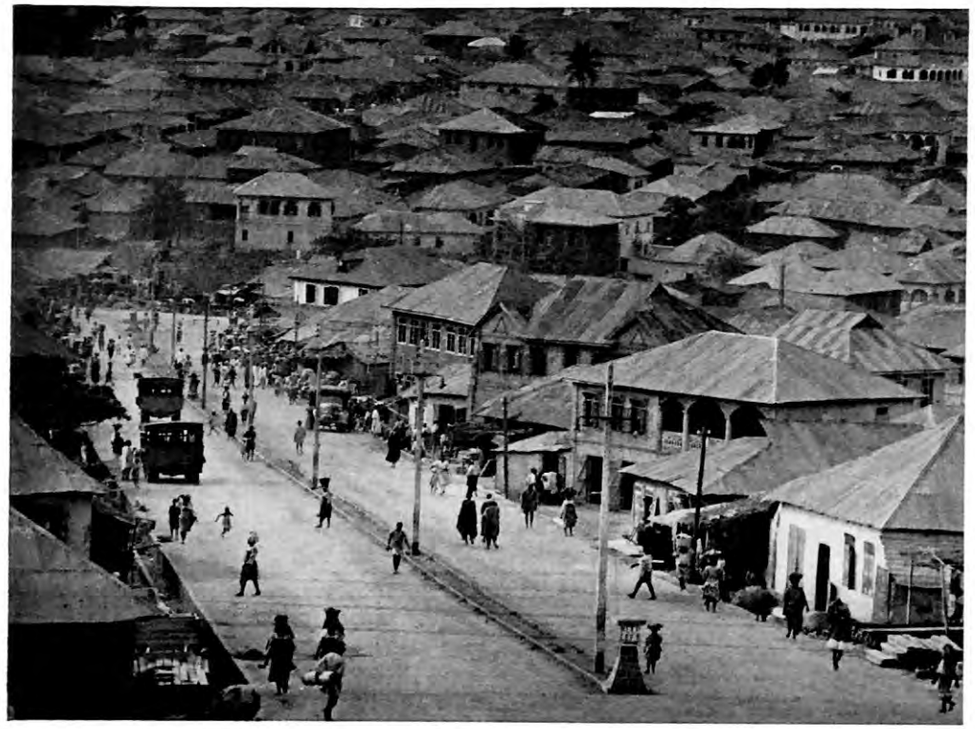
Modern architecture is distinguished by nothing so much as its determination not to turn aside from science and the effects of science, but to enter into them and wring from them a solution of value to humanity. Modern architecture, and its extension into town planning, has above all this task of interpreting applied science in humanistic terms. Of making industrialism fit for human use; building cities that ennoble life instead of degrading and destroying it; and of creating everywhere, out of the disparate and anti-social manifestations of machine production and centralised power, unities of resolved thought and feeling, in the form of buildings, groups of buildings and larger aggregations, in which life may know its bounds and flourish.

Do not make the mistake of imagining that because so large a part of the tropical world is undeveloped and is in so many ways different from the industrialised West that it lies apart from the problem. If the industrial development of Europe and America has been rapid, at what rate will not the tropics advance! Remembering

2 *Kano, Nigeria*

3 *Small-holdings, Northern Nigeria*





4 *Ibadan, Nigeria*

5 *Mangrove swamps, Niger Delta*

what this means for the people concerned, the magnitude of the errors that may be committed, and the patent indestructibility of all things made, it is our duty to be at some pains to understand the nature of the task, the needs of the people, the means of fulfilling them, and above all, how seriously and with what addiction to truth must we perform each of us our commissions as creators of this future matrix of tropical existence.

The three main considerations:

There are three main considerations influencing architectural design in the tropics which it is necessary to distinguish as belonging particularly to the zone. These concern, first, *people and their needs*; second, *climate and its attendant ills*; and third, *materials and the means of building*.

(i) People and their needs

We have never known in a life devoted to architecture that people of any class or race knew exactly what it was they wanted of a building until it was done for them, when for a certainty they knew what they did not want, or how far the building fell below what they thought they had wanted. It is difficult for lay people to imagine even the simplest grouping of architectural spaces and their cost. It is also difficult for architects to imagine what underlies the barely expressed needs of those who come to them for advice.

But it is less difficult for an architect than for the layman since he is, by aptitude and training, more able to analyse these needs and set financial limits to them; yet he will only understand them because they are already familiar to him, since he shares them with his clients, or by the exercise of imagination.

You may say that people are the same the whole world over, with which we would agree as a basis for understanding. This at least prevents the error of imagining that some people are stupid and others not, or some satisfied with whatever is given them because they have not the means of objection.

But people as individuals are different from people in social groups, and the intelligence of an individual *vis-à-vis* a known set of circumstances may be seriously lowered if the circumstances change; and more so if they keep on changing. His reactions to them may give an entirely false impression, which in its turn may change as his appreciation and understanding of his circumstances improve.

We found, for instance, in interviewing groups of future occupiers of different grades of government houses at Chandigarh a wide divergence of views on the importance of local habits and customs affecting house design as between different age groups and income groups, the younger and the poorer welcoming, and the older and richer resisting, change.

In the resettling of a displaced fishing village on the Gold Coast, all concerned made the signal mistake of assuming that the community which had previously existed in single-roomed huts would be happy to continue in single-roomed dwellings.

It was the African members of the committee who most quickly sensed the need for meeting the changing circumstances not only by an increase in the size of the dwellings but by such variety in their composition as would deal with the inequalities of growth and the weakening of close family ties.

These two examples may be multiplied until the problem of people in a state of change and movement is seen as one demanding the exercise of the most ranging imagination if it is to be solved by architects and planners in such a way as to create social organisms that will satisfy and outlast the developing circumstances.

What changes will the controlled powers and released waters of the Damodar Valley Project bring to those teeming people of North India? What will be the effect of the Volta River Scheme on the forest people of the Gold Coast?

These are the dramatic high-lights of applied science and capital. But change is everywhere in the tropics. Was it not yesterday that the first truck rumbled into the bush village? Was it not, more exactly, during the last war that the landing strips were cut through the rain forest, where now the regular service plies? Along the roads the buses run taking country people into town, suggesting something new, destroying something old. In the stores machine-made cloths oust homespun, machine-made pans oust local pots. New goods breed new desires, even in the road-side stall; while in the cinema, seductively, insidiously and indelibly the brand of Cain is imprinted on the upturned simple minds, the curse of artificial want pronounced, and the hunger for the city implanted.

These are the surface markings of a progress of the human mind towards a state beyond our calculations but susceptible to the influences of our present actions. It is a movement comparable to that which has overtaken Russia, but operating, unlike it, in an atmosphere relatively free from coercion, and for that reason, of greater value.

Let it not be assumed, therefore, that a region that now appears sunk in agricultural apathy will remain so, or make the mistake of imagining that what has been destroyed by industrialism may be restored by the revival of old ways, of crafts and skills rejected by the people themselves. What has been destroyed by the machine will more likely be replaced by it, or will never be replaced, the god of destruction being, like Vishnu, the god of creation also. It was the African members of a committee set up to implement the ideas of Meyrowitz of Achimota who objected to the attempts to revive weaving, pottery, etc. as crafts by Europeans who had long ago accepted the machine for all the normal purposes of manufacture.

If, as we believe, this state of mind exists as one of the dominant phenomena of tropical life, there falls upon the architect the special task of providing buildings and towns conceived with sufficient generosity and imagination to allow of the fullest exercise of expanding consciousness, and to meet the complicating mechanisms of modern life without sacrificing human freedom and dignity in the process.

In most of the regions with which we will deal, the pace of development is modifying and sometimes destroying habits and customs stretching back into the dim past and

interwoven with religious belief. By the time the architect comes on the scene, traders, missionaries and governments have exerted their influences for good or ill, and it remains to be considered in what ways architecture and planning can remedy past mistakes and safeguard the future.

The turnover from a communal to a cash economy involves changes that affect the whole fabric of individual and communal life, deprive it of old beauties and dignities, and too often leave in their place only the crude values of money and power.

A great deal of this is inevitable, and is accepted by the people concerned in their anxiety to share in what they see as the benefits of Western civilisation and culture. But *we* now know where the shoe pinches. Unable to undo many of the evils that have arisen through misunderstanding of the uses of industrialism, we are the more able to recognise them; and have worked out tolerably satisfactory answers in the form of organisms in which the social and the industrial elements are blended so as to provide a possible, even a desirable, life for all classes of people involved.

