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Climatic Conditions and Design Considerations for Hot and Dry Climate of Ahmedabad, India

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***Abstract*— This paper studies the climatic conditions of hot and dry climate of India and the climatic conditions of Ahmedabad region. The study of sun path, wind speed, Average temperatures and precipitation, maximum temperatures and solar radiation received on each face of a building and roof in Ahmedabad. The paper suggests the basic design consideration for the building in Ahmedabad region to provide a cost efficient building for a year round performance.**

***Index Terms*—hot and dry, climatic conditions, solar radiation, design strategies, cost efficient building.**

I. Introduction

INDIA can be broadly categorized into five regions with distinct climates (hot and dry, warm and humid, composite, temperate and cold).The hot and dry zone lies in the western and central part of India i.e. Rajasthan, Parts of Gujrat, Parts of Maharashtra.

It requires special provisions in the functional design of buildings with respect to human thermal comfort and energy efficiency. Climatic of the hot and dry region are:

1. Hot dry in summer and cold in winter
2. Very little rainfall
3. Very low humidity
4. High temperature difference between night and day
5. Hot winds and frequent dust storms
6. High summer day time temperature (32-36 c)
7. High direct solar radiation
8. Clear sky most of the year
9. Sandy or rocky ground with very low vegetation cover.

In summer, the maximum ambient temperatures are as high as 40–45 ºC during the day and 20–30 ºC at night. In winter, the values are between 5 and 25 ºC during the day and 0 to 10 ºC at night. The climate is described as dry because the relative humidity is generally very low, ranging from 25 to 40 % due to low vegetation and surface water bodies.

The night is usually cool and pleasant. A generally clear sky, with high solar radiation causing an uncomfortable glare, is typical of this zone.

As the sky is clear at night, the heat absorbed by the ground during the day is quickly dissipated to the atmosphere. Hence, the air is much cooler at night than during the day.

II. Climate of Ahmedabad

The region Ahmedabad is situated in the banks of River Sabarmati, the most prominent and important city of Gujarat i.e. Ahmedabad experiences a semi-arid hot climate. The weather and climate in Ahmedabad is largely influenced by the Arabian Sea. The average temperature of the city ranges in between 12 degrees to 41 degree Celsius. Like most of the other parts in India, the climate in Ahmedabad also revolves round three main important seasons. Let us check the weather in Ahmedabad during the three major seasons.

Summers in Ahmedabad- Summers enter the city in the month of March and continue till July. The summer months in Ahmedabad are characterized by extreme hot and dry climate. The minimum average temperature is about 23°C while the maximum temperature is 43°C. The highest temperature that has been recorded in the city till date is 47°C.

Monsoons in Ahmedabad- South western monsoons sweep into Ahmedabad in mid-July. During this time weather and climate in Ahmedabad is humid. Monsoon continues till the month of September. The average annual rainfall received by the city is 93.2 cm. The monsoons are often characterized by torrential infrequent rains.

Winters in Ahmedabad- Ahmedabad experiences a very dry climate in the winter months i.e. from November to February. With average temperature of minimum 15°C and maximum 30°C, the Ahmedabad climate is pleasant and comfortable during this time. In January, Cold Northerly winds blow through the region. The lowest temperature that has been recorded in Ahmedabad during the winters is 5°C.

A. *Sun Path*

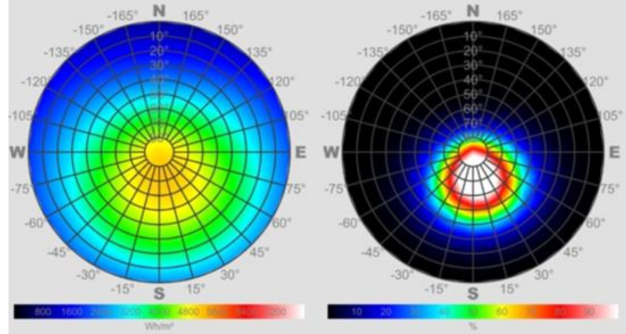

Fig. 1. Yearly Solar Radiation on different directions and slopes

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Left diagram shows the surfaces with maximum total solar energy whereas Right diagram shows Active Strategy Analysis (surfaces with maximum performance through all months of the year).

