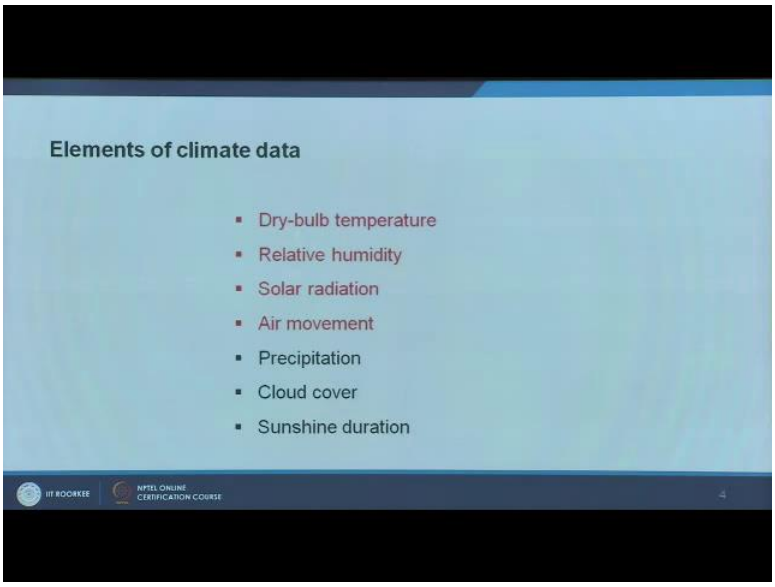
Principles and Applications of Building Science
Dr. E Rajasekar
Department of Civil Engineering
Indian Institute of Technology, Roorkee

Lecture - 02
Climate Classification

In this module, I will be teaching you about climate classification. The major contents are, what are the climate variables, how do we account for them, and how climates are classified, how climate analysis is done for architectural project, and then what are the basic design strategies, which we can infer, based on this climate classification.

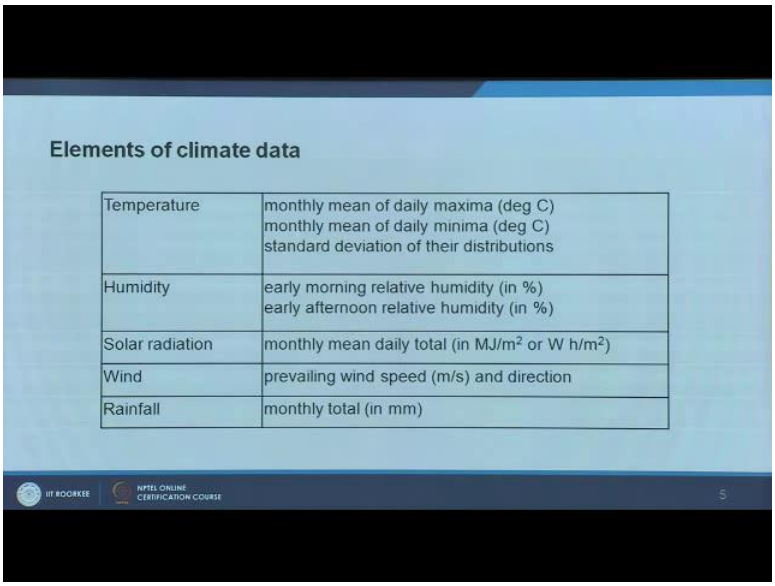
(Refer Slide Time: 00:45)



So, primarily what are the climate variables we are going to talk about? Dry bulb temperature that is the most basic parameter, environmental variable, followed by relative humidity, both is measured by using a device called Stevenson screen, which we know very much.

A lowered box, inside which the temperature and humidity sensors are kept, then solar radiation, air movement, precipitation, cloud cover, and sunshine duration, in a specific location. These are the major elements, based on which climate classification is done, as for temperature is concerned, 3 parameters are important.

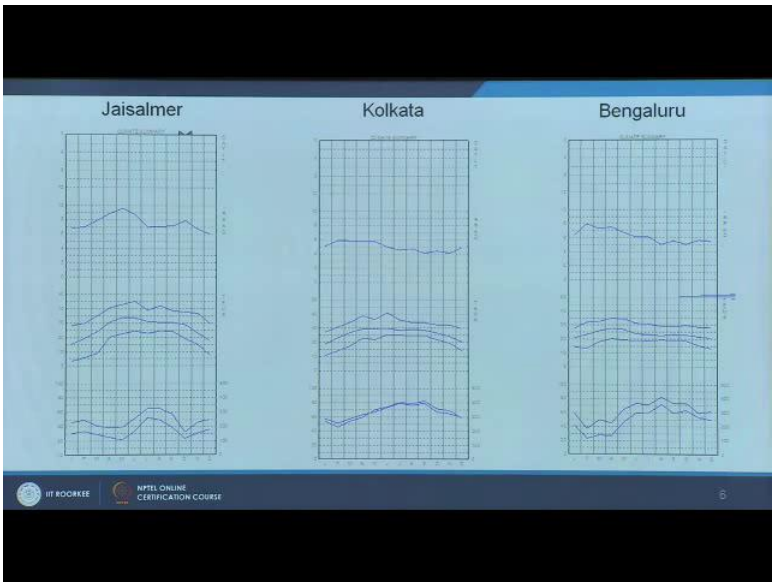
(Refer Slide Time: 01:17)



First is, to take monthly, monthly mean, daily maximum. So, if today is 42 degree maximum, you keep counting it for the next 30, 31 days, then the monthly mean maximum, then the monthly mean daily minimum, similarly, and the standard deviation, standard deviation is very important in this, it is a very critical indicator, for example, there are certain temperature anomalies.

