Climate Responsive Architecture a Study on Hot Climate
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Abstract:
As the quote by Vitruvius indicates, designing buildings in harmony with their climates is an age-old idea. To design in conformity with climate, the designer needs to understand the microclimate of the site, since all climatic experience of both people and buildings is at this level. Besides adjusting the building design to the climate, it is also possible, to a limited extent, to adjust the climate to the needs of the building. We cannot agree with Mark Twain when he said, "Everyone talks about the weather but no one does anything about it." It is easy to see how man changes the microclimate by such acts as replacing farmland and forest with the hard and massive materials of cities, irrigating a desert and making it a humid area, and constructing high-rise buildings to form windy canyons. Unfortunately, these changes in the microclimate are rarely beneficial since they are usually done without concern for the consequences. Most serious, however, are the changes we are making to the macroclimate. Large-scale burning of fossil fuels is increasing the amount of carbon dioxide in the air. Carbon dioxide, like water vapor, is transparent to solar energy but not to the long-wave radiation emitted by the earth's surface. Thus, the ground and atmosphere are heated by the phenomenon known as the greenhouse effect. The heating of the earth might create very undesirable changes in the world's climates. Also, various chemicals are depleting the ozone layer, and large-scale cutting of tropical forests might also be creating worldwide changes in climate. To properly relate buildings to their microclimate and to make beneficial changes in that microclimate, we must first understand the basics of climate.

Keywords: Passive design, thermal performance, sun path, climate and microclimate.

1. INTRODUCTION

1.1. CLIMATE
The climate or average weather is primarily a function of the sun. The word "climate" comes from the Greek "klima," which means the slope of the earth in respect to the sun. The Greeks realized that climate is largely a function of sun angles (latitude) and, therefore, they divided the world into the tropic, temperate, and arctic zones. The atmosphere is a giant heat machine fueled by the sun. Since the atmosphere is largely transparent to solar energy, the main heating of the air occurs at the earth's surface. As the air is heated, it rises and creates a low-pressure area at ground level. Since the surface of the earth is not heated equally, there will be both relatively low- and high-pressure areas with wind as a consequence. A global north-south flow of air is generated because the equator is heated more than the poles. This global flow is modified by both the changes in season and the rotation of the earth.

The atmosphere is mainly heated by contact with the solar heated ground. On an annual basis, the energy absorb by the earth equals the energy radiated by back into space. In the summer there is gain while in winter it is loss.

The rotation of the earth deflects the north–south air currents by an effect known as coriolis force.
Another major factor affecting winds and, therefore, climate is the uneven distribution of land masses on the globe. Because of its higher heat capacity, water does not heat up or cool down as fast as the land, and the farther one gets from larger bodies of water the more extreme are the temperatures. Mountain ranges not only block or divert winds but also have a major effect on the moisture content of the air. A good example of this important climatic phenomenon is the American West. Over the Pacific Ocean solar radiation evaporates water, and the air becomes quite humid. The westerlies blow this moist air over land where it is forced up over the north south mountain ranges. As the air rises, it cools at a rate of about 3.6 degree F for every 1,000 feet. When the temperature drops the relative humidity increases until it reaches 100 percent, the saturation point. Any additional cooling will cause moisture to condense in the form of clouds, rain, or snow. On the far side of the mountains, the now drier air falls and, consequently, heats up again. As the temperature increases, the relative humidity decreases and a rain shadow is created. Thus, a mountain ridge can be a sharp border between a hot, dry and a cooler, wetter climate. Mountains also create local winds that vary from day to night. During the day, the air next to the mountain surface heats up faster than free air at the same height. Thus, warm air moves up along the slopes during the day. At night, the process is reversed: the air moves down the slopes because the mountain surface cools by radiation more quickly than the free air. In narrow valleys, this phenomenon can create very strong winds up along the valley floor during the day and down the valley at night. Also at night there is little moisture to block the outgoing long wave radiation; consequently, nights are cool and the diurnal temperature range is high - more than 30°F. On the other hand, in humid and especially cloudy regions, the moisture blocks some solar radiation to make summer daytime temperatures much more moderate below 90°F. At night, the outgoing long-wave radiation is also blocked by the moisture, and consequently, temperatures do not drop much. The diurnal temperature range is, therefore, small - below 20°F. It should be noted that water has a much stronger blocking effect on radiation when it is in the form of droplets (clouds) than in the form of a gas (humidity). The various forces in the atmosphere interact to form a large set of diverse climates.