B. Wind Speed

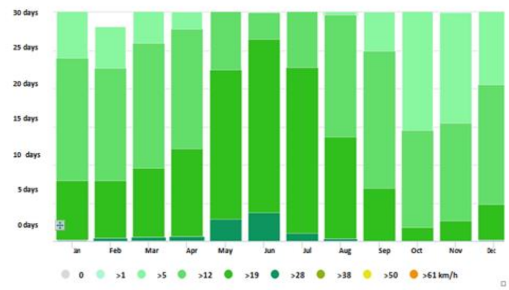


Fig. 2. Wind speed (days per month)

The diagram for Ahmedabad shows the days per month, during which the wind reaches a certain speed. An interesting example is the Tibetan Plateau, where the monsoon creates steady strong winds from December to April, and calm winds from June to October.

Wind speed units can be changed in the preferences (top right).

C. Average Temperature and Precipitation

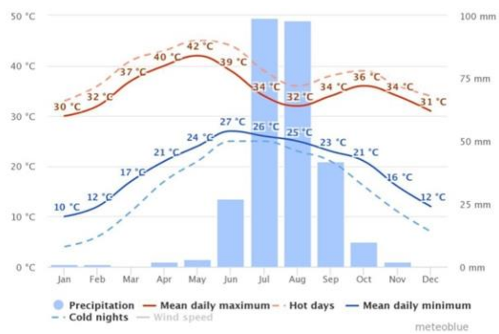


Fig. 3. Average temperature and precipitation

The "mean daily maximum" (solid red line) shows the maximum temperature of an average day for every month for Ahmedabad. Likewise, "mean daily minimum" (solid blue line) shows the average minimum temperature. Hot days and cold nights (dashed red and blue lines) show the average of the hottest day and coldest night of each month of the last 30 years. For vacation planning, you can expect the mean temperatures, and be prepared for hotter and colder days. Wind speeds are not displayed per default, but can be enabled at the bottom of the graph.

D. Maximum Temperature

The maximum temperature diagram for Ahmedabad displays how many days per month reach certain temperatures. Dubai, one of the hottest cities on earth, has almost none days below 40°C in July. You can also see the cold winters in Moscow with a few days that do not even reach -10°C as daily maximum.

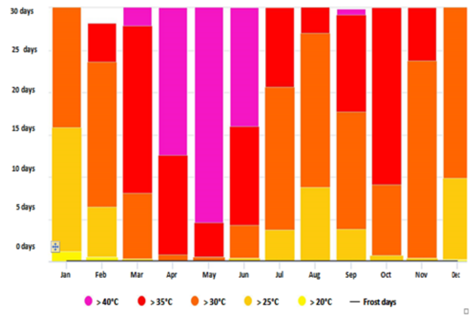


Fig. 4. Maximum temperature

E. Cloudy, Sunny, and Precipitation Days

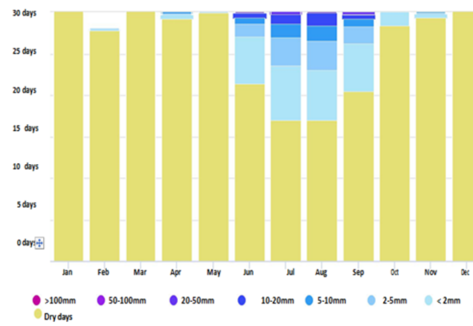


Fig. 5. Cloudy, sunny, and precipitation days

The precipitation diagram for Ahmedabad shows on how many days per month, certain precipitation amounts are reached. In tropical and monsoon climates, the amounts may be underestimated.

F. Precipitation Amount

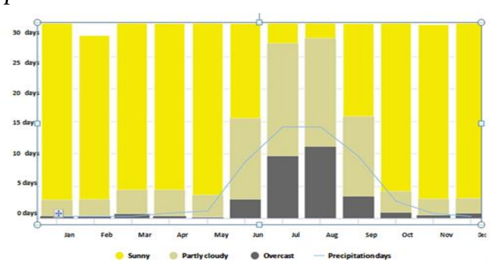


Fig. 6. Precipitation amount

The graph shows the monthly number of sunny, partly cloudy, overcast and precipitation days. Days with less than 20% cloud cover are considered as sunny, with 20-80% cloud cover as partly cloudy and with more than 80% as overcast.