For example 2 or 3 days stood up in temperature, or fall of specifically due to rain or some other disturbances, then the monthly mean maximum, might be skewed little bit. So, in order to correct these things, we will also look at the standard deviation of their distribution. Followed by humidity, we take twice in a day, which is important, two main time positions are important, one is early morning, which is typically high, then early afternoon, relative humidity, solar radiation in terms of monthly mean daily total, then wind, speed and direction, and rainfall. These are typical climate summery charts we call, which is simply used for inferring the climatic pattern, or the climatic characteristics in a given location.

(Refer Slide Time: 02:24)

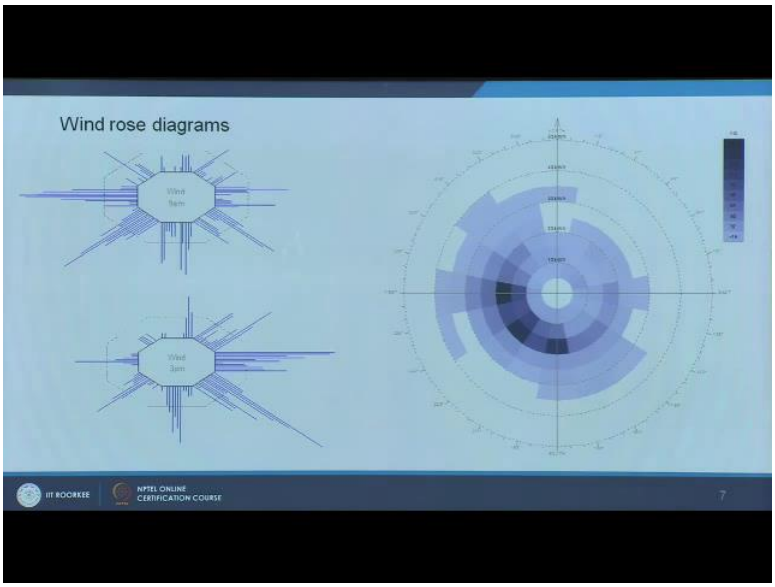


So, let us consider 3 different locations - Jaisalmer, which is representing hard and dry climate, Kolkata, representing a warm and humid climate, and Bengaluru, representing a moderate climate. Let us read this chart first, the x axis, we have months starting from January to December, and the y axis, there are 2 sides to it. If you start from this, for example, this is the temperature, in temperature degree centigrade, this is the monthly mean maxima, minima, and the daily mean value, and this is radiance, and this is the daily towers, on the left side, here you find the relative humidity, and on the right side, we have the solar radiation.

So, if you compare the 3 cities, this gives a quick picture of how the climatic characteristics are, in a given location. For example, if you want to compare Jaisalmer with Kolkata, we can see the temperature maxima, versus minima, how much is the diurnal variation, for example, if we take the month of June, the diurnal variation is somewhere between 45, and the minimum goes to 25 degree. So, 20 degree diagonal variation is seen, whereas, in the case of Kolkata, the same in the month of June. If we see this is going up to around 38 degrees, 37 degrees 38 degrees, minimum is somewhere around 24. Relatively in Bangalore, the diurnal variations are even lower. Similarly, we can compare the radiance, relative humidity, and solar radiation.

Another important parameter, the wind, though we can look at elaborate wind rose chart, I will demonstrate a few tools, which you can use in the following sessions, but to take a quick look at it, this is a wind rose diagram.

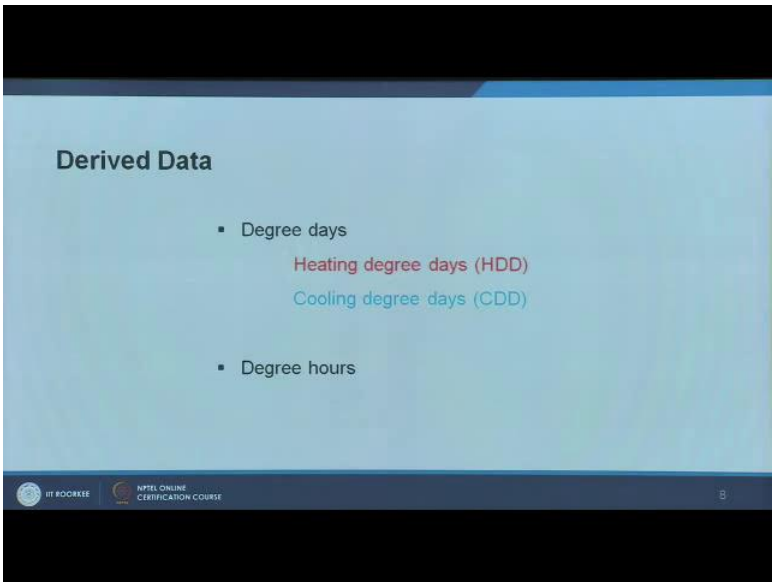
(Refer Slide Time: 04:10)



This has little critical information about wind. Circles, this tells you concentric circles. This tells you the wind velocity, 10 kilometers, 20, up to 50 kilometers in this graph, particular graph. Then of course, you get the direction of the wind, and the color intensity indicates the number of hours.

For example, looking at this graph, there is high speed wind coming from this direction, then you have higher intensity winds, as well, it is going for further close to 150 hours you get in this particular velocity, say around 20 kilometers in this direction. For specific building applications, we simplify this chart, and use a chart, which is just having 8 simple directions, cardinal directions, in which the wind vectors are identified. Again we take two times, morning and evening, typically how the breeze is. For example, if you are taking a coastal area, you will have clear phenomena of the seaward, and land side wind movement, which will be clearly depicted in these things.

