overseas building notes

Information on housing and construction in tropical and sub-tropical countries

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BUILDING FOR COMFORT

NATURAL SHADE:
the ally of the builder in warm climates.
A village mosque, oasis in a hot and mainly arid country.

Overseas Division
Building Research Establishment
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BUILDING FOR COMFORT

The architects' approach to design for comfort under tropical conditions.

INTRODUCTION

Architects are trained to design buildings so that they can fulfil certain required functions, giving full consideration to all site and environmental conditions. Building in hot climates brings inevitably the additional problem of adequate cooling, which can certainly be catered for by mechanical means, but in siting and designing tropical buildings it would be well for the architect to give serious consideration to the well-tried traditional methods which enable occupants to be as comfortable with maximum economy.

In these days of mechanisation, a complete air-conditioning system can be designed to provide the required internal environment but this has the major disadvantage of high initial cost and subsequent running and maintenance expenses. Mechanical plant is subject to failures; skilled maintenance staff and spare parts are not always available. Moreover, buildings may be required where there is no electrical power. But if plant is to be installed, its size and running costs can be kept to a minimum by giving careful thought to the structure and its siting.

It is not practicable to plan a building exclusively on economic, functional or formal grounds and expect a few minor adjustments to give a good indoor climate. Unless the design is fundamentally correct in all aspects, no specialist can make it function satisfactorily. Climate must be taken into account when deciding on the overall concept of a project, on the layout and orientation of buildings, on the shape and character of structures, on the spaces to be enclosed and, last but by no means least, the spaces between buildings. In other words climate must be considered at the early design stage.

The designer's job is 'multi-problem solving'. He must cope simultaneously with

topographical
climatic
psychological
physiological
economic
social
functional
operational
and structural problems

without losing sight of questions of communications and the general city and regional planning context of his task.

It is impossible to establish an order of priority in dealing with these problems. During the early stages of a project an idea or design concept must be produced which does not preclude the solution of any of these problems, and promises to solve a good number of them in a convincing and elegant manner.

This paper is intended to remind designers of the basic principles which will assist in providing favourable conditions of life through natural means - 'Naturally conditional buildings'.

Dominant climatic characteristics affecting human comfort are:

(a) air temperature	needs to be lower than the temperature of the skin, in order to cool it by convection.
(b) air movement	brings new air into contact with the skin.
(c) radiation	when protected from the sun and surrounded by cooler surfaces the body will lose heat.
(d) humidity	impedes evaporation.

CLIMATE TYPES

Climates vary considerably but it is useful to have a rough classification of those, with heat as the dominant (though not the only) problem, with which we are concerned.

Warm humid climates of the equatorial belt. Characterised by,

high ambient temperatures,

high humidity,

high and fairly evenly distributed rainfall, small diurnal and annual variations of temperature, little seasonal variations, light winds and long periods of still air.

Tropical island climate. This sub-group is similar to above except for: dominance of trade winds, which facilitate heat loss by convection and evaporation.

Climate of the hot dry arid zones. Characterised by,

high day temperatures,

low night temperatures,

low humidity,

low precipitation,

large diurnal and annual ranges of temperature, distinct seasonal variations between hot summers and cool or cold winters, little air movement except for local thermal, winds and dust storms.

Maritime desert climate - where sea and desert meet. This sub-group is characterised by, higher moisture content in air, precipitation still low, humidity tends to reduce diurnal variations, differential heating and cooling of land and sea, produces alternating land and sea breezes.

Composite climate. This has two, three or four distinct seasons. One season may be similar to that of an arid desert, another to warm humid region, while a third may have cold nights, pleasantly sunny and warm days, low humidity, little precipitation. Transitional periods of varying length may occur between the clearly discernible seasons.

Composite climate of the tropical uplands. This sub-group is similar to above but with the added complication of night frost and in some cases snow. Incoming and outgoing radiation is of greater importance.

CLIMATIC REQUIREMENTS

Warm humid climate

Indoor comfort dependent largely on: control of air movement and radiant heat. Maximum air movement past the body must be encouraged to ensure rapid evaporation of sweat from the skin. Solar heat must be prevented from reaching the building occupants either directly through doors and windows or indirectly by heating the structure and thereby re-radiating the heat to the occupants or warming the indoor air. Buildings must cool quickly after sunset to give maximum night-time comfort.

These requirements call for: light, well-insulated construction of walls and roofs, reflective surfaces, correct shading and design for good breeze penetration.

Hot dry climate

Advantage can be taken of the large temperature difference between day and night. Cool night air may be stored by closing doors and windows during the day and opening them at night. The passage of heat through walls and roofs can be slowed down so that it is out of phase with the daily heating and cooling of the outside world. To achieve this the fabric of the building must be slow to heat up. As little heat as possible must be permitted to penetrate through external openings. Good shading of walls and openings, reflective colouring to unshaded outdoor surfaces and heavy insulative outer construction are needed to provide indoor comfort during the day. Maximum night comfort on the other hand requires a light construction which can cool rapidly after sunset.

