

Course Name: Bioclimatic Architecture: Futureproofing with Simple and Advanced Passive Strategies

Professor: Dr. Iyer Vijayalaxmi Kasinath

Department of Architecture,

School of Planning and Architecture, Vijayawada

Week: 03

Lecture 01

Climate characteristics in India - warm-humid, hot-dry

Hello everyone. So, in the last couple of classes, we saw how climate is classified. We saw how Koppen classification is accepted worldwide and how it is extremely detailed, and it is denoted with a lot of subclassification. We also saw how India has classified its climate. That is basically warm-humid, hot, dry, composite, temperate, and cold. So, it is a very broad classification.

But Koppen is much more detailed. Today we will see what the climate types of India are and their characteristics. What do you mean by saying that a place is warm and humid or hot and dry or temperate or cold or composite? So, what aspects comprise its characteristics? First, we will start with the warm and humid climate. Under warm and humid climate, we will study its geographical distribution, what are the climate characteristics, what are the environmental challenges in a warm and humid climate, and what are the broad building design considerations for this climate.

Finally, we will also see what NBC says. First, let us look at its geographic distribution. Now, the National Building Code of India in NBC 2005 has divided the country into five climatic zones. It classifies the warm and humid climate zone with the following temperature and relative humidity: It says that the mean monthly maximum temperature should be above 30 degrees Celsius and the relative humidity must also be above 55%.

Or the mean monthly maximum temperature should be above 25 degrees Celsius and the relative humidity should be very high. It should be above 75%. Geographically, the warm and humid climate zone covers the coastal belt of India. If you actually see what NBC says, then the coastal belt of India is warm and humid. So, up to 300 to 400 kilometers inland of the coast, which covers most of the south part of India.

So, most of the warm-humid climate lies in the southern part of India, and a large part on the northeast side also falls under warm and humid. In general, if you see Colombo,

Singapore, Hawaii, Malaysia, Goa, Mumbai, Vishakapattinam, Kolkata, Puri, Tripura, these places fall under warm and humid zone. Today, we will take the case of Chennai as a city and look at its climate classification, as Chennai is classified as having a warm and humid climate. Now, Chennai has a dry summer, tropical wet, and dry climate as far as Koppen climate classification is concerned, and it is designated as AS in Koppen climate classification. If you look at the maximum average dry bulb temperature of Chennai, you can see that for most parts of the year, the maximum average dry bulb temperature lies between 31 and 37.

5 degrees Celsius. So the maximum temperature ranges between 35 degrees and 37.4 degrees during the month of May, March to May. So, this entire time period is a very warm time period for Chennai. The minimum temperature, if you see, then for most parts of the period, the minimum temperature ranges somewhere between 21 degrees to say, 27 degrees centigrade, which means the diurnal variation is not high.

That is the main characteristic feature that the diurnal variation is not high. Now, if we look at the climate of Chennai based on what is given by IMBD, we can see that for a particular year for almost 6 months, the record high temperature has crossed 40 degrees Celsius. So, if you look at the combination of the temperature and the relative humidity, you can see how taxing the climate could feel. Also, you can see that the mean daily maximum temperature for a large part of the year is above 30 degrees Celsius plus. So, this high temperature in combination with the high relative humidity makes this place very sultry and sticky, and you tend to sweat a lot.

Let us look at the humidity characteristics. So, the average relative humidity here ranges between 60 and 80 percent, and the humidity is low as compared to the other months between April and maybe early August or July. So, between April and July, when it is extremely hot, the relative humidity takes a slight dip. Otherwise, it is largely in the range of 60 to 80 percent throughout the year. The highest is during November to March, and it could range even between 90 and 96 percent, and the lowest is during March to June, and it ranges between 40 and 50 percent.

If you look at wind speed, the average wind speed ranges between 1.8 meters per second and 3.8 meters per second. Whereas, for the sultry part between October and December, the wind speed is very minimal, sometimes not perceivable, and can be said to be about 0 meters per second. In June, there is a tendency to have high wind speeds of even up to 7 meters per second.

So, generally, if we see, we can conclude that Chennai has high humidity and extremely low wind speeds. And let us look at precipitation. The precipitation period of the year lasts

for about 6 to 9 months starting from April to January with a sliding 31-day rainfall of at least 120 mm. The month with the most rainfall in Chennai is November, with an average rainfall of 280 mm. The rainless period of the year lasts for 3 months from January to April.

The month with the least rain in Chennai is March, with an average rainfall of about 10 mm. The intensity of rainfall will vary from one warm-humid place to another warm-humid place. Kerala is also classified as warm-humid and you can see Kerala's rainfall is much higher than that of Chennai's. If we look at the sky cover, the average sky cover ranges between 29 and 74 percent. The maximum sky cover is during October, which is around 91 percent, and the minimum sky cover ranges from 10 to 15 percent in January to April.