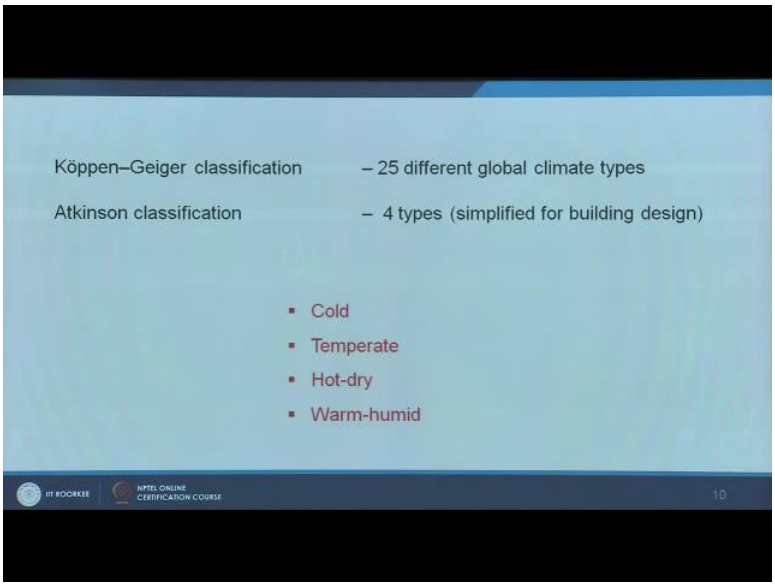
(Refer Slide Time: 05:24)



This will help us; more or less identify the climate type, the major parameters and their variations across the year, and typical wind pattern. We can also have wind rose diagram made for different months, different seasons, as we wish to. These are primary data. Then we start deriving data out of this. There are 2 main things, which you will commonly come across.

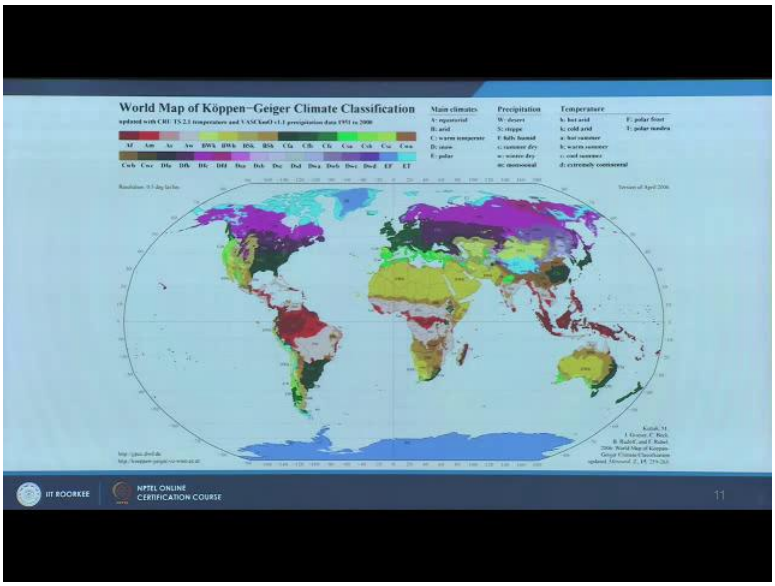
A typical metrological site will give you something called degree days. There are two types in this heating degree days, and cooling degree days. Heating degree days, tells you how many days in that particular season or year require heating. Just the number of days it will tell you. Then the cooling degree days is set. As far degree hours are concerned, it is like a cumulative value, it actually sums up in terms of degree hours. So, how many degrees are exceeded, and then how many hours are exceeded, the product of it will give you the total magnitude. So, when the degree hours are more, say heating hours are more, cooling degree hours are more, it tells you this is the magnitude of heating, or cooling requirement. It is a total sigma value that we are going to get.

(Refer Slide Time: 06:17)



Keeping this in mind, let us look at climate classification. Most commonly referred international classification is the Koppen-Geiger. Initially, it had 25 different climate types, but following that, it was also extended. There are many versions of this Koppen-Geiger classification. As far as building applications are concerned, we typically look at Atkinsons classification, which has 4 major climate types, starting from cold, temperate, hot dry, and warm humid. Apart from this, another climate type is added, which is a composite, say for example, when a given location does not have a regular climate pattern, or a similar pattern for more than 2 months, it may be too cold in winter, too hot in summer. Sometimes, it is too rainy as warm humid climates, then, we classify it as a composite zone. So, 2 to 3 months the climate pattern or characteristic, of that location keeps changing.

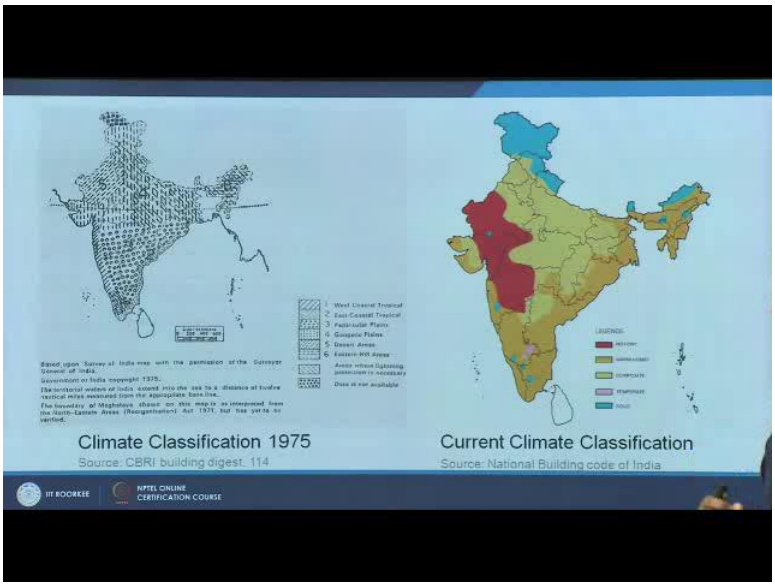
(Refer Slide Time: 07:17)



This picture tells you the world global classification as per Koppen-Geiger system. If you look at this, there are 5 main climate types, a, represents equatorial, b, represents arid, c, is warm and temperate, d, is snow and e, is polar. Apart from this, based on precipitation, there are 6 types, dessert, steppe, full humid, summer dry, winter dry, and monsoonal. As far temperatures are concerned, there are 8 different types, hot, arid, up to polar tundra region. So, if you come close to India, there are specific regions, which are indicated in color scale.