Composite climates

Buildings have to satisfy the needs of the hot dry periods as well as those of the warm humid periods. In some cases it is necessary to cater also for the cooler or cold seasons. Many of the requirements and objectives for the hot dry and warm humid seasons are compatible. Where apparently incompatible needs arise, it becomes necessary to weigh the length and intensity of the various seasons and to study their detailed features in order to find design data that make an integrated solution possible. The same applies to island climates, maritime desert climates, and tropical upland climates.

TRADITIONAL SOLUTIONS

Many of the older houses built in local traditional manner are 'naturally conditional'. This is the result of repeated cycles of trial and error and embody the experience of generations of builders. However these traditional solutions should be studied but not necessarily copied, since they could have been developed under conditions that have ceased to exist or developed to fulfil needs that today can be met more satisfactorily by other means, eg thatch and earth are widely used whenever they are readily available. Both have favourable thermal properties which help to provide comfortable conditions indoors, yet both have disadvantages:

thatch roofs harbour insects and have high fire risk, while

earth walls deteriorate quickly.

Even in rural areas these materials are being replaced by modern building materials.

Not all traditional buildings are comfortable: climatic comfort is sometimes subordinated to other requirements, particularly security.

Traditional solutions must be seen as satisfactory only within the limits of the technology available at the time. Modern technology, wisely used, should make it possible to arrive at solutions that are better and cheaper.

CLIMATIC ANALYSIS

Meteorological data to building specifications

Identification of the climatic type gives the designer a general idea of the type of building that will be needed, but a careful analysis of climatic data is required in order to make the correct decisions on shape, orientation, spacing of buildings, treatment of spaces between buildings, plan form of each unit,dimensions of rooms, fabric of walls and roofs, size of openings, treatment of the outside surfaces, all of which are influenced by climate.

From regional to the site climate

Sources of information on climate are the meteorological stations in or near major cities and at all civil airports. The readings from the nearest observatory give the best climatic information available for the region but must be accepted with reservation.

Meteorological instruments are usually located at a place where they are not affected by special topographical features, nearby buildings or vegetation, so that data recorded by such instruments are bound to differ from readings in the streets of large cities or on the shores of a lake.

Narrow streets, like narrow valleys or gorges, affect the direction and velocity of the wind so that large built-up areas have higher night temperature; at the same time ponds, woods and parks exercise a moderating influence on the daily rhythm of heating and cooling. Shores of the sea or of large lakes produce their own wind patterns which may differ markedly from those further inland.

In locating and planning a new town, a large housing project, university campus or other large scheme it would be worth while setting up a site observatory well in advance of the commencement of the design work. For smaller projects or single buildings the designer must use the information available regionally together with his judgment based on personal study of the site.

Type of climatic data required

The requirement is to obtain a picture of typical weather conditions to be expected at different seasons. A designer resident in the locality is fully aware of these conditions but it is an advantage to translate them into comparative figures, but to a designer living elsewhere it is essential. Climatic design is based on typical or normal conditions, and to attempt to design for extreme conditions would be expensive and might make the building unbearable during normal weather conditions.

Monthly means of daily maxima and minima are generally adequate for climatic design but note should be made of the extremes and their frequency. Data on air temperature and humidity provide an idea of the climatic stress to be expected. Daily and annual ranges of temperature, average duration of bright sunshine, measurements of rain and wind complete the picture and indicate possible sources of relief.

Comfort Zones

Climatic stress can be assessed by setting the figures of monthly mean maxima and minima temperatures and humidity against those for ideal comfortable conditions.

Ideas of what is comfortable vary from person to person but research has disclosed remarkable agreement on the upper and lower limits beyond which at least 70% of test subjects complained of discomfort. The 'comfort zones' are between these limits. Physiologists have established comfort zones for a number of locations expressed in air temperatures and they vary regionally according to humidity and annual mean temperature.

Inhabitants of warmer climates prefer, as might be expected, somewhat higher temperatures than those living in cooler regions or in areas with hot summers and cold winters. There is also general agreement on higher comfort limits for the day and lower for the night.

It is possible therefore to estimate approximate limits of comfort for every month of a region, provided we know the annual mean temperature and the humidity figures for the month under consideration.