1.2. MICROCLIMATE

For a number of reasons, the local climate can be quite different from the climate region in which it is found. If buildings are to be relate properly to their environment, they must be designed for the microclimate in which they exist. The following factors are mainly responsible for making microclimate deviate from the macroclimate:

1. Elevation above sea level: The steeper the slope of the land, the faster the temperature will drop with an increase in elevation. The limit, of course, is a vertical ascent, which will produce a cooling rate of about 3.6 degree F per 1,000 feet.

2. Form of land: South facing slopes are warmer than north facing slopes because they receive much more solar radiation. For this reason ski slope are usually found on the north slopes of mountains. South slopes are also protected from the cold winter winds.

3. Size, shape, and proximity of bodies of water: As mentioned before, large bodies of water have a significant moderating effect on temperature, they generate the daily alternating land and sea breezes, and they increase the humidity.

4. Soil types: The heat capacity, color, and water content of soil can have a significant effect on the microclimate. Light-colored sand can reflect large amounts of sunlight, thereby reducing the heating of the soil, and, thus, the air, but at the same time greatly increases the radiation load on people or buildings. Because of their high heat capacity, rocks can absorb heat during the day and then release it again at night. The cliff dwellings of the Southwest benefited greatly from this effect.

5. Vegetation: By means of shading and transpiration, plants can significantly reduce air and ground temperatures. They also increase the humidity whether or not it is, already too high. In a hot and humid climate, the ideal situation is to have a high canopy of trees for shade, but no low plants that could block the breeze. The stagnant air from low trees and shrubs enables the humidity to build up to undesirably high levels. In cold climates, plants can reduce the cooling effect of the wind. Vegetation can also reduce noise and clean the air of dust and certain other pollutants.

6. Manmade structures: Buildings, streets, and parking lots, because of their number and size, have a very significant effect on the microclimate. The shade of buildings can create a cold north like orientation on what was previously a warm southern exposure. On the other hand, buildings can create a cold north like orientation on what was previously a warm southern exposure. On the other hand buildings can create shade from the hot summer sun and block the cold winter winds. Large areas of pavement, especially dark colored...

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asphalt, can generate temperatures as high as 140 degree F. The heated air then migrates to overheat adjacent areas as well.

2. BUILDINGS

In the world history of the traditional, classical and vernacular, buildings are often described as the notion of the “fabric” as a modifier of exterior and interior climates. However, it is important to recognize that buildings serve many purposes-functional, social, symbolic and aesthetic. These functions are interwoven in the design of buildings and in the use and experience of buildings. In the architecture of the Renaissance, the climatic principles were generally overridden by the requirements of proportion, symmetry and the correct use of the Orders. Several theories may explain external environment, internal environment, people’s responses and the building fabric as interconnected and these four categories interacting in a complex way. The separation of the purposes-functional, social, symbolic and aesthetic can be useful in analysis and the separation of the Climate Building People strand is the structure of this package presented here. At the same time, it would be interesting to note that the ways in which buildings respond to climate and generate thermal comfort is closely related to the other three purposes of the buildings. A good way to understand Climate - Building interaction is to study examples of building which have been designed and constructed in extreme climates, without the benefit of scientific analysis, professional designers or recorded meteorological data. The variations in the natural climatic conditions are plotted graphically the form of a sinusoidal curve describing the diurnal pattern of increasing and decreasing temperatures. The diagram below shows an abstraction of the levels of climatic controls possible. Precisely controlled indoor climate can only be achieved by active or mechanical systems (the straight lines in the diagram above). However, this may not be the aim of the building designer. Passive design can well attenuate the extremities of the climate and sometimes cause desired comfort indoors, with little seasonal or diurnal variations. The passive systems may not provide 100% climatic control, but they substantially reduce the task of the active systems and hence make them more economical.