The new towns of Britain are a large-scale application of principles deduced from experiments made earlier in the century. They are also a continuing experiment, since they deal with new problems thrown up by the accelerating urban pressures of the last few years.

The new housing policy of the London County Council is successfully, though as yet on a small scale, finding an economically and socially valid solution to the over-crowding of cities, pointing to hopeful and quite possible ways of urban living.

Once it is recognised that the industrial process includes, with the process itself, the welfare of its workpeople, it should be a matter of ignorance, shame and discredit for any mining or large industrial organisation anywhere in the tropics to house its labour with the brutal lack of imagination so common in the past.

But there are other aspects associated with the rapid state of change that are not so easy to deal with. It very often happens that the inherited skills of indigenous people are made useless by the new system of living, and how to achieve a new balance of useful and gainful skills, and how to bridge the gap between one system of building and another is something that touches both architect and planner.

South Nigerians built mud-and-thatch huts that suited their village needs; they wove grass mats of astonishingly dignified design; and used decorated calabash vessels in great variety. These skills were an integral part of their tribal or village life, and the loss of personal identity in turning from thatch to corrugated iron, from earthen pot to mass-produced pan, and handwoven or printed cloth to machine-made leaves them, as it were, with their hands empty, unable to express themselves and release their personalities in creative occupations.

This is serious enough in the villages where the process is not complete and the effects not so noticeable. Transferred to a town, the dislocation is more marked. Neither the population – de-communalised, unproductive and incomplete – nor the system of building, is fit material for urbanism.

To present such people with prefabricated dwellings, if it were economically possible, which fortunately it is not, would be a gift of doubtful value, serving still further to separate them from their upbringing. There has to be found the means of introducing to them town plans in which traffic may move and drainage be possible, and systems of building more rigid, accurate, adaptable to the installation of services and more easily maintained, but involving skills that compensate in some degree for what has been lost.

Everything that we do at these levels should aim at building up a new community life, based less on family and communal sanctions, since the new division of labour must be accepted as a necessary element of westernised production, but introducing skills and crafts by means of which self-respect and personal dignity may be restored.

(ii) The hot-wet tropics (climate and its attendant ills)

In the temperate zones sun and rain succeed each other in moderate alternation throughout the changing year, sustaining a varied animal world with balanced economy. In this *humid* tropic all is overdone. Burning sun alternating with torrential rains brings to life an unending cycle of massive vegetation, dwarfing man by the vigour of its growth, and accompanied by an insect and parasitic life more deadly than the larger animals of the so-called jungle.

The differences between temperate and tropic zones are graded by the varying combinations of sun and rain cloud and their effect upon animal life, in which we may be included, and vegetable life, and also the insects, our insidious enemy.

Rainfall, with the slanting and infrequent sun of the North, brings to the western isles of Britain wet grass and bog. An equal rainfall in an Indonesian island under a vertical sun but half obscured by cloud brings to life a strident vegetation and a myriad insect life more energetic than man. In the one case temperature is below blood heat but the body can be warmed by food, movement and shelter. In the other case temperature is near or above blood heat, and under the constant canopy of cloud the saturated air brings no relief to the surface of the skin.

In the first case, a house if it shuts out rain and cold has done its job and the body is at ease. In the second it must shut out rain and sun, but the body is still uncomfortable unless it can be cooled by breezes, natural or artificially induced. The sun raises the temperature, but the saturated air prevents the radiation that keeps the body in normal adjustment.

The much higher temperatures of the *hot-dry* tropics can only be sustained with less discomfort because the body is free to lose heat through the evaporation of sweat. But the effect upon building reverses the order in the hot-wet tropics. There the cooling effect of breezes is sought after; here the heat and dust-laden air are shunned: man is forced to retreat before them. This sun, coming from a pale blue cloudless sky, beats upon the earth, dries up its vegetation and radiates fiercely from above and upward from the earth. The Arab swathes himself in hanging robes that insulate him from the worst of it, places a visor of fabric before his eyes, and retreats when he

can behind thick walls of mud through which only the barest minimum of light can penetrate. If the ideal in the hot-wet tropics is an arbour of leaves, then here it is a cave.

The traditional house of North India often included a cellar room, lit sparingly just above ground level and with openings arranged to bring a minimum of ventilation without raising the temperature.

The life below the hot-wet tropic cloud is less rigorous and more supportable. The seasons may bring, in some parts, whiffs of the desert draught, and the protecting clouds roll back for periods long enough to disclose the true nature of the vertical sun; but for the greater part of the feebly seasonal year cloud and sun alternate, and life is passed in a humid air to which neither day nor night brings much alteration.

Under these circumstances the body requires less energising nourishment and less cover. The pressures of climate enforce a rhythm of movement and relapse of energy given out and restored by sleep. Even for the busy European, life is simplified and could be still further were he not tempted by cheap domestic service to reproduce the paraphernalia and complications of his own life at home instead of working upward from the delightful minimum that is all that tropical life requires.

The strongly marked succession of seasons that plays so important a part in our life in Europe and North America is nearly entirely absent in the humid tropics. Throughout the year, the sun rises and sets like a clock, dividing the day into equal parts of light and darkness with few fine shades between, and its oscillations about the line, a few degrees this way and that, control the distribution of the rains, which in their turn affect the temperature of the days and nights, but do little to deflect the unending renewal of vegetation or to break the monotony of existence.

Caught within the magic circle of growth, lulled by its constancy, controlled by disease and warfare, the people of the tropics have slumbered on for centuries, little touched by what took place in the world outside them, maintaining themselves in a varying balance against the forces of nature at once so propitious yet so insidious.

Now, their imaginations fired by what once but touched their cupidity, having seized their opportunity in time of war, they enter a world that aims at subjugating nature to the necessities of man on planetary scale, and it has to be seen whether the system that has fertilised the temperate zones for the support of great populations, leaving surpluses of wealth and time and thought, can tame the subtler menaces of tropical life and maintain a balance between man and nature, including insect life.

Of the insect life there is something to say, for it can be as destructive of the materials of building as of human life. Below the ground or in fantastic castles of mud live termites whose natural food is anything of the composition of wood and for which, through mud tubes and tunnels of their own making, they will travel distances and bridge gaps. Time being on their side, they can defeat the best-laid schemes of man, and wood, the so obvious and abundant material of building, is half useless in an economy of building that cannot afford and is unable to contemplate the constant renewal that was the commonplace of communal organisations.

Other insects and growths flourish in the humid climate: borer beetles, silver-fish beetles, cockroaches, more mobile and ten times more destructive than elsewhere; mysterious fungi covering and attacking walls and surfaces; and moisture itself, decomposing into rust and verdigris what in temperate latitudes remains hard and bright.

These are, you may say, but the incidents of decay for which substitutes will be found as we in our time have found means of circumventing mould and damp and the gnawing of mice and rats. And so it may be, but we are on the edge of knowledge and have not as yet properly measured the natural forces with which, in establishing tropical life over large areas, we will have to contend.

The reserves of raw forest timber, contrary to first impressions, are not inexhaustible and the forest land when denuded changes in character and climate. It may be we are right not to use up overmuch for building and to search for substitutes and economies, for in so doing we may be aiding a more equal co-partnership of effort which, if tropical people are to flourish, must replace the unequal exchange of raw materials for manufactured goods. Thus weighing up the immediate problems of tropical building and responding rationally, architects may encourage the economical disposal of timber as plywood treated to resist insects, or find uses for non-ferrous metals, the source of which is now, and whose manufacture will later be found, in the countries themselves.

But we repeat, we are on the edge of knowledge only and much more must be known, not only of the facts themselves: of climate, animal and insect life, materials and the behaviour of materials – but of their correlation in a widening and complicating civilisation. Building is an important human activity, the index of prosperity and the key to many other departments of life. The more we can know of it and of its place in the scheme of things the better an instrument it will become for the use of the people.

It is for this reason that we would urge upon all tropical governments the need for research on the widest scale into the needs and the means of building: detailed research in each country and correlated research between them. This research we see as including the work of specialist-scientists, since the extent of the ground work is considerable; but directed in its course by a much wider vision, looking always for the related values of building and society in an attempt to turn to the utmost human account the total circumstances by which any particular country may be surrounded.