Table 1 Comfort limits (i)

Annual mean temp	Over 20°C		15-20°C		Under 15°C	
Average relative humidity (percentage)	Day	Night	Day	Night	Day	Night
0 - 30	26-34	17-25	23-32	14-23	21-30	12-21
30 - 50	25-31	17-24	22-30	14-22	20-27	12-20
50 - 70	23-29	17-23	21-28	14-21	19-26	12-19
70 - 100	22-27	17-21	20-25	14-20	18-24	12-18

CLIMATIC STRESS AND HOW TO RELIEVE IT

Having established the limits of comfort it is possible to set the figures for monthly mean maximum and minimum temperatures against them and to record the number of days or months that are too hot, too cold or comfortable and thus to provide a picture of the duration and nature of the climatic stresses to be expected in a locality. The picture thus defines the problem for the designer, and indicates those features of the climate for which some measure of relief from climatic stress can be obtained through skilful design.

Diurnal range (DR) is the difference between day and night temperatures and is very important.

A large DR is indicative of dry weather and clear skies: the indoor climate can be improved by the periodic opening and shutting of windows and by the retarding of the inward flow of heat through heavy walls and roofs.

A small DR is indicative of overcast skies and of a humid climate or season: air movement is the principal source of relief.

A large DR suggests intensive solar radiation by day and strong outgoing radiation by night: shading and reflective colouring is important, night-time cooling of horizontal surfaces, is pronounced.

A small DR belongs to regions or periods of heavy rainfall: problems are, protection from driving rain, storm-water drainage, fungus growth and insect problems. The identification of this type of climate also tells the designer he can expect good ground cover and little trouble from dust or ground glare.

Annual mean range of temperatures (AMR) is not as important as the DR but worth recording as an additional guide to the type of structure needed for a particular climate.

A large AMR requires massive internal walls and ceilings to reduce seasonal extremes of temperature, while for a small ARM a light type of structure is preferable.

Wind is an important component of the weather. In humid climates it is a blessing and can influence the layout, orientation and shape of buildings, if skies are normally clouded. In dry climates it carries dust, and brings little relief from heat and so it must be excluded.

DESIGN DECISIONS

The translation of climatic data into specifications for buildings is relatively easy if the weather is either invariably humid or invariably dry. In such conditions two extreme types of buildings emerge.

Buildings for hot dry climates

Orientation: north or south for habitable rooms.

Layout: compact planning (buildings shade each other).

Internal plan: rooms grouped around and opening onto courtyards.

External openings: small, near ceiling.

External walls and roof: heavy.

Outside surfaces: where not shaded - reflective.

Internal walls: massive.

Courtyard: shaded floor.

External circulation: shaded.

Special precautions are needed against dust storms, insects, termites, overlooking and theft.

Buildings for warm humid climates

Orientation: north-south for habitable rooms.

Layout: air movement through and around buildings.

Internal plan: single-banked rooms (to allow for cross ventilation).

External openings: large, at body level (from floor to ceiling) protected.

External walls and roof: thin, insulated.

Outside surfaces: where not shaded - reflective.

Internal walls: Lightweight construction preferred in order to allow through passage of air.

Verandah: covered.

External circulation: shaded.

Special precautions are needed against heavy rain, insects, termites, overlooking and theft.

Building for composite climates

Straightforward cases of hot-dry, warm-humid climates are unfortunately for the designer not very common. Most human settlements have composite climates where the annual cycle may include hot, temperate, cool, dry or humid seasons of varying duration and intensity. The relative length of the seasons must be considered in deciding on the type of building required and in order to eliminate the need for guessing, Carl Mahoney has developed a simple set of tables for the recording and analysis of climatic information, but these cannot be condensed into this short paper. They are however readily available.[(1)]

BASIC REQUIREMENTS

To protect the interior of a building from the extreme effects of solar radiation, to provide for reasonable air movement to assist the cooling of the body by evaporation, the protection of the eyes from strain caused by extremes of light and dark.

This will be discussed at length in the section which follows.

PROTECTION FROM SOLAR RADIATION

Siting and orientation

Walls facing east and west receive more radiation from the direct rays of the sun and should therefore be kept short. Openings in these walls, glazed or not, should be few and as small as possible. This results in rectangular buildings on an axis as near to east-west as practicable with openings for access, ventilation and light on the north and south (the longer) walls. In a hot arid climate it is advisable to group buildings close together to give some shade to each other and provide small shady spaces between, large sunlit areas are thereby avoided. Buildings should be sited so that their openings do not face directly onto brightly sunlit surfaces of other buildings or boundary walls.

Shade

All openings into buildings should be shaded from direct entry of the sun's rays. Walls should be shaded where possible. Those facing east and west are difficult and expensive to shade so they should preferably have no openings. Walls facing north and south can be shaded by a comparatively small overhang to the roof because of the high arc of the sun.

Solar charts enable sun angles to be calculated for any position on the earth's surface, for any time of the day, any day of the year. A shadow angle protractor superimposed over the particular solar chart, reveals shadow angles for buildings of any orientation.[(1) (3) (4)]

Construction

Buildings in hot arid areas should ideally be constructed, as traditionally, of heavy walls and roofs, both of which gain and lose heat by radiation slowly. The heat gained by solar radiation on the external surface during daylight does not pass through the material to be re-radiated internally until some time later, depending on material and thickness. One hour per 25 mm (1 in.) thickness for a dense material such as brick or concrete. If the nights are cooler and the rooms are still in use this delay can be an advantage.