3. BUILDING CONFIGURATION

Shape and surroundings of any building plays a very important role in governing the energy consumption in any building. Such factors may cause heat gain when cooling is required and heat loss when heat gain is required. For any given enclosed building volume, there are numerous ways in which actual dimensions of height, length and breadth can vary resulting in different total surface areas. Thus two buildings, both having the same volume and built of the same materials, may have quiet different surface areas and hence different rate of heat loss and heat gain. The way the volume and surfaces of the building are oriented also severely affect the heat gain or loss from a building. This is best illustrated when we consider the sol air temperature effect for faces of the buildings in certain orientations. The building configuration may be such that they shade each other mutually. The amount and effectiveness of the shading, however, depends on the type of building clusters. Martin and March (1972) have classified building clusters into three basic types, i.e. pavilions, streets and courts. "Pavilions" are isolated buildings single or in clusters, surrounded by large open spaces. The "street" comprises of long building blocks arranged in parallel rows, separated by actual streets as open spaces. "Courts" are defined as open spaces surrounded by buildings on all sides. Detached buildings and those at the end of a row of buildings or similarly positioned flats in multi-storey buildings, that have more than one external wall, will obviously have greater heat gain and losses than those with only one external wall. The building designer should keep in mind that building with more than one external wall should not be confronted in the same way from an energy saving point of view as buildings with two or more external walls. Surfaces that are in direct contact with the external environment may require insulation.

Based on the climatic factors, India can be divided into six climatic zones, namely, hot and dry, warm and humid, moderate, cold and dry, cold and sunny, and composite. India comes under the composite zone. The characteristic features of composite zone are as follows:

3. HOT AND DRY CLIMATE

Most of western Rajasthan experiences an arid climatic regime. Cloudbursts are responsible for virtually all of the region's annual precipitation, which totals less than 300 millimeters (12 in). Such bursts happen when monsoon winds sweep into the region during July, August, and September. Such rainfall is highly erratic; regions experiencing rainfall one year may not see precipitation for the next couple of years or so. Atmospheric moisture is largely prevented from precipitating due to continuous downdrafts and other factors. The summer months of May and June are exceptionally hot; mean monthly temperatures in the region hover around 35 °C (95 °F), with daily maxima occasionally topping 50 °C (122 °F). During winters, temperatures in some areas can drop below freezing due to waves of cold air from Central Asia. There is a large diurnal range of about 14 °C (57 °F) during summer; this widens by several degrees during winter. East of the Thar Desert, the region running from Punjab and Haryana to Kathiawar experiences a tropical and sub-tropical steppe climate. The zone, a transitional climatic region separating tropical desert from humid sub-tropical savanna and forests, experiences temperatures that are less extreme than those of the desert. Average annual rainfall is 30–65 centimeters (12-26 in), but is very unreliable; as in much of the rest of India, the southwest monsoon accounts for most precipitation. Daily summer temperature maxima rise to around 40 °C (104 °F). The
resulting natural vegetation typically comprises short, coarse grasses.

3.1 COMFORT REQUIREMENTS FOR HOT AND DRY CLIMATE
In many arid, desert regions, buildings are designed with flat roofs, small openings, and heavy weight materials. These materials include dried mud in rural areas and reinforced concrete in urban areas. The thick exterior roof and walls help to absorb temperature fluctuations and, therefore, keep internal temperatures from rising above the outside surface temperature. An important function of the roof is its color. A white or light colored roof will stay approximately the same temperature as the outdoor air during the day, and six to ten deg C cooler than the outside air at night. This is an important feature because the cooler nighttime air will be channeled down by the sloop of the roof and into the rooms in the building. One function of the small openings is to prevent dust, a huge problem in Africa, West Asia, and West Australia, from entering buildings. Windows are arranged so that equal areas are open on the windward and leeward sides of the building. The reason for this is very simple, the air stream can be directed into rooms that need constant ventilation such as the bedroom. When one window is positioned higher than another, thermal force will direct the airflow from the high window to the lower. Courtyards, patios, and verandas are other common features of buildings in hot climates. With high walls, these outside areas provide shade and a relaxing environment to their inhabitants for social gatherings, evening entertainment, food preparation, and domestic work such as laundry. Concrete is the most common material used in the walls because it has low cost and high thermal capacity which in turn reduces internal temperatures. This keeps the patios cooler and more enjoyable. Another way to provide shade in a more aesthetically pleasing way is through greenery. For example, trees, shrubs, and bushes provide natural shade from the sun while giving the courtyard area a pleasing look. Why are these outside areas so important? They are important because essential functions happen outside like cooking and entertaining. The outside environment in hot regions is just as important as the inside because it is a daytime relief from the intense climate. The following chart was created to show the optimal comfort temperature for an outside area in a hot region. As one can see, depending on the orientation of the building, there is a different corresponding optimal temperature. Generally between the afternoon hours of the day (1:00pm to 4:00pm), the most comfortable temperature is around 30-35 degrees C.