For example, the coastal areas this represents A and M. A, is equatorial, and M is monsoonal. So, most of this west coast is classified, and say part of Sri Lanka, it is classified as equatorial, monsoonal climatic zone. Say most part of India, it shows as A W that is, A is equatorial, and winter dry. Similarly, the climate classifications of India can be inferred from map.

(Refer Slide Time: 08:24)



Let us take a closer look at how Indian classification works out like. Interesting thing is that, if you look back in 1975, we had this particular climate map of India. Initially we had 6 major climate zones. We had west coast tropical, we had east coast tropical then we had peninsula plains, Gangatic plains, for most part of India, then dessert areas, and then eastern hill areas. These were the type of climates, which were available way back in 1975. These two things actually represent, where lighting protection is required, in those days, they did not have much data for northern tip of Kashmir.

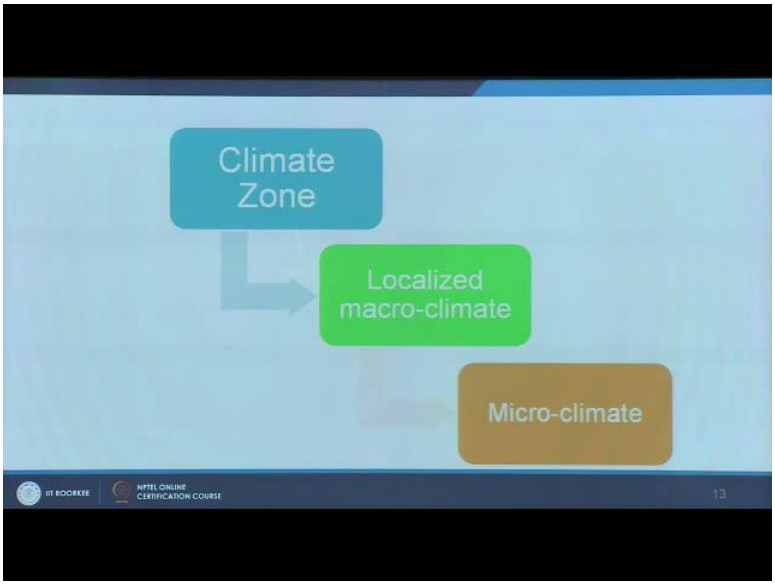
But later, national building core was revised, when the climatic classification was also revised, as a part of it. Now we have officially 5 climate zones. We have hot and dry, but just turn on this belt, we have warm and humid for most part of this coastal peninsular area, then we have composite climate, which takes around 30 percent, one third of Indian geography, then we have temperate climate or moderate climate, small patches of it, then we have cold climates, and Kashmir, and far north east region.

So, as far the major climate zones are concerned. We have 5 major climate zones. So, we talked about major climate zones. Now, next interesting thing is, not all the locations present within, say for example, warm humid, or composite climate, resembles the same. For example, take a city like Delhi, which is in composite climate, city as Lucknow, composite climate, and city as Hyderabad, which is also classified as composite climate.

We have Nagpur, which is also a composite climate. Not all of these locations resemble the same, in terms of their climatic pattern.

So, we can further narrow it down to localized macro climate. This is still a macro climate, this is not micro climate, and this is macro climate, but still, we can term it as a localized macro climate.

(Refer Slide Time: 10:04)



This is a result of the geography around, for example, if there are hilly areas around, there may be a solar re-radiation, long wave radiation, intensity will be more, or if it is on a ghat area it maybe susceptible to more precipitations. So, depending on altitude, latitude, longitude, these vary again. Sunshine hours will vary from north to south of India.

The third step, or the third micro level is the micro climate, for example, take a given city, like Delhi for example, the climate type, or the climate severity, for example, in the core of New Delhi, in and round Rashtrapathi Bhavan area, versus what happens in Noida or Gurgoan, or any city for that example, these are called micro climates. These are more localized than this; we term them as micro climate. The phenomenon like urban heat Islands, are more closely associated with micro climate of a given location. I did a small climate assessment, taking a set of locations, specifically across warm and humid climate

(Refer Slide Time: 11:03)

I will not going to talk about more of the statistical analysis which happened, there was a processing which was done, which is called statistical climate clustering, statistical clustering analysis which was basically done. We took the hourly weather data, temperature, humidity, radiation, and precipitation data, for these locations. This represents Buvaneshwar, this is Chennai, Guwahati, it is like a chain starting from west coast, it starts at Jamnager, and goes all the way to west coast, east coast, you have Mangalore, then you have Vizag, Trivandrum, you have Kolkata all the way to Guwahati and north eastern tip.

So, all these locations are classified as warm and humid, as per the national building code. What we did was, we build the data which are resembling each other, for example, how do you say a specific set of days, or summer days? Specific set of days are winter, monsoon, etcetera. So, I divided this into 4 specific seasons in a year, based on which these bubbles are shown here. What you see in this, the size of the bubble represents, the more number of days, on x axis you have, the tout maximum, a specific daily tout maximum, here we have the direct solar radiation maximum on a particular day.