This should be a progressive research which in India, for instance, would be an instrument of the Planning Commission, fact-finding, but policy-suggesting. And it should be, rightly considered, not a static laboratory affair but both static and perambulant, not all the secrets being available at the scientist's bench.

Every work of building, if it is progressive, is an experiment and a research involving a wide range of non-human phenomena and human interests. Every time a building is created hundreds, nay thousands, of decisions and selections are made impinging on the structure of society.

First there comes the organisation of the social need for which the building is

destined, in which, since a building will last indefinitely, the future trend of society must be weighed against its present demand and its course thereby deflected for good or ill, helped to an adjustment with circumstances to come, or hindered.

(iii) Materials and the Means of Building

Next comes the selection of materials for the work, what are most suitable and economical, whether adapted to local skills and traditions, or breaking from them and establishing new skills and future traditions; what resist best the ravages of climate or insect life or promote conditions of health and well-being; what are of local interest only but should resist the levelling effect of unspecific thought and action; what though more costly now possess properties that make them inevitably indispensable.

From materials to the complications of structure, the putting together of materials by human labour or its substitute the machine. If materials are the matter, then structure is the manner of building, and just as it is from the manner of ancient building that archæologists are able to deduce the nature of the civilisations for which it was constructed, so inversely, in arriving at a structure that conforms with present needs and economies, we are taxing, as closely as we know how, the capacity of our civilisation to perform one of its most important acts; we are giving it another and another chance of proving that it can rise superior to its circumstances and force the intractable materials and powers of nature to perform a service to man.

The act of building is immediate and opportunist in so far as its chief necessity is to build; but whenever it is seriously undertaken it must take thought for a long future and weigh performance against first cost. It must probe deeply into the productive possibilities of a country, its resources of material and skill, its transport, its powers, its fund of artisan intelligence, its wage structure; and constantly it must be aware of the process of change with a view to a closer adjustment to it, leading to a more complete and more secure mastery over circumstances.

For any type of building, taking into account all the factors bearing on it, there is an ideal structure, or perhaps several but related ideal structures, which will solve the problems presented and conform to the economies laid down. Where a country is deficient in materials that are suitable for the work it must pay for their importation and if it finds them really necessary, set about manufacturing them, or substitutes for them, and thus raise its standard of living and power of survival. This India has done at the instigation of British interests in the first case, and largely with outside capital, and to it the whole tropical world is now addressing itself, with varying degrees of skill, knowledge and forethought.

Provided the present foundations are well laid, the varying adjustments to tropical circumstances will be made and an architecture and a form of urbanism will emerge closely connected with the set of ideas that have international validity, but reflecting the conditions of climate, the habits of the people and the aspirations of the countries lying under the cloudy belt of the equatorial world.

CHAPTER ONE

Climate

Definition of the tropics and tropical climate; how this can be measured and its effect on men and materials

SO FAR as the architect is concerned he is interested not so much in what lies geographically between the zones of Cancer and Capricorn, as in an area where the climate is closely defined by extremes of heat combined with extremes of humidity or dryness. These and the liability to tornadoes, sandstorms, earthquakes and other generally understood tropical features are what give to most people the idea of the word "tropics", the limits of which do not exactly coincide with the zone between Cancer and Capricorn.

The "*hot-dry*" tropics have a season of very high day temperatures (80–110° F. or more), generally with moderate night temperatures (60–75° F.) and periodic heat waves with hot days and hot winds and low humidity. They have a short winter with moderate temperatures and cold nights (40–50° F.) and low rainfall.

Life in these regions is associated with dust and discomfort, flies and other insects, and a lowered vitality among the human inhabitants.

The "*hot-wet*", *humid*, tropics differ from the hot-dry tropics in having a high humidity throughout the year, even in the dry season, and a smaller variation in day and night temperatures (75–85° F. in the hot season, 50–70° F. in the cool season). These two climates register the tropical extremes which bring to the architect two different sets of building problems, with heat as a common denominator.

In the dry climate dust and cracking are two special evils, in the humid climate fungi and rot.* In the hottest season the hot air must be kept out of the house: in the humid climate air movement of any kind is a relief to the sweating skin. In some parts of the tropical world there is not one climate but a mixture of both, as in West Africa, where on the humid coast there are periods of what is in fact a hot-dry climate. It is a question of assessing the right planning and design for each of these two opposite climates and finding from this the right "mix" for the local condition.

Conditions covered by the term "hot-wet tropics" are to be found in the following countries:

Mexico	Nicaragua
The Caribbean Islands	Costa Rica
Guatemala	Panama
Honduras	Colombia

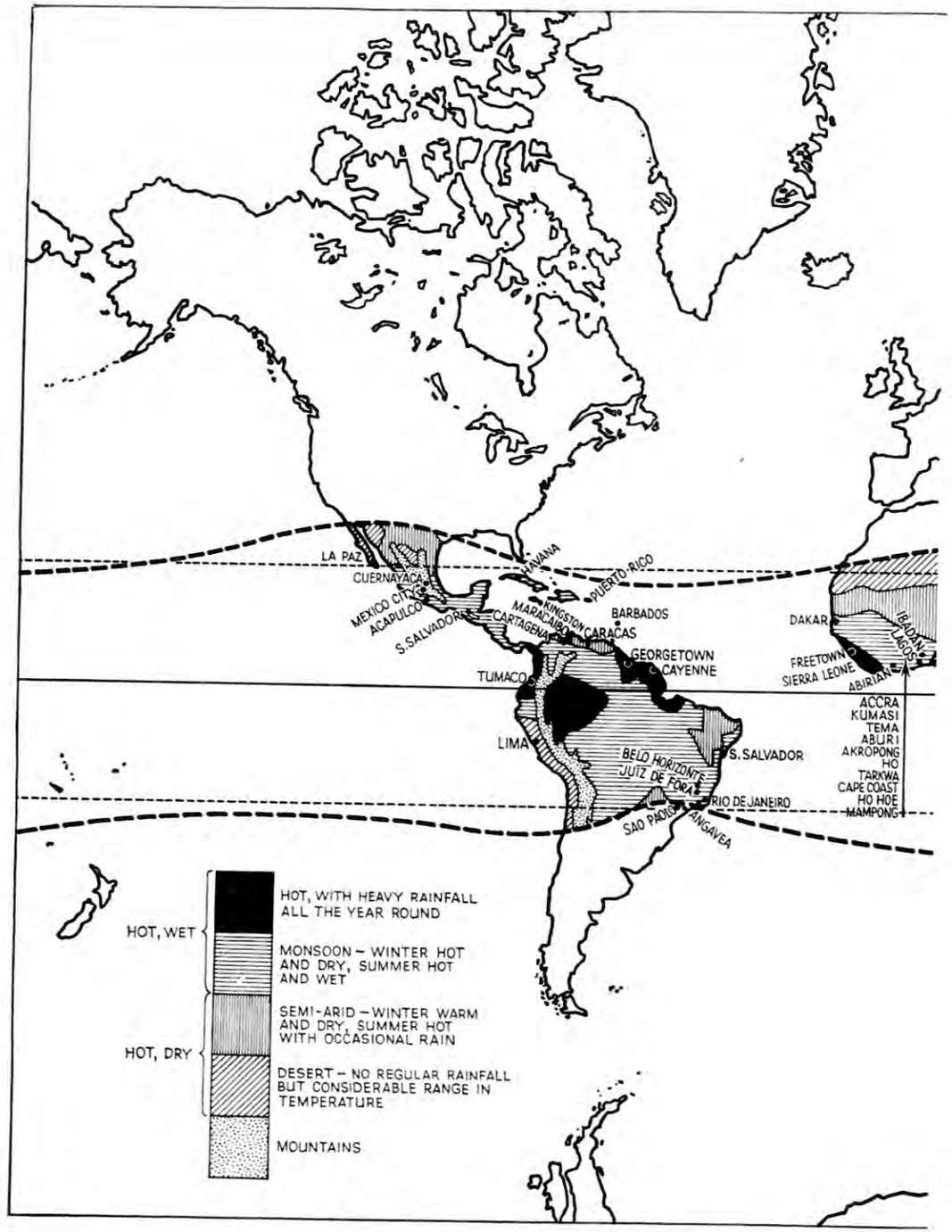
* Appendix, page 303.