3.2 NEED FOR PASSIVE DESIGNS
India has different climatic conditions ranging from extremely hot conditions to severely cold conditions. Energy availability is scarce and people have to protect themselves from these extremities of the climate in a natural way. Traditional architecture exhibits variety of building design suited to the respective climatic conditions. The month wise climatic data available for 233 stations spread over the whole country has been analysed by the CBRI, Roorkee. The various climatic zones thus determined have been delineated on the map of the country. The various stations have been categorised under one or the other climatic zone if their climate conformed for six or more months, otherwise it is placed under the composite zone. The idea of using solar energy to heat and cool our buildings is not new. For centuries man has made use of sun’s energy. In early days sun was used to temper the indoor climates. The earth’s climate is dependent on solar energy. Earlier, man was aware of the advantages of finding a cave or placing wall openings in the direction of the sun’s path to capture its warmth during winter days and the unique ability of certain materials to retain sun’s warmth and release it later after the sun had set. Therefore, the designs, materials and orientation that exploited the natural energy flows around the inhabitants were chosen. Basic form and material were carefully refined to introduce solar heat or to keep out the sun as per requirement. Man continually explored new avenues of harnessing solar energy for the service of mankind. It is only during the recent times that these essential principles of design set forth in the rich heritage of ancient architecture have been neglected. Despite the increased sophistication and reliability of solar powered devices, none of the early applications of solar energy survived competition with the emerging use of cheaper fossil fuels. Although solar energy was free and readily available, the capital investment was very high.

3.3 PASSIVE TECHNIQUES AND FEATURES
The first step to achieve passive cooling in a building is to reduce unnecessary thermal loads that might enter it. Usually, there are two types of thermal loads
(1) Exterior loads due to the climate.
(2) Internal loads due to people, appliances, cooking, bathing, lights etc. Proper zoning of different components and local ventilation of major heat sources can reduce the overall impact of internally generated heat loads

Depending on the weather, the thermal load enters into a building in three major ways:
(a) Penetration of direct beam sunlight.
(b) Conduction of heat through walls, roofs etc.
(c) Infiltration of outside air.

4. HEAT GAIN PREVENTION TECHNIQUES
A. Reduction of Solar and Convective Heat Import
The interaction of solar radiation by the building is the source of maximum heat gain inside the building space. The natural way to cool a building, therefore, is to minimise the incident solar radiation, proper orientation of the building, adequate layout with respect to the neighbouring buildings and by using proper shading devices to help control the incident solar radiation on a building effectively. Good shading strategies help to save 10%-20% of energy for cooling. Properly designed roof overhangs can provide adequate sun protection, especially for south facing surfaces. Vertical shading devices such as trees, trellises, trellised vines, shutters, shading screens awnings and exterior roll blinds are also effective. These options are recommended for east-facing and west-facing windows and walls. If ambient temperatures are higher than the room temperature, heat enters into the building by convection due to undesirable ventilation, which needs to be reduced to the minimum possible level. Adequate wind shelter and sealing of windows reduces the air infiltration and this requires proper planning and landscaping. Figure 2 shows some of the heat gain prevention techniques.

B. Orientation of Building
Maximum solar radiation is interrupted by the roof (horizontal surface) followed by the east and west walls and then the north wall during the summer period, when the south oriented wall receives minimum radiation. It is therefore desirable that the building is oriented with the longest walls facing north and south, so that only short walls face east and west. Thus only

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the smallest wall areas are exposed to intense morning and evening sun.

C. Shading by Neighboring Buildings
The buildings in a cluster can be spaced such that they shade each other mutually. The amount and effectiveness of the shading, however, depends on the type of building clusters. Martin and March (1972) have classified building clusters into three basic types, i.e., pavilions, streets and courts. Pavilions are isolated buildings, single or in clusters, surrounded by large open spaces. Street, long building blocks arranged in parallel rows, separated by actual streets in open spaces and courts are defined as open spaces surrounded by buildings on all sides.