If we look at vegetation, vegetation grows quickly here due to the ideal environment of sunshine and precipitation. So, it is a combination of a place that has good sunshine as well as precipitation, and therefore vegetation grows quickly. But it also depends on the soil conditions. Depending on the soil condition, the nature of vegetation changes. These conditions create an ideal environment for lush tropical vegetation, including rainforests and wetlands.

Major types of vegetation in warm and humid regions include the tropical evergreen, the semi-evergreen, the tropical dry deciduous, and the mountain subtropical and temperate types of vegetation. For example, vegetation in Kerala has a large area of dense evergreen forests. Whereas Jamnagar majorly has mangrove forests, thorn forests, and shrubs. So, there is no one common type of vegetation found here. The only commonality is that towards the coast, coconut trees are found in abundance.

Otherwise, based on the combination of soil temperature and precipitation, the nature of vegetation varies. So moisture in the air combined with moderate heat and high rainfall is preferable for the growth of vegetation. The plant's underground cover helps reduce reflected radiation, and the ground surface does not heat much. So if we look at tropical evergreens, these flourish in areas that have rainfall of over 200 centimeters. Evergreen forests are essential for not only promoting greenery on the planet but are also useful in the continual survival of animals and plants in the forest ecosystem.

And if we look at semi-evergreen, these are transitional forests between tropical wet evergreen forest and tropical deciduous forest. Plants go quickly They are difficult to maintain and manage in this kind of scenario. High humidity, a large amount of sunshine, and precipitation facilitate the growth of trees, shrubs, ground cover, moss, and algae. So there can be lush tropical vegetation. Now let us look at the impact on buildings.

Now, the first is the structural concern. Material degradation due to moisture is a major

concern because it is a humid place, and moisture or humidity is the first enemy of any building. So, material degradation due to moisture, corrosion, and wood decay- these are part of degradation. Second is algal and moss growth. The growth of mould can cause decay of materials and cause infections and respiratory illnesses in human beings.

If you look at most places having this climate, the spread of epidemics is pretty fast because of the moist conditions. If we look at thermal comfort, achieving thermal comfort through natural ventilation is not only difficult in warm- humid climate because of the high temperature and humidity but also because of low wind speeds. Therefore, there has to be support of external wind speed in order to have thermal comfort. we look at energy consumption increased use of air conditioning and fans due to high temperature is another major concern and this concern actually enhances the energy consumption of the place again, which is related to greenhouse gas emission and global warming. So, in general, we can say that warm- humid climates are characterized by high temperatures and high levels of humidity throughout the year.

So, the temperature is high, the trend of temperature is that it is very high, then high levels of humidity, humidity levels are also high. The seasonal variation in temperature and humidity is small. So, low diurnal variation and frequent rainfall are very common. You can see rainfall being almost nil or less only for a few months. Otherwise, in every month there are a few days when there is precipitation.

Some locations experience rainfall almost daily. And these have an effect on the thermal comfort because people feel very sultry and sticky in these places. Let us quickly look at the broad design considerations that must be followed in this place. Heat loss to the air by convection or conduction is not consequential. Comfort is achievable by encouraging outdoor breezes to pass through the buildings.

As there is no significant cooling down at night, the walls and the roof surface temperatures tend to even out and settle at the same level as the air temperature. Radiant heat loss from the body will be negligible as the surface temperatures are near the envelope temperature. Radiant heat gain from the sun and the sky needs prevention. While deciding on building massing and spatial configuration in a warm and humid climate, the two main considerations are reduction of solar exposure on the building envelope. This helps in managing solar heat gain through the building envelope like walls, roofs, and windows.

Utilization of wind flow to ventilate internal spaces to evacuate heat and provide thermal comfort to the occupants. The main building envelope or facade should feature that influence daylighting in residential units, which must also be considered. The building envelope design should aim at achieving a reduction in cooling thermal energy demand

and an improvement in thermal comfort with provision for adequate daylighting in typical spaces such as bedrooms, living room and kitchens. Very specific building design considerations must be that the principle of thermal storage cannot be relied on or used in this climate because the temperature of the outside air is almost the same as the day and night due to very low diurnal variations. A building cannot be cooled off at night to allow storage of heat during the day.

A reflective upper surface, a double roof with roof ventilation, a ceiling with its upper surface highly reflective and heavy—these can provide good resistive insulation. The roof and ceiling should have low thermal capacity. The features of the main building envelope that influence the demand for cooling thermal energy and thermal comfort in a residential unit are that the size and location of window openings should be important. Shading systems for windows should be adequate. Window glazing should have correct properties.