III. Design Consideration for Hot and Dry Climate of Ahmedabad

A. Landscaping

Landscaping is an important element in altering the micro-climate of a place. Proper landscaping reduced direct sun from striking and heating up building surfaces. It is the best way to provide a buffer for heat, sun, noise, traffic, and airflow or for diverting airflow or exchanging heat in a solar-passive design.

It prevents reflected light carrying heat into a building from the ground or other surfaces.

Fig. 7. Landscaping

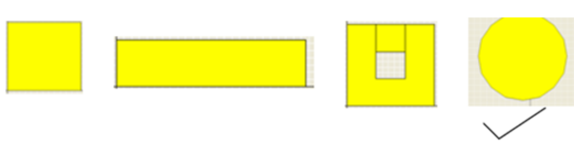
Deciduous trees provide shade in summers and sunlight in winters; hence, planting such trees on the west and southwestern side of the building is a natural solar passive strategy. On the other hand, evergreen trees on the north and north-west of the building provide shade round the year. The use of dense trees and shrub plantings on the west and southwest sides of a building will block the summer setting sun.

Fig. 8. Natural cooling

Natural cooling without air-conditioning can be enhanced by locating trees to channel southeasterly summer breezes in tropical climates like India. Cooling breezes will be able to pass through the trunks of trees placed for shading. Shade can also be created by using a combination of landscape features, such as shrubs and vines on arbours or trellises. Place trees approximately half the width of the tree's canopy from the building and spaced at 1/4th to 1/3rd the canopy width. This parameter should also be considered for good daylight integration inside the built spaces.

B. Building Form

Building form can affect solar access and wind exposure as well as the rate of heat loss or heat gain through the external envelope. The volume of space inside a building that needs to be heated or cooled and its relationship with the area of the envelope enclosing the volume affect the thermal performance of the building. Building form can affect solar access and wind exposure as well as the rate of heat loss or heat gain through the external envelope. The general design objectives are –



Compactness- The building form also determines the air flow pattern around the building directly affecting its ventilation. The compactness of the building is measured using the ratio of surface area to volume (S/V). The depth of a building also determines the requirement for artificial lighting. The greater the depth, higher is the need for artificial lighting. The circular geometry has the lowest S/V ratio thus the conduction gains from the building envelope as well as solar gains from windows are least, in circular geometry in comparison to other building geometries which is most energy efficient in hot & dry climate.

Sheltering or self-shading- Built form, which is designed such that it is self-shaded through massing or articulation results in sheltered built forms, and cuts off a large amount of direct solar radiation. In hot & dry climate, the envelope should be designed so that it remains shaded for the greater part of the day; the external walls should be so planned that they shade each other.

C. Water Bodies

Water is a good modifier of micro-climate. It takes up large amount of heat in evaporation and causes significant cooling.. It possesses very high thermal storage capacity much higher than the building materials like Brick, concrete, stone. Large bodies of water in the form of lake, river, and fountain generally have a moderating effect on the temperature of the surrounding area due to the higher thermal storage capacity of water compared to land and cause variations in airflow. During the day the air is hotter over the land and rises, drawing cooler air in from the water mass resulting in land breezes. During the night as the land mass cools quicker, the airflow will be reversed. Water evaporation has a cooling effect in the surroundings.

D. Orientation

Orient the buildings with the long axes in the east-west direction so that the longest walls face north and south, and only the short wall face east and west.

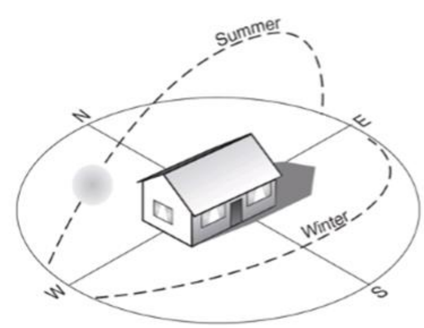


Fig. 9. Orientation

TABLE I
AVERAGE SOLAR RADIATION

Average Solar radiation Intensity on various facades of a building in hot & dry climate (Ahmedabad city)		
Facade Orientation	**Solar Radiation Intensity (W/m^2)**	**Month of maximum solar intensity**
North Facing	80	May (in morning hrs), June (in evening hours)
South Facing	600	December, January (winters)
East Facing	600	March
West Facing	500	March

Examples of average Solar Radiation received on various facades in hot & dry climate zone of Ahmedabad City.