Venezuela	Uganda
The Guianas	Mozambique
Brazil	Madagascar
Ecuador	India
French West Africa	E. Pakistan
Sierra Leone	Ceylon
Liberia	Burma
Gold Coast	Thailand
Nigeria	Malaya
French Equatorial Africa	Indonesia
Belgian Congo	Indo-China
Kenya	Philippines
Tanganyika	Australia

This tropical area is shown on the map on page 32, subdivided into the hot-wet and hot-dry zones. It is with the "hot-wet", humid, side of it that this book chiefly deals, a climate, as we have mentioned in the introduction, rarely found the whole year round in any parts of the hot-wet tropics, where for some part of the year the equivalent of a hot-dry climate is experienced. Altitude, proximity to the sea, the character of the soil and other such factors also modify the ruling tropical conditions.

6 *A. Clothing* *B. Health* *C. Acclimatisation*

What are the factors that make up "climate" in its impact on human beings? The primary factors are physical (8): the temperature and the humidity of the air; its rate of movement; and the radiation of the floor, ceiling, walls or other surrounding surfaces. State of health, degree of acclimatisation and suitability of clothes are contributory factors, difficult to measure exactly; and there are further factors, psychological in character and having to do with environment, which are important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CARACAS
GEORGETOWN
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IBADAN
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ABIDJAN
ACCRA
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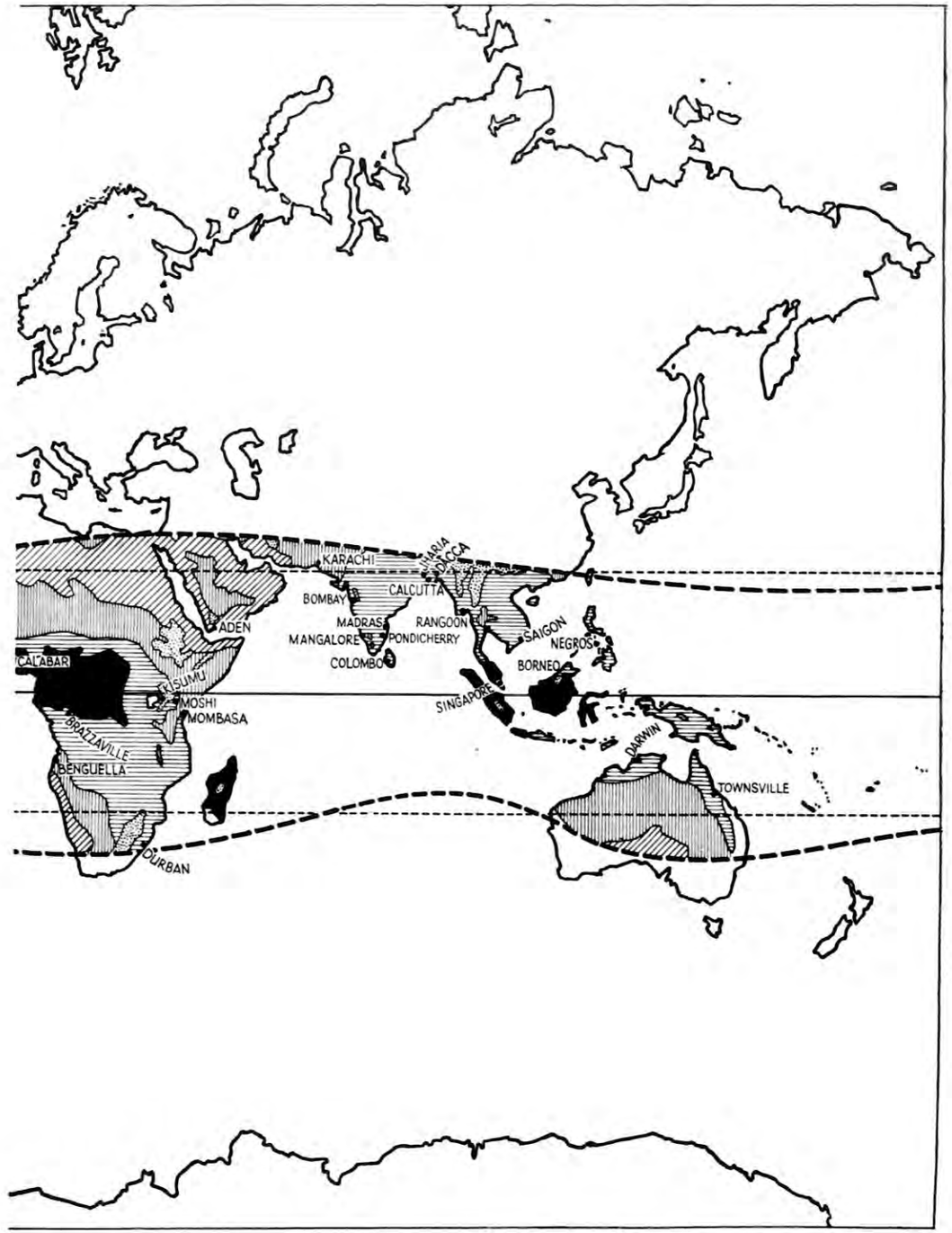
TEMA
ABURI
AKROPONG
HO
TARKWA
CAPE COAST
HO HOE
MAMPONG
HOT, WET
HOT, WITH HEAVY RAINFALL ALL THE YEAR ROUND
MONSOON – WINTER HOT AND DRY, SUMMER HOT AND WET
HOT, DRY
SEMI-ARID – WINTER WARM AND DRY, SUMMER HOT WITH OCCASIONAL RAIN
DESERT – NO REGULAR RAINFALL BUT CONSIDERABLE RANGE IN TEMPERATURE
MOUNTAINS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BORNEO
SINGAPORE
CALABAR
KISUMU
MOSHI
MOMBASA
BRAZZAVILLE
BENGUELLA
DURBAN
DARWIN
TOWNSVILLE

Table 1 *Characteristics of warm and hot climates: from the standpoint of their effect on building design.*

Characteristics of warm and hot climates *	Warm Humid	
	Equatorial	Island; trade wind
TEMPERATURE: Daily range (average).	10–15° F.	15° F., or slightly more.
Day-time air temperature (mean max. d.b. in shade).	Usually 85–90° F. Rarely exceeds 90° F.; during rain-storm may fall below 80° F.	85–90° F.
	Hardly ever above skin temperature of human body.	
Night-time air temperature (mean min. d.b. in shade).	75–80° F.; on clear nights in low 70° F.'s.	65–75° F.
Annual range.	Slight seasonal variation; 5–10° F.	Fairly small seasonal variation; 10° F.
Sky temperature.	About same as surface air temperature. Sky important source of radiant heat.	At night, when cloudless, below air temperature.
HUMIDITY: Vapour pressure; absolute humidity. Relative humidity.	25–30 mb. 55–100%.	17½–25 mb. 55–100%.
RAINFALL: Annual rainfall	High; usually over 80 in. and may exceed 200 in.	Fairly high, 50–70 in.; marked local variation due to topography.
Other characteristics of rainfall	May exceed 20 in. in wettest month; usually 10–15 in. In a heavy storm, 2–3 in. may fall in an hour. Close to Equator, usual for rain to fall in early afternoon.	Usually 7½–10 in. in wettest month. In a cyclone, up to 10 in. may fall in single storm. Driving rain likely on windward coast.
SKY CONDITIONS: General appearance.	Cloudy; 6/10–9/10. Sky bright when thinly overcast or when white cumulus clouds do not obscure sun (2,000 ft.-lamberts or more). Dull when thickly overcast (250 ft.-lamberts or less).	Clear or partly cloudy; 4/10. Except during storms, when dark and dull. Blue skies, especially on windward coasts of low brightness (500–750 ft.-lamberts).

* *Note:* This table is tentative. It is based on the characteristics of climates which are considered to set the building designer more or less similar problems. Local climatic data should always be studied. The table was prepared by the Colonial Liaison Officer, Building Research Station, Watford.