We have 95 percent confidence interval here. So, that the extremities are avoided. What we find, this is Jamnagar, which has maximum, as I said, this is 95 percentile, so you are not seeing the extremities, but still, you have a considerable amount of summer, since the circle is big, the bubble is big, you have more number of days, which have, say, for

example, around 37 degree mean maximum temperature. And the solar radiation is also quite high, whereas, if you want to compare the summers in Guwahati, sorry Jamnagar, with Guwahati. Guwahati is green in color; summer in Guwahati appears somewhere here. The solar radiation is high, but the temperatures are quite lower. So, this clearly shows, what is the difference in the localized macro climate. This is again not micro climate, summer in Jamnagar versus summer in Guwahati, winter in Jamnagar is somewhere here, and winter is Guwahati is somewhere here.

If you closely take a look at each of these cities, versus the climate data, you will get a fair idea of, how far these climate severities are, in these particular locations. Say some of these places, if you take this blue, this is Bhuvaneshwar. Winter in Bhuveshawar, fairly small, number of days, very few numbers of days you experience winter, low solar radiation and lesser temperature. So, like this you can take a pretty detailed look, and compare these cities with one another. This is similar climate clustering, which is done for composite climatic region.

The last slide we saw was for hot and humid, sorry, warm and humid climate, this is for composite climate; the axis remains the same.

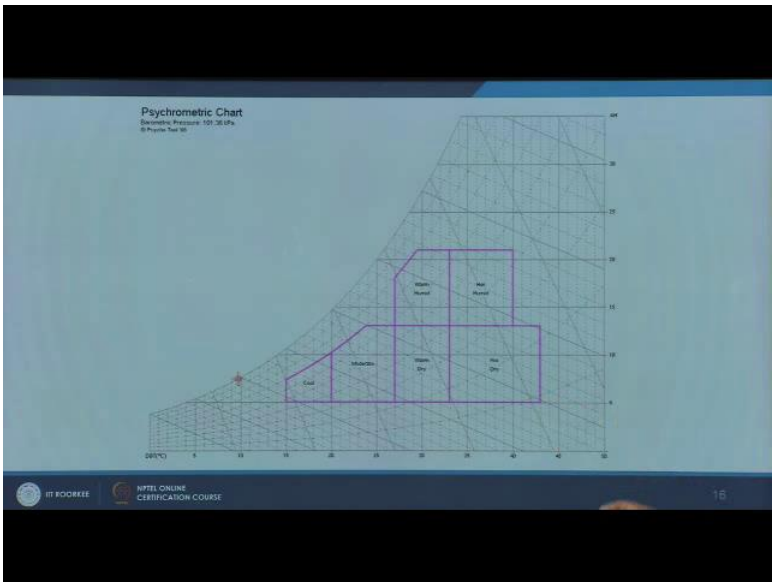
(Refer Slide Time: 14:04)

It is the temperature, the daily temperature mean maxima, this is a solar radiation again, but what we find here is, only two typical seasons data has been presented, this is for summer and this is for winter, there is more number of cities here. there are about 20

cities starting from, this is Allahabad up to Sarangpur, there are 20 cities located in composite climate. I would recommend you to take a closer look at this, similarly, size of bubble, versus the temperature and humidity solar radiation extremities, and how the thermal severity will be there, in these locations.

Now, how do we start using this? Numbers are good, but how do we translate them into design? This is where a role of architect or designer gets more interesting. So, first we have to get them onto the way, in which, buildings can be designed. So, what I have shown here is, the psychrometric chart, with a overlay of climatic classification. You know the psychrometric chart well. Hope you know how to read this, you have temperature, drabble temperature, under a lower axis, you have absolute humidity, or moisture content, and these lines represent the relative humidity.

(Refer Slide Time: 15:04)

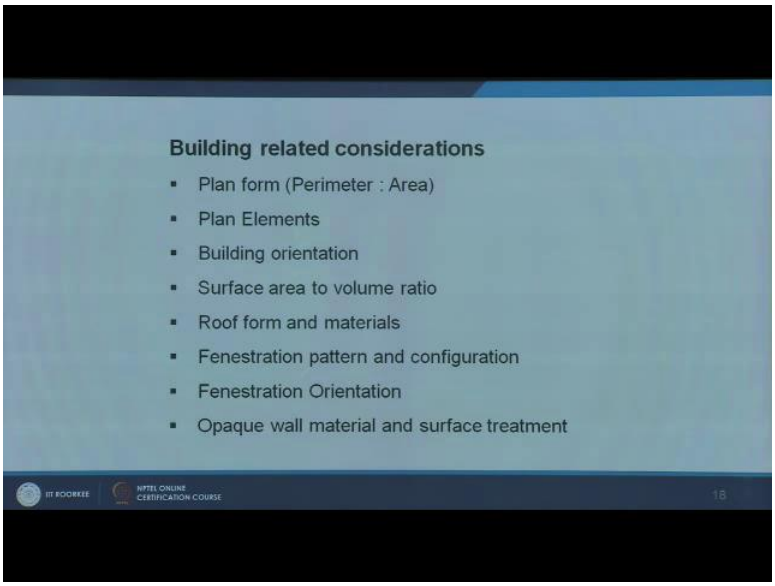


The overlays of climate zones are clearly seen here. You have the cold climate, you have a moderate climate, here, warm dry, hot dry, warm humid, and hot humid. So, example if I have to call a particular city as hot and dry, the majority of the data has to be located around this particular region. I mean the whole year data might be dispersed well across the psychrometric chart. You will have monsoon so naturally, you will have a humid period in the year, and you have a colder season.