South orientation receives maximum solar radiation during winters which is preferable. East and West receive maximum solar radiation during summer. West is a crucial orientation because high intensity of solar radiation is received during summers, when the internal gains are also at its peak. Thus, designers need to be very careful while designing West facade and spaces behind West facade. Orientation also plays an important role with respect to wind direction. At building level, orientation affects the heat gain through building envelope and thus the cooling demand, orientation may affect the daylight factor depending upon the surrounding built forms, and finally the depending upon the windward and leeward orientation fenestration could be designed to integrate natural ventilation.

E. Shaded Envelop

1) Roof

All the elements of a building are vulnerable to heat gains. Proper shading is therefore a very important aspect in building design. It is observed using software simulations that, shading of roof, walls and windows have considerable potential in reducing the cooling energy consumption. This section explains the technical details and advantages of shaded envelope (Roof, Walls and Windows).

Fig. 10. Roof

Shading roof: Shading of roof through design features like pergolas or solar photovoltaic panels helps in reducing the incident direct solar radiation on the roof surface. This in turn helps to reduce the air temperature of the roof and conduction gains in the space below. It is observed using software simulations that shading of roof has equal potential in reducing the cooling energy consumption to that of an insulated roof.

Cool roof: Along with shading of roof, solar passive design also recommends cool roof. Cool roofs are roofs covered with a reflective coating that has high emissivity property which is very effective in reflecting the sun‘s energy away from the roof surface. This quality greatly helps in reducing the cooling load that needs to be met by the HVAC system. Combination of insulated roof with cool roof has high saving energy potential.

2) Window

External shading is the most effective ways of shading, as it cuts off direct sunlight during summer and allows winter sunlight to enter inside the space. However, in cloudy weather or if not designed properly, these can reduce daylight availability inside the space. For such cases, external moving shading devices are preferred.

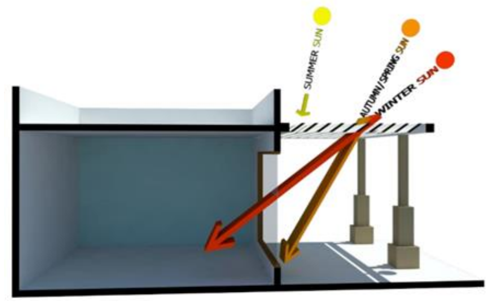


Fig. 11. Window

External shading devices should be designed according to the orientation of façade. For instance on North orientation minimum or no shading is required. On South orientation external shades should be designed after studying the sun path. Shading devices on South orientation could be permanent in nature, as most part of the day, Sun remains in South orientation. It is preferable to design movable external shading devices on East and West facades, so that the shades could be removed after sun faces opposite orientation.

3) Wall

Shading walls from direct sun can be one of the simplest and most effective ways of reducing the heat load on a building. Clever use of shade can dramatically improve the comfort conditions inside and reduce reliance on expensive air conditioning systems. As in the hot & dry climate, the East and West facades receive maximum solar intensity especially in summers, shading the East and West facades is a challenge. As eastern and western walls heat significantly in summers, Overhangs may not be enough. The entire east and west walls have to be shaded to protect from the strong summer solar intensity.

IV. Conclusion

The purpose of the current study was to determine the features of hot and dry climate in India and the climatic conditions of Ahmedabad region.

The study focused on the design consideration for hot and dry climate of Ahmedabad and the better strategies for planning of a year round building. The solar passive technologies can increase the efficiency of the building and reduces the cost of the project by avoiding the use of costly technologies for cooling purpose.

The proper location and choice of trees and water bodies in landscaping protects the building from direct solar radiation whereas orientation of the building with the long axes in the east-west will help in providing less sun radiation in the building. The shading provided for roof, window, and walls helps to prevent direct sun.

Proper using of thermal insulating material i.e. lime concrete, Rubber Crete concrete, pressed clay and many more material also give proper performance in hot and dry climate.

By enacting such sustainable building policies the overall cost of the building can be reduced. However, more research on this topic needs to be undertaken.

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