There must be insulating properties of walls and roofs. Color and finish of exterior surfaces must be taken care of. Provision for natural ventilation becomes very important. So, the building envelope design should aim to achieve reduction in cooling thermal energy demand with improvement in thermal comfort and provision of adequate daylighting in typical spaces like bedroom, living room, kitchens, etc. Very broadly, the design consideration should be that the orientation of glass should be to the north.

It should be shaded by vertical fins in a very hot climate because there are essentially no passive solar needs except to generate electricity. So, there is no need for trombe wall and such. Thin-screened porches and pechos can provide passive comfort. Then there should be a minimum or elimination of western facade glazing and habitable spaces on the west. Plants and vegetation can be used on the west to act as a buffer to cut away the intense solar radiation.

Traditional passive homes in warm- humid climates have high ceilings because hot air rises up and can escape if proper vents are provided. High-performance glazing on all orientations should provide good protection from hot, clear summers. Light-colored materials and a roof must be used. Use of cool roofs is very important here. What are cool roofs? We will see later as a strategy.

To facilitate cross ventilation, windows should be located on opposite sides of the walls with sufficient provision for breeze movement inside the rooms in such a way that furniture and other things do not obstruct breeze movement. Then use of open plan so that breeze does not get impeded. If soil is moist, the building can be raised high above the ground to minimize dampness. So, these are the primary building design considerations in a warm and humid climate. Let us now see the characteristics of a hot and dry climate.

If you look at the geographic distribution of hot and dry regions, these are generally found along 20 degrees to 35 degrees north and south of the equator. In India, this zone is demarcated as hot and dry. So, hot and dry regions in India are towards the western side, and they have the following temperature and relative humidity in general. Geographically, hot and dry climate zone cover parts of Maharashtra, Rajasthan, Gujarat, Kutch region. Today, we will take the example of Jaisalmer, which is at 26.

9 degree north and 70.9 degree east and assesses climatic characteristics. So, if we look at the temperature, these figures here show the average minimum dry bulb temperature and average maximum dry bulb temperature throughout the year. Now, you can see the average maximum dry bulb temperature lies in the range of 24 degrees Celsius to 43 to 44 degrees Celsius. So, these places are extremely hot.

The average maximum temperature goes up to 42.26 in May in Jaisalmer. In general, 49.2 is common for a few days in the summer. In winters, the average maximum temperature in Jaisalmer can reach 23 to 25 degrees Celsius. The average minimum temperature could range between 25 degrees to 28 degrees in the summer period.

So, in the summer the temperature ranges between 25 to 28 degrees Celsius whereas in the winters the temperature could dip even up to 9 degrees Celsius. The mean monthly maximum temperature is above 30 degrees Celsius and the relative humidity is above 55 percent. So, hot-dry regions experience high diurnal variations. Sometimes the diurnal variations could even be up to 20 degrees to 25 degrees centigrade. If we look at the relative humidity, the maximum average relative humidity is between 55 to 67 in the months of July to September.

The minimum relative humidity is between 31 to 36 in the month of March to May and October to November. So, when the temperatures reach 45 to 49 degrees Celsius the relative humidity is about 35 percent. So you can imagine the amount of dryness one can feel. So very little humidity and a high temperature feel like the skin is burning. If we look at the wind speed, the average wind speed is higher during May to September, which ranges from about 2.

6 meters per second to 5.9 meters per second. Average wind speed ranges between 0 and 2 meters per second for the rest of the year. So it's either very calm or there are sandstorms. Let us look at precipitation. The rainy period of the year lasts for about 3 to 3.5 months from June to September, with a sliding 31-day rainfall of at least 2 cm.

The month with the most rain in Jaisalmer is August, with an average rainfall of about 5

cm. The rainless period of the year lasts for 8 months from September to June, and the month with the least rain in Jaisalmer is December, with average rainfall of about 1 centimetre. The sky cover is maximum during July to September, and it ranges between 20 and 40 percent. The least average sky cover is between October and December, which is around 4 to 8 percent. So, clouds are so little that the sun feels tormenting and the high solar radiation causes glare.

If we look at the climate characteristics of a particular year, you can see that for some days of the year, the temperature has even touched 50 degrees centigrade. Whereas the humidity is so low during this period, the humidity is about 20% RH. So you can imagine the amount of dryness and heat sensation in this area. You can see that about 8 months for about 8 plus months the temperature crosses 40+.

40 degrees Celsius for about 8 months. So, it shows that the temperature is intensely hot for a larger part of the year. If you look at the minimum temperature, then the minimum temperature can go up to 7 or 8 degrees Celsius. Now here you can see when the mean daily maximum is, say we will take randomly this. September, when it is 37 degrees Celsius, the minimum temperature is 24 degrees Celsius, indicating a diurnal variation of 13 degrees Celsius.