Intermediate Climates	Hot Dry		Upland
Monsoon; Sudan	Desert or semi-desert	Maritime desert	Mountain, plateau (usually over 4,000 ft. above sea-level)
Dry season: 20° F. or more. Wet season: 10–15° F.	20° F. or more; may exceed 40° F.	10–15° F.	20–30° F.
Dry season: 90° F. or more. Wet season: 85–90° F., may fall below 80° F.	Up to 100° F., or more.	Up to about 100° F.; but in cooler season may be 70–75° F.	Depends on altitude; at 6,000 ft., 75–85° F.
—	Usually above skin temperature of human body.		Usually below skin temperature.
Dry season: 70–80° F. Wet season: 75–80° F.	Warmer period: 75–85° F.; cooler period: 50–65° F.		At 6,000 ft., 50–55° F.; but may fall below 40° F. Ground frost possible.
10–20° F.	20–30° F.; at tropics may exceed 30° F.	15–25° F.	Depends on latitude; at Equator, slight; at tropics, 20–30° F.
Varies with season.	Depends on dust in sky; when clear, below air temperature.		On clear nights, markedly below surface air temperature, causing ground frost.
Dry season: 13–16 mb. Wet season: 20–25 mb. Dry season: 20–55%. Wet season: 55–95%.	7½–15 mb.; in rainy season up to 20 mb. 10–55%.	15–25 mb. 50–90%.	Drier season: 8–12 mb. Wetter season: 12–16 mb. 45–100%.
Seasonal, 20–50 in.; variable.	Slight and variable; less than 10 in.		Variable; but usually fairly low; often less than 40 in.
Little or no rain in dry season; 7½–10 in. in wettest month.	Flash storms, in which up to 2 in. may fall, occur occasionally.		Rain often falls in heavy showers. Evaporation in dry season vigorous. Risk of hail.
Depends on season. During rains; as tropical, humid sky. Immediately after rains, clear and blue, as island sky. Later in dry season, bright with increasing dust in lower part of sky, as desert sky.	Vapour in sky may be replaced by dust; then sky, particularly towards horizon, bright (1,000–1,500 ft.-lamberts or more). In sandstorms, sky darkened by dust (250 ft.-lamberts or less).	As desert sky, but likely to be more cloudy.	Clear or partly cloudy; 4/10. During rains, may be overcast; in dry season, some dust haze. Visibility generally good, or very good.

Table 2 *Characteristics of warm and hot climates: from the standpoint of their effect on building design.*—contd

Characteristics of warm and hot climates *	Warm Humid	
	Equatorial	Island: trade wind
GROUND CONDITIONS: General appearance.	Luxuriant vegetation; abundant shade. Green predominates, but bare ground usually red or brown. Morning mist over low ground.	Depends on rainfall. Vegetation less luxuriant and a lighter green. Very bright, light-coloured coral rock and sand.
Soil moisture.	Usually damp. High water table; ground may be waterlogged.	Usually dry, with fairly low water table.
AIR MOVEMENT.	Low, especially in jungles; but strong during rain squalls, wind gusts of 25 m.p.h. or more.	On windward coasts, wind may blow steadily at 15 m.p.h. or more. In trade wind zone, prevailing wind N.E. and E., northern hemisphere; S.E. and E., southern.
OTHER CHARACTERISTICS.	High humidity accelerates mould and algal growth and rotting. Thunderstorms frequent, but high proportion of electric discharges air to air.	Risk of tropical cyclones (hurricanes). Close to coast, corrosion due to salt in atmosphere is marked.

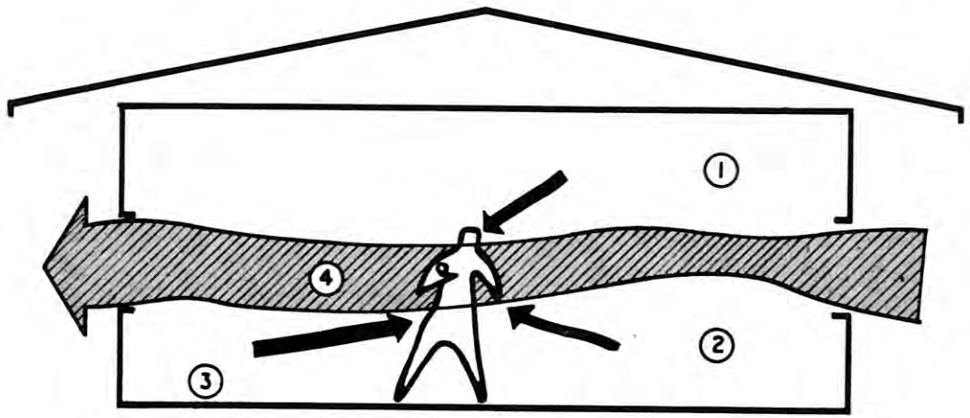
* *Note:* This table is tentative. It is based on the characteristics of climates which are considered to set the building designer more or less similar problems. Local climatic data should always be studied. The table was prepared by the Colonial Liaison Officer, Building Research Station, Watford.

Intermediate Climates	Hot Dry		Upland
Monsoon; Sudan	Desert or semi-desert	Maritime desert	Mountain, plateau (usually over 4,000 ft. above sea-level
During rains, green. As dry season progresses, vegetation dries and ground becomes bright – browns or reds.	Little vegetation; ground and rocks, brown or red. Close to sea, white glare from salt pans.		In wet season, green but usually not very luxuriant vegetation. In dry season, vegetation may wither; ground turns brown or red.
May be damp in rains, but dries rapidly. Risk of soil erosion.	Ground very dry. Dries rapidly after any rain. Water table deep or non-existent. On coast, ground water likely to be brackish.		May be damp in rains but dries rapidly.
Seasonal. Fairly strong and steady during monsoon period (or its equivalent).	Winds usually hot or warm. Risk of whirlwinds or tornadoes. Stiller at night than in daytime.	May be affected by monsoon winds; also by local on–off shore day–night wind pattern.	Variable; in mountainous country, topography has an important influence.
Change in relative humidity dry-wet season and vice-versa causes materials, especially timber, to shrink or swell excessively.	High sun temperature and rapid cooling at night may cause materials to crack and break up.	Risk of corrosion due to salt-laden atmosphere; also danger due to salts rising from ground.	Strong solar radiation, especially strong ultra-violet radiation; dew at night. Thunderstorms, with fair proportion of electric discharges air to ground. Risk of hail.
Risk of dust and sand storms.			

as helping to sustain a possible and even an enjoyable life under conditions of physical strain.

An architect should know how to create the right kind of "feeling" or atmosphere for the particular climate he deals with and to do this well he must know the major scientific facts and understand the physiological ones.

Because of the complication of the subject the word "temperature" is realised to be inadequate and it is spoken of either in terms of "equivalent" or "effective" temperature. There comes a point, varying from one person to another, and from those in active motion to those who remain still, where hot and saturated air restricts the body's normal loss of heat by radiation, convection and evaporation. Loss of heat



8 *Key* 1. *Humidity*
2. *Temperature*
3. *Radiation*
4. *Air movement*

by radiation and convection only occurs when the temperature of the air and surroundings is less than body temperature; and loss of heat by evaporation presupposes an air dry enough to absorb further moisture. High temperatures and humidities strain the temperature-regulating machinery of the body, particularly when performing muscular exercises, and unsuitable clothing and pathological conditions make it still more difficult for the body to adapt itself, for it must at all times lose heat to the external environment *at a rate equal to its internal heat production*, in which statement many warnings as to diet, alcohol consumption and similar excitements are contained, together with those concerning the creation of conditions in a house mitigating or removing the chief causes of bodily stress.

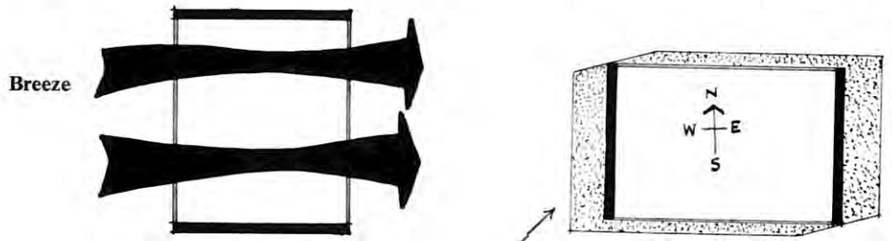
A great deal of research has been done into climates and their major characteristics are known.

These are shown on the chart, page 34 *et seq.*, prepared by the Building Research

Station at Watford, and the diagrams explain the major characteristics of the tropics: heat, vegetation, rainfall, wind, population density and religions (10).

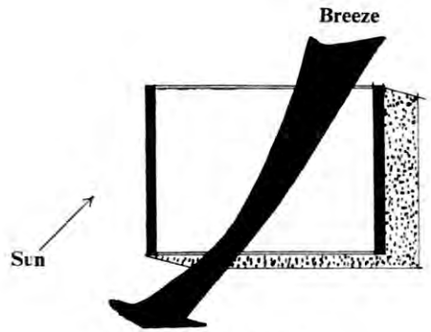
The usual method of measuring climate involves the use of a silvered (or whirling) dry-bulb thermometer (319) to ascertain true air temperature, a globe thermometer for radiant effect, a Kata thermometer for air movement and a wet-bulb temperature by whirling psychrometer. Air movement is particularly important in a hot humid tropical climate.