So, you will still have a few days which are on the colder side, but still majority, for example, of the extreme condition, like summer, it should be in this, and then we can

term it as hot and dry. Similarly, for warm humid or hot humid. Now let us take a look at specific locations in India, and how climate analysis can be done and presented. So, it can be for a project design that you are working on or it can be for an academic exercise. Let us see, step by step, how climate analysis can be done, and understood basically.

(Refer Slide Time: 016:20)



So, what are the basic considerations that we talk about in terms of buildings? We have the first major consideration that is the plan form, in terms of numbers. you can translate it as perimeter to area ratio. You can imagine a square versus a hedge shape building.

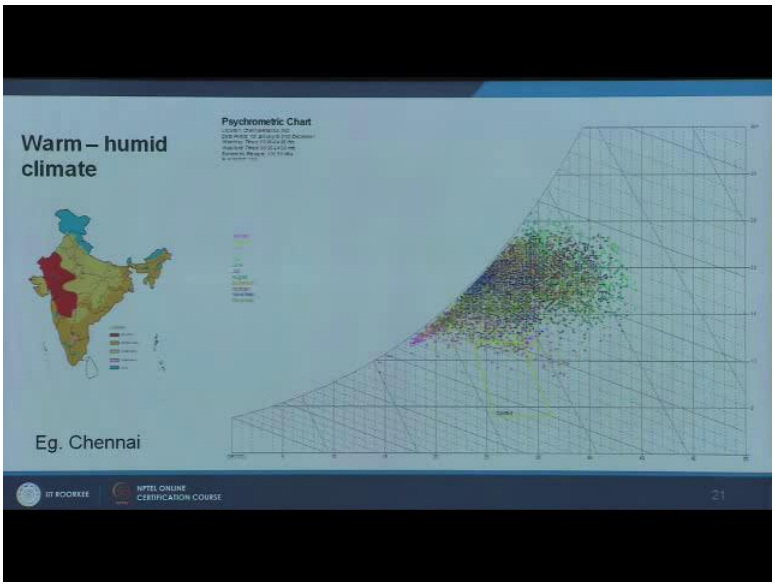
The same area can be accommodated with the lesser perimeter. In the square as compared to the hedge shape, which, the same area gets accommodated into a larger perimeter. So, the plan form, in terms of perimeter to area ratio is very crucial. Following this, you have the plan elements, for example, it can be presence or absence of deep shading devices. Roof form, or the pergolas, or the presence of balconies, anything like that, then we have of course, the building radiation which we looked at, in terms of solar analysis.

In another module, I was demonstrating how a building can be oriented, with respect to the solar radiation. Then another important parameter talks about the volume, it is about surface area to volume ratio, how much floor area can be accommodated in a given volume. So, this tells you actually the, sorry, how much volume can be accommodated

with a given surface area. I would recommend, you can compare, a square or a rectangle, with that of a hemispherical structure.

In a hemispheric structure, classic example of a building built form is an igloo. So, they have a hemispheric doom shaped building, in which they reside. The surface area to volume ratio is considerably lower, very less surface area, and more volume is accommodated. Instead if you have a linear rectangle, then the surface area to volume ratio differs - Roof form and materials fenestration pattern and configuration, then orientation of the fenestration, which side to put windows, where not to put then opaque wall material, and surface treatment. Part of it we will look at in this module, we will talk more about this fenestration pattern, wall material, and surface treatment in the following modules.

(Refer Slide Time: 18:21)

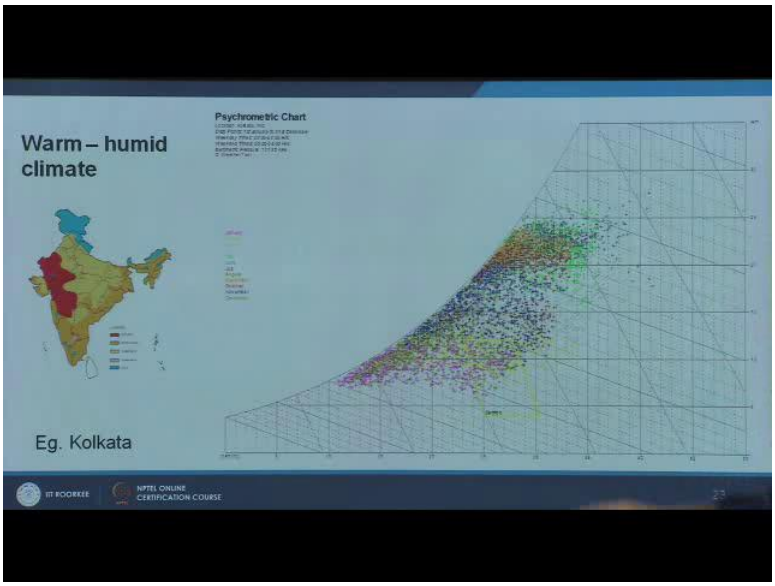


Let us take one climate of (Refer Time: 18:15), we will be looking at specific city example and how climate analysis can be done. First, let us look at warm and humid climate. We have, all across starting from this zone, goes up to north east, the same psychrometric chart, which I showed you. We have overlay of the climate zones in this particular boundary represents, the monthly mean temperatures of each month. There are twelve points, which are connected, that is why you are getting a distorted shape. I can read some of these months, here it is May, there is December here, you have October, here march, is somewhere located here April, August is here.

So, typically if you connect these, these are monthly mean temperatures. Say monthly mean in May goes around 37 degrees, somewhere here, monthly mean in December goes to around 27 and a half, 28 degrees, here. This particular zone, this is for the location Chennai, this is where the monthly data gets connected, but if you take a closer look at this, this is the same data, instead of monthly mean, every hour data points are plotted, 8760 hours that is, that is 365 into 24. Every hour, the temperature and humidity data is plotted.