D. Shading by Vegetation
Shading by trees and vegetation is a very effective method of cooling the ambient hot air and protecting the building from solar radiation. The solar radiation absorbed by the leaves is mainly utilized for photosynthesis and evaporative heat losses. A part of the solar radiation is stored as heat by the fluids in the plants or trees. The best place to plant shady trees is to be decided by observing which windows admit the most sunshine during peak hours in a single day in the hottest months. Usually east and west oriented windows and walls receive about 50% more sunshine than the north and south oriented windows/walls. Trees should be planted at positions determined by lines from the centers of the windows on the west or east walls toward the position of the sun at the designated hour and date. On the south side only deciduous trees should be planted.

E. Shading by Overhangs, Louvers and Textured Façade
The devices which provide shading to an opening can be classified into three types:

i) movable opaque, e.g., roller blind, curtain etc can be highly effective in reducing solar gains but eliminates view and impedes air movement;

ii) louvers which may be adjustable or fixed affect view and air movement to some degree and provide security; and

iii) fixed overhangs: easy to attain on single storey buildings with overhanging roof. Also gives rain protection to walls and openings and has little or no effect on view and air movement.

Maximum solar radiation in summer is incident on the roof. It is, therefore, advisable to protect the roof from the sun as far as possible.

F. Shelter Against Hot Winds
Hot winds during summer in hot and dry climatic conditions are a source of large convective heat gain and a source of extreme thermal discomfort. Wind shelter for a building can be provided by taking the advantage of the existing topography, such as an elevated landmass or by creating wind barriers in the form of trees, shrubs, fences or walls. Usually, an opaque barrier creates a turbulent flow of wind and one has to avoid the accumulation of heat from the sun-irradiated surfaces between the barrier and the surface.

5. ROOFING TECHNIQUES
A building can cope up with seasonal weather changes by tuning itself to the heat sources or heat sinks with which it is coupled. The heat sources should be at temperatures higher than the temperatures inside the building, whereas the heat sink must be at a lower temperature. Usual heat sources are sun or the earth, while the heat sinks are the ambient air, radiant sky and the earth. Figure 3 shows the traditional and modern roofing techniques.

A. Shading of Roof and Walls
Surface shading can be provided as an integral part of the building element or by the use of a separate cover. Highly textured walls have portions of their surfaces in the shade. The radiation absorbing area of such a textured surface is less than its radiation emitting area and therefore it will be cooler than a flat surface. The increased surface area will also result in an increased coefficient of convective heat transfer, which will permit the building to cool down faster at night when the ambient temperature is lower than the building temperature. An alternative method is to provide a cover of deciduous plants or creepers. Because of the evaporation from the leaf surfaces, the temperature of such a cover will be lower than the daytime air temperature and at night it may even be lower than the sky temperature as in. In addition to shading, this arrangement provides an increased surface area for radiative emission, and an insulating cover of still air over the roof which impedes heat flow into the building, while still permitting upward heat flow at night. Although, the system of earthen pots is thermally efficient, the method suffers from practical difficulties because the roof is rendered unusable and its maintenance is difficult. An effective roof-shading device is a removable canvas cover. This can be mounted close to the roof in the daytime and at night it can be rolled up to permit radiative cooling. The upper surface of the canvas should be painted white to minimize the amount of absorbed radiation by the canvas and the consequent conductive heat gain through it.

B. Reflecting Surfaces
If the external surfaces of the building are painted with such colours that reflect solar radiation (in order to have minimum absorption), but the emission in the long wave region is high, then the heat flux transmitted into the building is reduced considerably.

C. Building Surface Cooling
Cooling of building surfaces by evaporation of water provides heat sink for the room air for dissipation of heat. Maintenance of water film over the surface of building element especially the roof brings down its temperature below the wet-bulb temperature of the ambient air even in the presence of solar radiation thus making the roof surface to act as a means of heat transmission from inside the building to the ambient air without increasing the humidity of the room air. Roof surface evaporative cooling consists of maintaining a uniform thin film of water on the roof terraces of buildings. This causes the roof temperature to achieve a much lower value than the other elements. The roof evaporation process can be very effective in hot and dry and also in warm and humid climate zones because of the incident solar radiation. The effect of roof surface cooling depends on the type of construction.