No climate is the same at any place throughout the year and an architect must so



9 *A. Ideal solution in relation to breeze*

B. Ideal solution in relation to sun



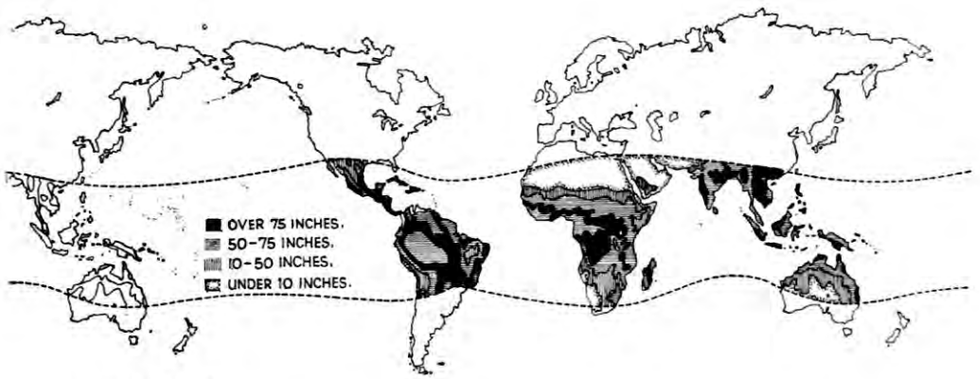
C. Compromise solution

design his building that it is comfortable at the extremes when comfort is most needed, and these can be arrived at by referring to the climatic chart (34).

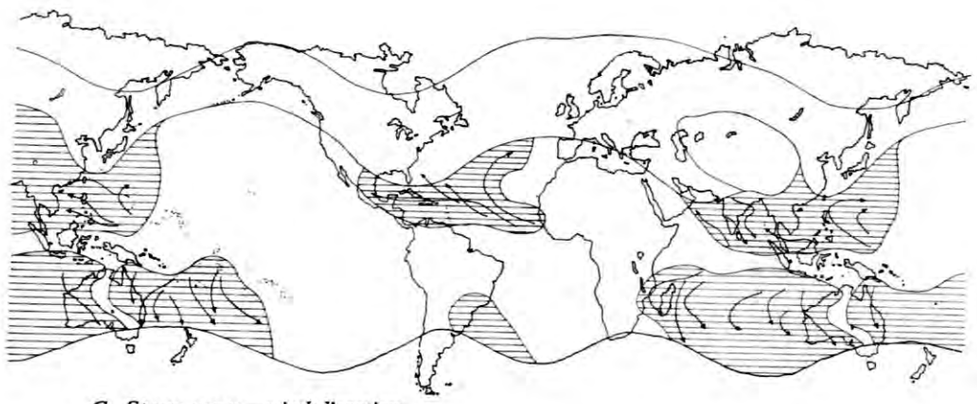
The difficulty is that little really scientific data exists, nor could the normal architect interpret it if it were obtainable. It is rather the general data he requires, and in a form which he can relate to his known experiences elsewhere; and having obtained this general data he can particularise and use his facts intelligently, and decide on a location and orientation for his building in which the best conditions are obtained.

But let us not at this moment forget that the scientific approach towards building is not the only one, and leaving for the moment artistic considerations out of account, there are also the religious and cultural customs of the people to be considered,

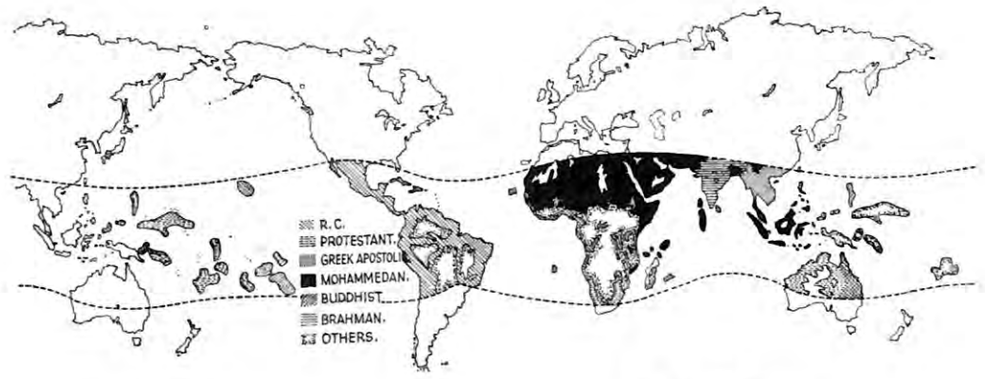
10 *A. Population*



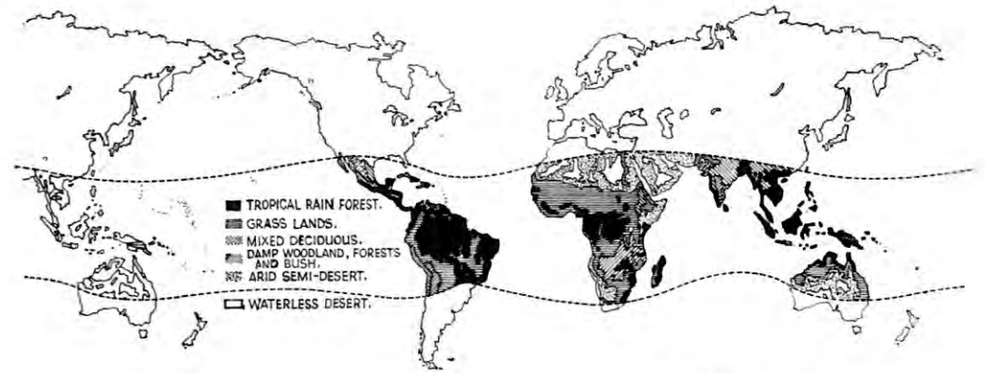
B. Rainfall



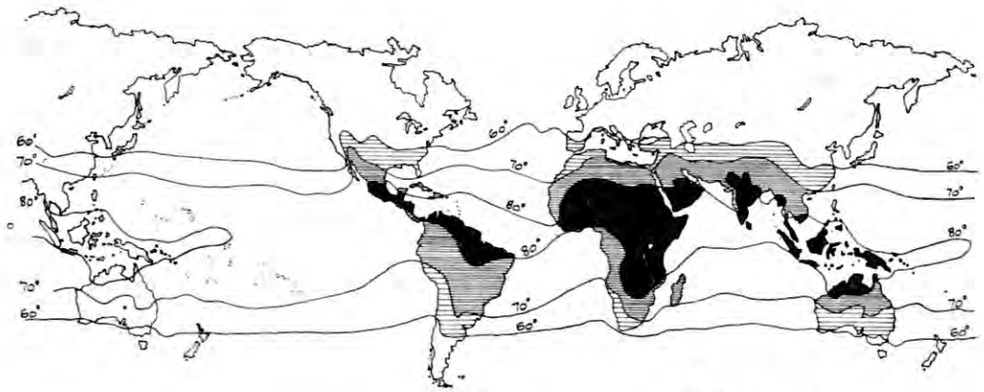
C. Storm areas—wind direction



10 *D. Religions*



E. Vegetation



F. Temperature

Table 3 *Tropical climate chart*, **Ibadan** **Hot-Wet**

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Remarks
Rainfall (inches)		0·38	0·83	3·49	5·49	5·88	7·46	6·31	3·38	7.00	6·12	1·65	0·38	48·42 Total. 46 years' record.
Mean daily temperature (°F)	max.	91·2	93·5	93·9	92·4	88·8	85·6	82·2	82·1	84·7	86·7	89·5	90·3	Period 1943–47.
	min.	69·2	70·5	72·7	72·5	71·9	71·0	70·0	70·0	70·0	69·7	69·9	69·2	
Relative humidity, per cent	7 a.m.	94	92	95	95	96	97	97	97	97	98	97	96	Period 1943–47.
	1 p.m.	51	49	54	60	67	74	78	78	75	70	63	56	
Most frequent wind direction and percentage frequency (average of 8 observations a day)		S.W.	S.W.	S.W.	S.W.	S.W.	S.W.	S.W.	S.W.	S.W.	S.W.	S.W.	S.W.	Period 1944–48 for Lagos Ibadan not available.
		18·0	33·2	30·7	35·1	30·5	34·6	51·2	58·4	53·6	31·8	29·2	20·6	
Tenths of sky covered by cloud	10 a.m.	3·9	5·6	5·4	6·1	6·1	7·0	9·1	8·9	8·6	7·4	6·7	6·9	Mean of 3 years.
	4 p.m.	1·7	3·4	3·3	4·5	4·9	6·2	7·5	7·9	6·4	4·7	4·4	1·3	
Storms and direction		Storms mainly from N.E. or S.E.												
Dust storms		No data.												
Insect pests		No data.												
Extra-climatic effects, i.e. cyclones, frost, risk to property from lightning, liability to snow, flooding, hail, mist, squalls, typhoons, earthquakes.		Lightning and thunder common from April to October.												