So, it can have very high diurnal variations. Let us look at the vegetation. The major types of vegetation in the hot and dry region include tropical thorn, tropical dry deciduous, tropical moist deciduous, and desert vegetation. Now, tropical thorn vegetation; these forests are a type of desert formation that consists of scrub-like vegetation. Vegetation in these areas is very scarce, and tall trees are laid against each other where there is a lack of grass. Tropical dry deciduous forests are a transitional type of forest between moist deciduous and thorn forest on the wetter side and thorn forest on the drier side.

They thrive in harsh and highly fluctuating climates. If we look at the tropical moist deciduous, they flourish in areas that have rainfall of over 200 cm. Evergreen forests are essential for not only promoting greenery on the planet, but they are extremely important because these places can even have oasis. The desert vegetation is mostly herbaceous or stunted scrub, with drought-resistant trees occasionally dotting the landscape here and there. In places like Jaisalmer, due to lack of precipitation and extreme solar radiation, there are few thorny bushes and cactus. Seasonal vegetation comprises a few grass species, shrubs, and dwarf trees.

If we look at the environmental challenges, there is a lot of water scarcity because low precipitation and groundwater depletion are the reasons. Soil degradation happens very fast because of poor land management and a lack of proper vegetation. Dust storms have an

influence on air quality, causing poor air quality. Solar radiation is extremely high with high temperatures.

Vegetation is sparse, limited to shrubs and a little ground cover. If we look at the impact on buildings, then the first is the structural concern. These materials tend to expand and contract more due to high diurnal temperature differences, and this can lead to cracks. Exterior paints and finishes can fade or crack under intense heat and light. Dark-colored external surfaces should be avoided since they absorb more heat.

Second is energy consumption. Increased use of air conditioning and fans leads to increased cooling loads. Passive design strategies have to be applied for energy demand reduction. Poor indoor quality air is often affected because there is no provision for too much ventilation because enhancing ventilation means bringing in hot air. Also, a combination of lack of fresh air inside the room with dust particles makes the indoor air quality poor.

Let us now briefly and broadly see the building design considerations. So, traditionally passive homes in hot-dry climate use high-mass construction with small recessed shaded openings. The traditional passive homes in hot windy dry climate use enclosed wall, shaded courtyards with small water bodies or fountains in the center. Window overhangs, which are designed for this latitude, and operable sun shades can reduce the load on air conditioning. Minimizing or eliminating west-facing glazing to reduce summer and afternoon heat gain is important. Double-pane high-performance glazing can be used, and flat roofs are very common, especially with light colors, because there is no heavy precipitation.

Besides, Earth sheltering is a very important strategy, which we will be seeing later during the course. Screened porches and patios, use of light color on the wall, then use of plant material to buffer the walls, but again there is lack of plant material, there is lack of vegetation because of the intense heat and less rainfall. So, these are some of the broad criteria for building design considerations. Let us quickly glance at what NBC guidelines say. The NBC guideline says that during the summer period for hot and dry climate and warm-humid climate, there must be a reduction in the ingress of heat during the day.

Then introduction of naturally through use of courtyard and wind towers properly positioned windows, etc. Try to have adequate air flow during the day. A substantial increase is recommended in warm and humid areas, whereas in hot-dry areas it should be minimal. Adequacy of air flow through use of courtyards, etc.

In warm and humid conditions, it should be substantive. Reduction of temperature

variation within the building during daytime and nighttime compared to temperature variation in the ambient is absent in warm, humid, and present in hot and dry. Adequacy air changes as required. must be high in warm- humid and should be present optimally in hot and dry during the summer period. During the winter period, the reduction in the ingress of cold into the building during the day should be valid for a hot-dry and warm- humid and during the monsoon, it should also be valid in hot-dry, and warm- humid. Reduction in air changes without compromising with the minimum requirement for the activity must be there in hot and dry during winter and not in the warm and humid.

So, warm and humid, there must be air changes throughout the year. Reduction in the egress of heat from within the building spaces during the day as well as during night should be there in hot and dry and should not be there in warm and humid. Adequate natural ventilation and air changes in all spaces must be there in warm and humid. There should be a marginal reduction in the ingress of cold into the building during day as well as night, which is not valid for hot and dry as well as warm and humid. Reduction of humidity within the building throughout the day and night during the monsoon should be available in hot-dry and warm-humid climate. A substantial increase in the natural ventilation in all spaces during the monsoon must not be there in hot and dry and must be present in the warm and humid.

So, these are the broad guidelines as given by NBC. So, with this, we stop today's class on climate characteristics of warm, humid and hot and dry. In the next class, we will look at the climate characteristics of yet another climate type. Until then, thank you.