D. Roof Ponds
Water stored on the roof acts as a heat source and heat sink both during winter and summer climatic conditions. The thermal resistance of the roof in this system is kept very small. In summer during the day, the reflecting insulation keeps the solar heat away from water, which keeps receiving heat through the roof from the space below it thereby cooling it. In the night, the insulation is removed and water, despite cooling the living space below, gets cooler on account of heat losses by evaporation, convection and radiation. Thus the water,
regains its capacity to cool the living space. In winter, the insulation is removed during the day. Water and black surface of the roof absorb solar radiation; the living space continues to receive heat through the roof. During night water is covered with insulation to reduce heat losses.

6. DESIGN CONSIDERATIONS FOR BUILDING IN WARM AND HUMID ZONE

The basic design strategy for warm and humid tropical zones can be summarized as follows: -

1. The reduction of heat gains by radiation and the utilization of air movements to remove heat from building elements and to assist the human organism (finding temperature balance by evaporative cooling) are the two equally most important factors. Thus, minimizing the exposure of external building surfaces to direct solar radiation (especially roofs, and east and west facades) should be achieved by the choice of the buildings’ form and its place amongst neighboring buildings, natural slopes or vegetation.

2. Openings in the most directly exposed facades should be avoided (specially sleeping room windows in west-facades) or very carefully shaded. Shading of all openings and outdoor spaces next to the building is desirable. Orientation of buildings and openings to allow good cross-ventilation of rooms and ventilated roof spaces by natural prevailing air movements also has highest priority.

3. Heat storage in building materials should be minimized, because due to the lack of low night temperatures a time lag of heating up and cooling out of thermal mass cannot be utilized (as it can be done in hot and dry climatic zones). Therefore, we should prefer lightweight materials with low absorption of radiation on the outside.

4. While traditional construction techniques in these zones often used thin walls of organic materials, sometimes made as woven, well ventilated mats, requirements of today's mass society (like security or fire resistance) lead to massive materials in many cases. Then the thermal mass should be reduced, e.g., by using hollow blocks or bricks for relatively thin walls and by placing a sufficient percentage of controllable openings in the walls.

5. Thermal insulation materials can have a reverse effect, when for some reason the temperatures indoor are even higher than those outdoor (e.g., due to a high occupancy of rooms for hours) and the building's insulation obstructs a quick heat loss. Also they are usually inefficient, when for the sake of cross ventilation the facade openings cause indoor temperatures which are very close to outdoor shade temperatures. Therefore, insulation materials should be carefully checked for efficiency, which is usually limited, e.g., to very exposed roof elements.

6. It has to be pointed out, that in warm and humid climate zones if is not the high air temperature (which is lower than in hot and dry zones) but its combination with high humidity that is the main problem to cope with.

7. In most warm and humid zones heavy seasonal rainfalls are occurring, which require a careful planning of water flows at and around the buildings. Sloped roofs with wide overhangs are, therefore, a traditional architectural pattern.

8. In context with cooling of buildings in warm-humid climates, the passive techniques mainly aim towards reduction in heat penetration through building envelope and provision of fenestration for inducing desired natural ventilation indoors.

9. Reduction in Heat Penetration through Building Envelope

Solar radiation incident on building envelope is the main source of heat responsible for raising the temperature of exterior surface of the envelope and also for creating temperature gradient across the thickness of the envelope. As a result, heat is conducted indoors thereby causing a rise in the interior surface temperature. Hence, reduction in the temperature of exterior surface is necessary for keeping the indoor surface temperature at a low value. Transparent window facing sun also permits direct entry of sun. This also contributes to the rise in the temperature of indoor surfaces. Hence, control of direct entry of sun through windows is an essential requirement for preventing the rise in interior surface temperature. Based on these considerations, various methods have been evolved for curtailment of heat flow through building envelope.

10. Optimum Orientation

It is well known that the amount of daily solar radiation incident per unit area on N and S facing walls is much less as compared to that on the walls facing other directions. Hence, for minimum solar heat gain by the building envelope, it is desired that the longer axis of building should lie along East-West direction. Further, the effect of orientation of a building on heat penetration through envelope also depends on the aspect ratio length/breadth of the building. For a building with square plan, i.e., aspect ratio 1:1 and glass area equally distributed on all the four walls, the effect of orientation is nil, while for a rectangular building with aspect ratio 2:1, the fabric load is reduced by 30% due to change in orientation from worst to best.