Information supplied by the Professor of Geography, University College, Ibadan, Nigeria.
Note: For air-conditioning engineers' requirements with regard to temperatures, relative humidity, etc., see Appendix X

Table 4 *Tropical climate chart*, **Kano** **Hot-Dry**

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Remarks
Rainfall (inches)		0·00	0·01	0·07	0·37	2·55	4·45	7·99	12·45	4·96	0·48	0·00	0·00	Average of 46 years' observations.
Mean daily temperature (°F)	max.	8·56	89·9	95·7	100·8	99·3	94·5	97·2	85·1	88·0	93·5	92·5	87·1	Period 1943–47.
	min.	56·1	59·5	65·9	72·4	74·6	73·9	71·1	69·6	69·4	68·1	61·6	56·9	
Relative humidity, per cent	7 a.m.	37	33	31	42	63	74	88	94	92	80	48	43	Period 1943–47.
	1 p.m.	13	12	12	19	32	46	60	71	61	36	15	12	
Most frequent wind direction and percentage frequency (average of 8 observations a day)		N.E.	N.E.	N.E.	S.W. =N.E	S.W.	S.W.	S.W.	S.W.	S.W.	S.W.	N.E.	N.E.	Period 1944–48.
		45·0	41·9	33·2	15·8	30·6	39·2	38·0	34·2	32·1	20·9	29·2	29·7	
Tenths of sky covered by cloud	10 a.m.	0·7	0 6	0·8	0·3	0·5	0·6	2·4	3·6	1·7	0·3	0·0	0·0	1943–47.
	4 p.m.	0·0	0·1	0·5	0·8	1·9	2·7	5·5	5·4	3·3	1·0	0·1	0·7	
Storms and direction		Storms mainly from N.E. or S.E.												
Dust storms		No data.												
Insect pests		No data.												
Extra-climatic effects, i.e. cyclones, frost, risk to property from lightning, liability to snow, flooding, hail, mist, squalls, typhoons, earthquakes.		Lightning and thunder common from May to September.												

Information supplied by the Professor of Geography, University College, Ibadan, Nigeria.
Note: For air-conditioning engineers' requirements with regard to temperatures, relative humidity, etc., see Appendix X

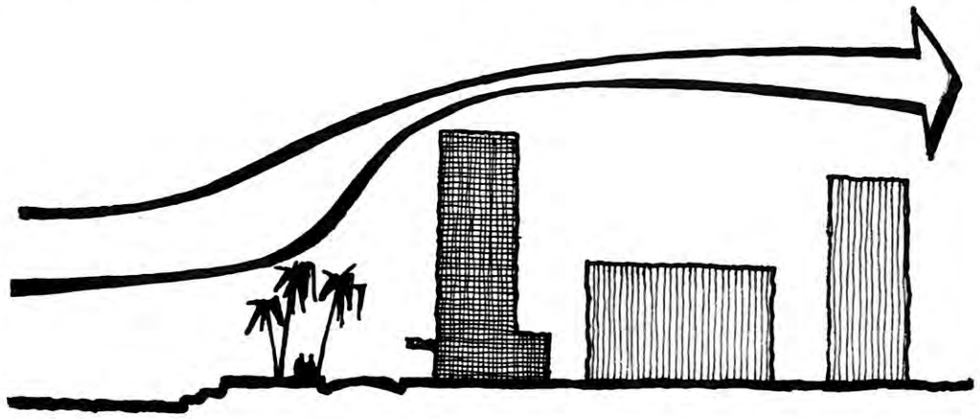
Table 5 *Details of living patterns in Singapore and Malaya*

Singapore – Chinese 77 per cent population; Malaysians 12 per cent; Indians and Pakistanis 7·8 per cent; Europeans and Eurasians 2·3 per cent; Others 0·9 per cent.
Malaya – Chinese 49·1 per cent population; Malaysians 37·6 per cent; Indians and Pakistanis 11·8 per cent; Europeans and Eurasians 0·5 per cent; Others 1 per cent.

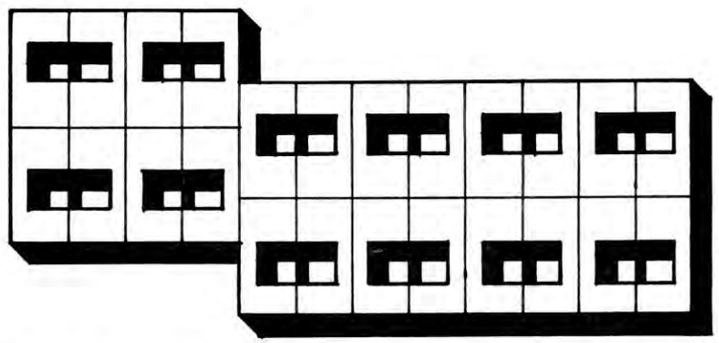
	Chinese		Malaysians	Indians and Pakistanis		Europeans and Eurasians
	Manual worker	Office worker	Manual worker	Manual worker	Office worker	Office: Government or professional classes
5 a.m.						
6 a.m.	*Rise* 5.30 a.m. 1*st meal* rice-porridge		*Rise* 5.30 a.m.	*Rise* 5.30 a.m. 1*st meal* 6–6.30 a.m.		(5.30 a.m. rubber planters, etc.)
7 a.m.	*Work* 7–	*Rise* 6.30 a.m. 1*st meal* 7.30	1*st meal* 6–7 a.m.	*Work* 7–4 p.m. or later in building trades	*Rise* 6.30 a.m. 1*st meal* 7 a.m.	*Rise* 6.30 a.m. *Breakfast* 7.30 a.m.
8 a.m.	Daily paid labour 7 a.m.–	Travel to office 7.45–8.	7 a.m.–2.30 p.m. if building labour daily paid.	Daily paid labour 7 a.m.–2.30 p.m. or later on overtime	Travel to office 7.30	Travel to office 8.15
9 a.m.	2.30 p.m. or later on	Work 8.30–5 p.m.			Work 8.30–4.30 p.m. or later	Work 8.30–4.30 p.m. or later
10 a.m.	overtime rates.	or later.				
11 a.m.	Main meal between 11–11.30 a.m.					
12 noon	Work			Main meal 11–11.30 a.m.		
1 p.m.		Lunch break 1–2 p.m.	Main meal 11–11.30 a.m.	Work or overtime	Lunch break 1–2 p.m.	Lunch break 1–2 p.m.
2 p.m.		Work	Work		Work	Work
3 p.m.	Rest or overtime					
4 p.m.			Rest			
5 p.m.	Sport-recreation, overtime,	Sport-recreation or	Sport-recreation	Sport and recreation	Sport-recreation, badminton,	Sport and recreation
6 p.m.	labour artisans, etc.	overtime.			cricket, hockey, tennis	"Overtime"
7 p.m.	DUSK	DUSK	DUSK	DUSK	DUSK	DUSK
8 p.m.		Dinner 7.30–8.30 p.m.	Supper 8–9 p.m. or earlier.	Supper 7–8 p.m.	Supper 8–9 p.m.	
9 p.m.	Bed					Older "Malayans"
10 p.m.		Bed	Bed 10 p.m. or earlier.			Bed
11 p.m.			N.B. The police and fire services generally recruit Malaysians. Time tables are staggered for those services throughout day and night	Bed	Bed	
12 mid-night						Small hours
	Diet: meat or fish, soups young bamboo shoots, rice flavoured with meat and fish etc. (pork in plenty)	*Diet:* ditto. Eat large quantities of pork. Drink tea and coffee	*Diet:* the Malays, a Muslim community, eat NO pork, but fish and mutton, many types of fish curried with rice. Drink mainly coffee; tea only occasionally. If strict Muslims, no alcoholic beverages	*Diet: Hindus:* 1. *Vegetarians:* vegetables, ghee with rice 2. *Non-vegetarians:* Meat and vegetables with rice. If Muslims, as Malays	*Diet:* Ditto	*Diet:* as in Europe

evolving in part from climate and part from history and religion. Vegetation also affects climate.