So, the colors represent the months, of course. You have more of pink in this area, that is January, whereas, you have more of greens here, in the month of May, which is somewhere hot as well as humid. So, now, there is a comfort zone. We will talk about comfort zone a little later, but this is the dispersion of data. As such we looked at, last time, it was a clear connect located somewhere in warm and humid, but you look at the whole data, it is more sultry, it is also getting more hot, but the dispersion is in this pattern.

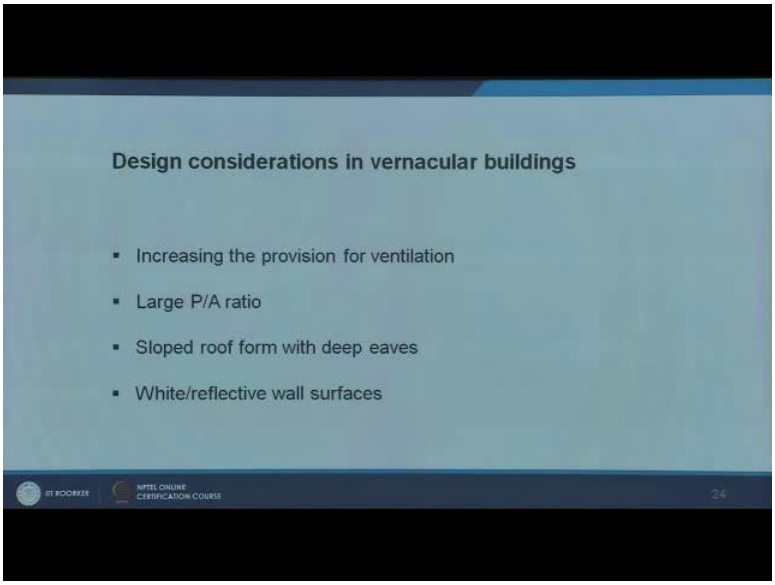
(Refer Slide Time: 19:58)



Take another city, for example, Kolkata. This is the same as, as I showed you for Chennai. This is where the dispersion of data. This is the monthly mean, if you connect them, more or less in warm humid, it also, it also spreads to warm dry, and moderate in certain months.

For example, for in the month of July, it goes down. There are two extremities, within which the data is spread. A similar look at the hourly data points, for more number of points, this yellow boundary represents the comfort zone. As I said, we will talk about comfort zone more elaborately in another session. For now, this is the comfort zone. More number of data points, compared to Chennai, lying within this particular boundary.

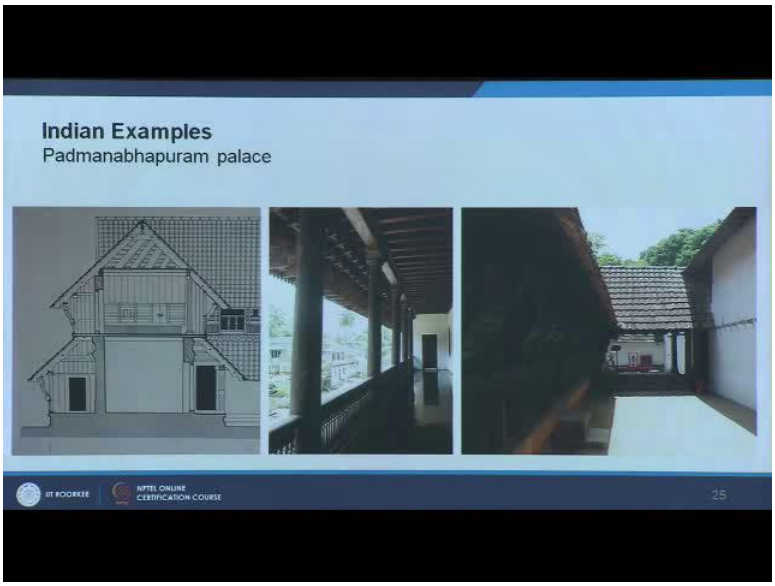
(Refer Slide Time: 20:45)



So, what do you do, as far design is concerned? We have to basically increase the provision for ventilation that is first major thing which has been traditionally done in any vernacular building; building form you take. The first thing, people did in this particular climate, is improve the provision for ventilation, more windows.

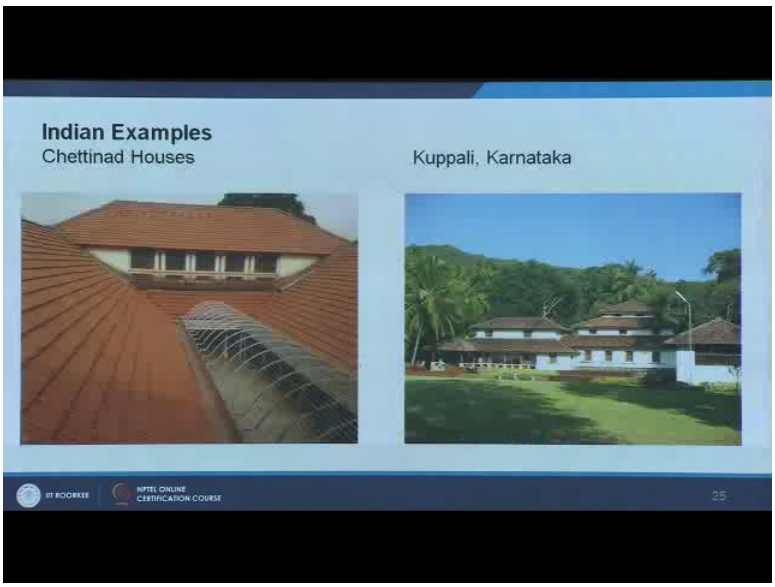
Then another thing which we can translate, we talked about is a perimeter to area ratio, large perimeter to area ratio, same area under a large perimeter. Hedge shape buildings for example, in place of compact square or rectangular buildings you go for more distributed planning. Slope roof, because coastal areas mainly precipitation is high, humid zones, warm and humid zones, typically you have more precipitation. So, slope roof forms are preferred, why you can reflective wall surfaces.