11. Shading of Windows

Louvers, overhangs or awnings provided on windows help control direct entry of sun into the room especially during summer months. Optimum dimensions of the louver depend on the duration of sunshine on the window facade. Windows of the same dimensions but oriented differently should have different dimensions of louvers to be effective. A simple box type louver3 may be suitable on an eastern facade, a slightly more complicated vertical and horizontal louver system on the southern facade and an egg crate type on the western facade. The northern facade receives only very early morning or late afternoon sunshine and hence no elaborate systems are needed and only rain shade is sufficient. It is reported4 that overhang with optimum dimensions can produce cooling load reduction of 12.7% in summer without causing any sufficient change in sunshine hours received in winter. It is worth mentioning that an overshadowing of the windows must be avoided as it reduces availability of daylight indoors, which in turn results in increased consumption of energy for artificial lighting.

12. Exterior Surface Solar Reflectance: Surface color of the external wall affects both the percentage of solar radiation absorbed by the external surface and also the long wave radiation emission. Hence, the heat flux transmitted into the building is considerably reduced when external surface is painted with a color with minimum absorption of solar radiation and high emission in long wave region. Such data for a few materials are given in Table 1. Simulation studies conducted at Lawrence Berkeley Laboratory USA indicate that by changing the overall albedo of a city from an existing value of about 0.2 to a white washed of 0.4 may result in saving of electrical energy by 40% to 50%.

13. Roof and Wall Insulation: Provision of insulation on walls and roof of a building increases their thermal resistance and curtails conductive heat flow through the building envelope. Recommended thicknesses of some of the insulating materials for roofs of unconditioned and conditioned buildings are given in Table 2. Introduction of air cavity in a wall also increases its thermal resistance. Studies on estimation of thermal properties of such a wall revealed that the overall heat

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transmission co-efficient U value of a 27.5 cm brick cavity wall (11.25 cm brick + 5.0 cm air gap + 11.25 cm brick) is 1.63 W/m² K while that of a 22.5 cm solid brick wall with 1.25 cm cement plaster on both the side U value is 2.26 W/m² K. Here, it is worth emphasizing that the thermal performance of the above cavity wall is slightly better than that of a 35 cm solid brick wall.

14. Energy Efficient Windows: Window is a critical component in the design of energy efficient buildings. The most effective way of window design to conserve energy is by optimizing the window size and location. Windows on East and West facades should be avoided as these are the worst orientations from the heat gain point of view. In air conditioned buildings, windows are considerably less insulating than other parts of the envelope of the structure. It is observed that for a single glazed window system the U value is 5.22 W/m² K which is less than the desired value. The U value is considerably less (3 W/m² K) for a window system consisting of a double glazing with an air gap of 12 mm-18 mm. Adoption of such a system reduces heat gain by at least 10%.

7. GUIDELINES FOR INDUCEMENT OF AIR MOTION Indoors

1. For achieving maximum benefit from natural wind, buildings need not necessarily be oriented perpendicular to the prevailing outdoor wind; these may be oriented at any convenient angle between 0o and 30o without losing any beneficial aspect of breeze. If the prevailing wind is from East or West, buildings can be oriented at 45o to the incident wind for diminishing the solar heat gain without significantly affecting the air motion indoors.

2. At least one window should be provided on windward wall and the other on leeward wall

3. Maximum air movement at a particular plane is achieved by keeping the sill height at 85% of the height of the plane.

4. In rooms of normal size having identical windows on opposite walls, the average indoor air speed increases rapidly by increasing the width of window up to about 2/3 of the wall width; beyond that the increase maximum is in much smaller proportion than the increase of the window width.

5. The average indoor wind speed in the working zone is maximum when window height is 1.1 m. Further increase in window height promotes air motion at the top level of window, but does not contribute additional benefits as regards air motion in the occupancy zone in buildings.

6. For a total fenestration area (inlet plus outlet) of 20% to 30% of floor area, the average indoor wind velocity is around 27% of outdoor velocity. Further increase in window size increases the velocity but not in the same proportion. In fact, even under ideal conditions the maximum average indoor wind velocity does not exceed 40% of the outdoor velocity.