These aspects of life are often ignored, particularly when designers from one civilisation design for another; and of course customs are continuously changing. But a glance at maps will give a general picture of the world, and it will be seen that



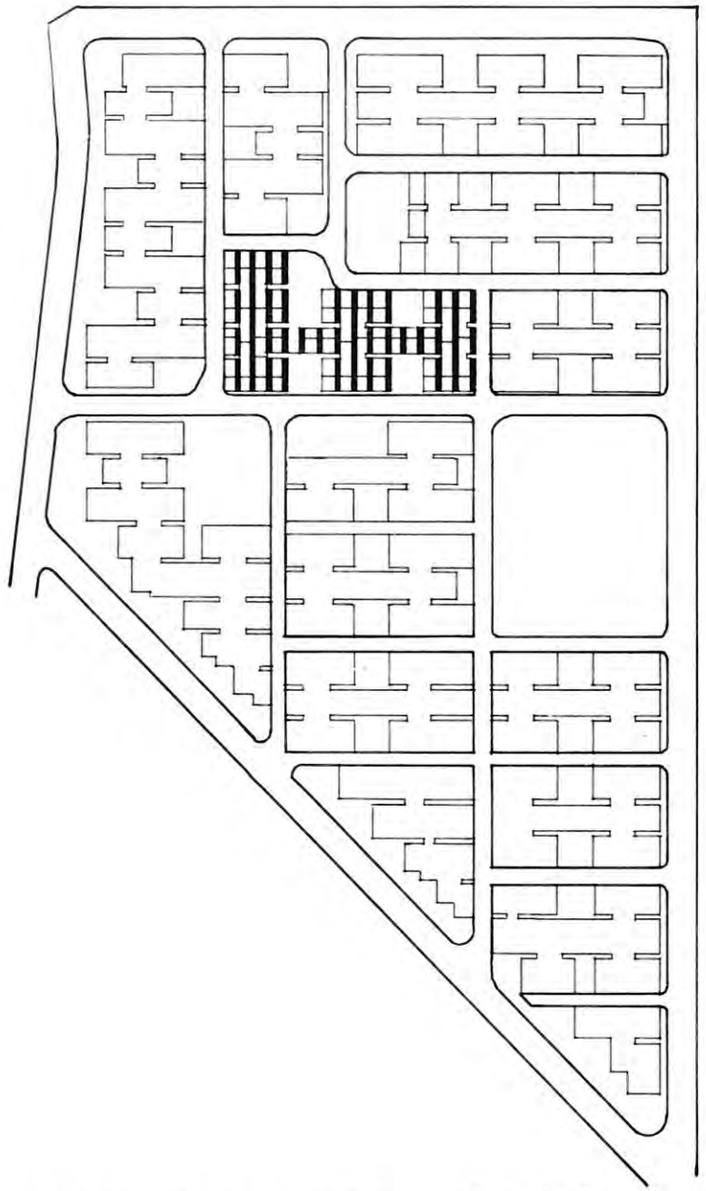
11 *A. Unfortunate obstruction of breeze by high buildings: hot-wet climate*



B. Back-to-back housing: breeze obstruction less important – economical: hot-dry climate

living habits of most tropical people vary considerably from place to place: times of getting up, cooking, eating, sleeping and working. The tables, pages 44 and 45, give instances of some typical hot-wet climate customs.

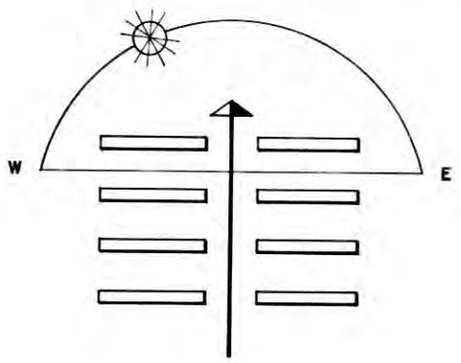
The major properties of sunlight are definite and predictable, so that ingenious instruments exist, of which the heliodon is perhaps the best known, by means of which the shadows which will be cast by a building can be measured and studied before the building is erected (317, 318).



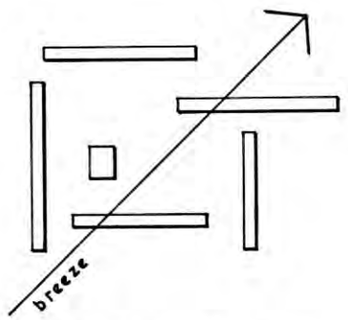
12 *Close-type housing layout in Morocco: only suitable for hot-dry climate*

Shading is an important method of cooling. Shading the air cools it and shading surfaces cools them, provided that the material used for shading does not itself collect heat and radiate it at the wrong time of day. The general equation is, in a

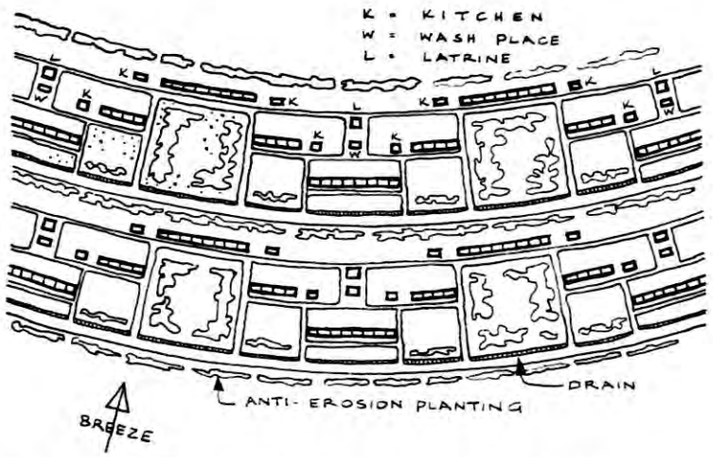
hot-wet climate, to face the building so that the long sides get the minimum of slanting sunlight (difficult to shade), and the maximum of breeze; and in the compromise which has to be struck the breeze is generally the more important factor.



A. Monotonous solution involving risk of breeze blanketing: hot-wet climate



B. Socially more enjoyable solution: less breeze blanketing: hot-wet climate



C. Open-type layout. Terrace housing planned for a convex slope, following contours to avoid erosion: hot-wet climate

13 LAYOUTS FOR HOT-WET CLIMATES

Though the individual building is all most architects are lucky enough to work on, because few towns are planned to order, and the *status quo* has to be accepted, the town-planning form, and especially in dense developments, is the dominant consideration. We can, for instance, recall that at Bombay, to quote an example of bad

planning, the buildings along the Marina Drive are so high that they break the breeze for the buildings behind. This question of town-planning form in relation to climate can best be illustrated by showing on plan and section suitable forms for a town plan for a hot-wet climate and that for a hot-dry, and the correct sections (11, *A*, *B*, 12, 13).

The implications of climate in relation to individual buildings and building construction generally will be found in later chapters and Appendixes.

Climate affects not only human beings but materials, and design must be modified accordingly. Earthquake, hurricane and cyclone bring particular forms of devastation, and the alternations of intense humidity and dryness, though less spectacular, are more widespread. We have outlined in the appendix the major precautions to be taken in dealing with violent forces and movements (pages 264–268).

It must be remembered that the forces at work are not only those of temperature, but also of humidity. We remember watching the cracks in a dining-room table open as the "harmattan" or dry wind season drew on in Accra, and close with the wet season. Of the behaviour of materials not enough is yet known (page 274).

The intensity of light can also be measured. The intensity of light from a tropical sky may be twice that of a torrid zone, which translated into building terms affects the size of window openings required.

This short chapter deals with climate and people in a general way and should be read in combination with the more detailed information to be found in the appendixes, so that before going on to the particular application of those facts to be found in the chapters that follow the reader has a familiarity with the underlying science of the matter. (Appendixes, page 255 *et seq.*).