It can be a disadvantage where there is little variation between day and night temperatures, unless the rooms are not used at night. Walls and roofs of thin, light construction heat and cool more quickly.

Roofs of heavy construction, that is reinforced concrete, are expensive. A lightweight roof of sheet material is cheaper and easier to construct. If properly insulated it will give reasonable protection from solar radiation, particularly if the external surface is coloured white.

Daylight

In more northern latitudes where skies are often overcast it has become customary to glaze fully the walls of classrooms, offices etc, to give an adequate standard of daylight within deep rooms. Where windows are provided on both sides of the room because of the requirement for cross ventilation and the sky is normally bright, a much reduced area of window is adequate. Research into the design for daylight in schools has been carried out by the Asian Regional Institute for School Building Research, particularly for the geographical situations of Colombo, Singapore, Bandung, Taipei, Hong Kong and Manila.[(6)]

AIR MOVEMENT

Natural air movement should be encouraged wherever possible, but must be controllable in case, for example, a light breeze should change into a hot, dusty wind.

Orientation

When considering orientation for both sun and breeze, the sun should be the prime factor in any compromise, and the orientation should still be as near to East-West as possible, unless the sky is normally overcast as in some warm humid areas.

Ventilation is more effective if the openings are set at an angle to the line of the direction of the prevailing wind than if they are at right angles to it.

Cross ventilation

Ventilation on both sides of a room ensures maximum air movement in conditions of light breeze.

Depth of ventilation

Air movement should be encouraged throughout the full depth of a room: floor to ceiling. Cooler conditions can be achieved with air movement near the ceiling than with hot air trapped under a high ceiling. Ventilation as near to the floor as possible is also necessary to give air movement around seated persons, or those lying on beds.

'Stack-effect'

In conditions of still air, movement will be encouraged by 'stack-effect', if ventilators are placed at both low and high levels. The occupants and their activities increase the internal air temperature above that of the external air which will flow in at low level as a result of the lighter warm air escaping at high level.

Design of ventilators: In low cost housing or schools

The many conditions considered above may be satisfied by a standard window design if it has controllable ventilation below and above it

(i) No breeze: low and high level vents open, windows closed.

(ii) Little breeze: all vents and windows open.

(iii) Hot dust-laden winds: all vents and windows closed on windward side.

(iv) Cooler conditions in mountains: vents and/or windows closed in cooler seasons as required.

If necessary fly screens can be provided.

Ceiling height: Its influence on indoor thermal conditions.

For many years there was a widespread, but largely erroneous, belief that ceilings should be high for health and comfort in warm climates, due perhaps to the space required by hand-operated 'punkah' fans, formerly used in colonial buildings, or ceiling fans. Building regulations in some tropical countries required a minimum ceiling height of 2.750 m (9 ft) 3.050 (10 ft) or even 3.650 (12 ft) in habitable rooms. This meant that, compared to where a ceiling height of 2.500 m (8 ft) is required, wall areas were increased by 12 to 30 per cent causing building to be more expensive, especially when of more than one storey needing extra lengths of services and staircases. This subject is discussed fully in Overseas Building Note No 155[5].

Mechanical Aids to Ventilation

Where electricity is available and the necessary additional finance for installation, running and maintenance costs can be met, large diameter slow revolving ceiling fans can usefully be installed in classrooms and other rooms of assembly. These would improve ventilation when there is little natural air movement.

Ceiling heights would normally be higher for these larger rooms.

COLOUR

Colour used with care will affect an environment physically as well as psychologically.

Use of Colour Externally

The colour of an external surface affects the absorptivity of the wall or roof to the sun's radiation in the order shown in Table II [2].

Table 2 Colour absorptivity

perfectly black	100%
ordinary black	85%
dark green, dark grey	70%
light green, light grey	40%
white oil paint	20%
new whitewash	12%
white emulsion paint somewhere between	20%-12%

It is therefore an advantage to colour all roofs and unshaded walls of buildings as near to white as possible.

Boundary walls and screen walls should be in dark colours, browns, greens, blues, so as not to reflect heat and glare. Shaded walls of buildings can be in bright cheerful colours which will enliven the whole effect.

Hard landscaping (paving) should preferably be in dark colours or, if light, should have a broken surface to avoid reflecting heat and glare.

Use of Colour Internally

Ceilings should be white in order to reflect maximum light from the windows and spread it as evenly as possible throughout the room. White or light grey window walls will reduce the contrast between the light window aperture and the surrounding wall as seen from inside, thus minimising glare.

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