7. In regions having fairly constant wind direction, the size of the inlet should be kept within 30% to 50% of the total area of fenestration and building should be oriented perpendicular to the incident wind. Since, inlets smaller than outlets are more sensitive to change in wind direction, openings of equal sizes are preferred in the regions having frequent changes in wind direction.

8. In case of room with only one wall exposed to outside, provision of two windows is preferred to that of a single window.

9. Windows located diagonally opposite to each other, with the windward window near the upstream corner, give better performance than other window arrangements for most of the building orientations.

10. Provision of horizontal sashes inclined at an angle of 45o in the appropriate direction helps to promote the air motion inside rooms. Sashes projecting outward are more effective than those projecting inwards.

11. Roof overhangs help air motion in the working zone inside buildings.

12. Verandah open on three sides is preferable because it causes an increase in the room air motion for most of the orientations of building with respect to the incident wind.

13. Horizontal louver, i.e. a sunshade, atop a window deflects the incident wind upward and reduces air motion in the zone of occupancy. A horizontal slot between the wall and horizontal louver prevents upward deflection of air in the interior of rooms. Provision of L type louver increases the air motion in the room provided that the vertical projection does not obstruct the incident wind (Figures 13(a) and 13(b)).

14. Air movement at working plane 0.4 m above the floor can be enhanced by 30% using a pelmet type wind deflector.

15. A partition placed parallel to the incident wind, has little influence on the pattern of air flow but when located perpendicular to the main flow, the same partition creates a wind shadow. Provision of a partition with spacing of 0.3 m underneath, helps augmenting air motion near floor level in the leeward compartment of wide span buildings.

16. Air motion in a building unit having windows tangential to the incident wind is accelerated when another unit is located at end-on position on downstream side.

17. Air motion in a shielded building is less than that in an unobstructed building. To minimize the shielding effect, the distance between the two rows should be about 8 H for semidetached houses and 10 H for a long row of houses. However, the shielding effect is diminished by raising the height of the shielded building.

18. Air motion in two wings oriented parallel to the prevailing breeze is promoted by connecting them with a block on the downstream side.

19. Air motion in a building is not affected by constructing another building of equal or smaller height on the leeward side, but it is slightly reduced if the leeward building is taller than the windward block.

20. Hedges and shrubs deflect the air away from the inlet openings and cause a reduction in air motion indoors. These elements should not be planted at a distance less than 8 m from the building because the induced air motion is reduced to minimum in that case. However, air motion on the leeward part of the building can be enhanced by planting a low hedge at distance of 2 m from the building.

21. Trees with large foliage mass having trunk bare of branches up to the top level of window, deflect the outdoor wind downward and promote air motion in the occupancy zone inside the buildings.

22. Ventilation conditions indoors can be ameliorated by constructing buildings on earth mound having a slant surface with a slope of 10o on upstream side.

23. A non-conventional system of ventilation, commonly called wind tower, helps to induce air motion in rooms devoid of windows on two exposed walls. The wind tower consists of a vertical wind carrying shaft with a wind scooping attachment atop thereof. On its vertical sides, the shaft is provided with several openings, which connect the tower to the different rooms intended to be ventilated. Openings in rooms are also provided on walls other than the one facing the tower. Such an arrangement of openings facilitates cross ventilation in the rooms. The impingement of wind on the face of the tower causes development of positive pressure thereon. As the wind flows around the building, separation of flow

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takes place at the windward edges and negative pressure is created over all the leeward faces of the building. Thus, a pressure difference exists between the tower inlet and openings located on the leeward side of the rooms. Consequently, flow of wind occurs from tower inlet to the room openings. In the process, the wind entering through the wind tower sweeps the room area and finally exits through the room opening thereby ventilating the room.

8. CONCLUSION

With the globalization, we all lost our relationship with the environment, and the resulting built environment which was non responsive to the environment needed. This was resulting high amount of energy, which in turn increases the temperature of air around the building and urban canyon. Streets are the stage set upon which the drama of urbanity takes place. Street canyon refers to a street with buildings lined up continuously along both sides. The dimensions of a street canyon are expressed by its “aspect ratio”. The psychological quality of a canyon is basically discussed with elements such as accessibility, gathering public ness, safety, comfort, livability and participation. These psychological qualities greatly affected by environments comfort conditions of that street or canyon.

9. REFERENCE


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