(Refer Slide Time: 21:33)



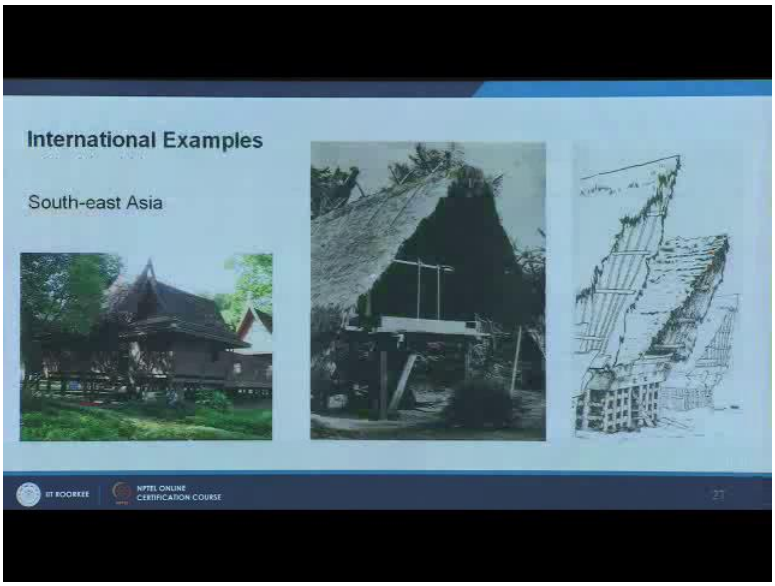
Or the earlier graphs, you also looked at the solar radiation, intensity is quite high during summer. So, you go for white and reflective wall surfaces.

(Refer Slide Time: 21:55)



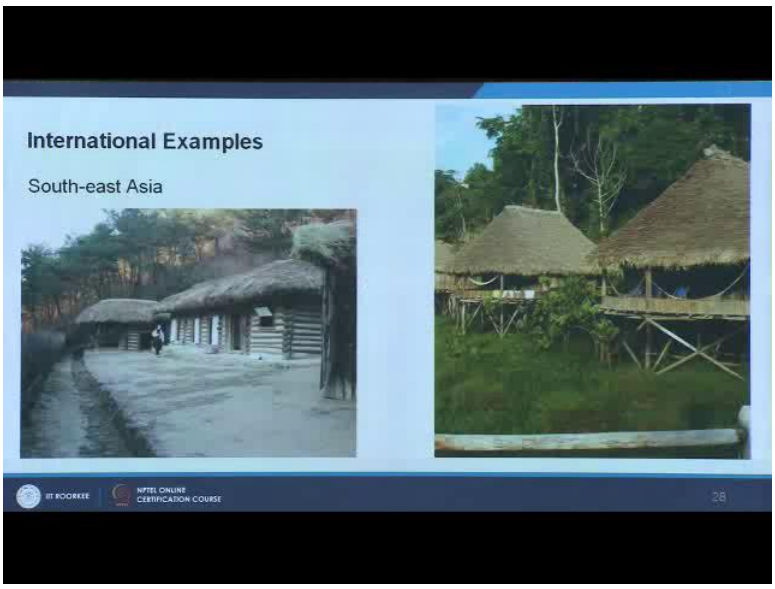
Classic examples, Indian examples, most of the vernacular buildings have lowers, nicely shaded balconies, improved ventilation pattern, white reflective surfaces, nice courtyards, spread out plans; this is not a very compact plan form. The perimeter to area ratio, I would recommend you compare them, and see, the plans are more loosely packed.

(Refer Slide Time: 22:00)



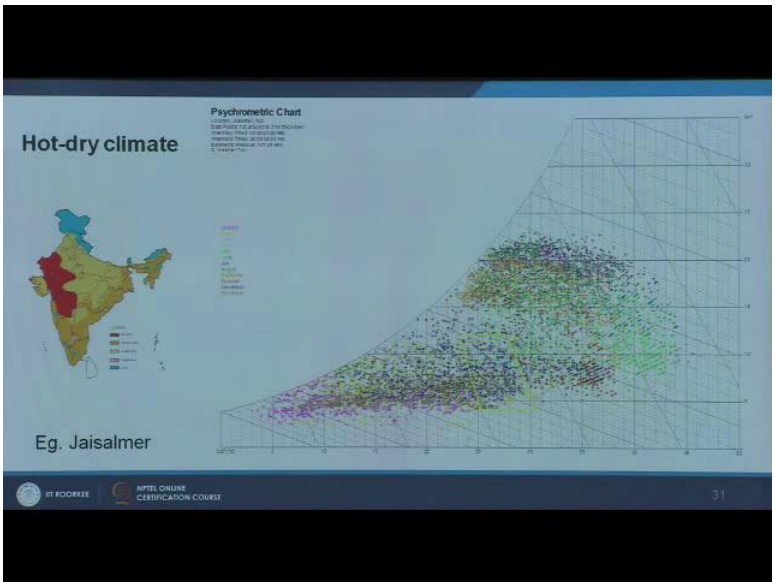
More examples for warm and humid climate, and how design was represented, some international example, more or less the roof forms, the planning were more or less resembling this is some example from South East Asia. You can find more examples further.

(Refer Slide Time: 22:14)



Few, few pictures I have put in ventilation, is given the primary importance apart from the roof form.

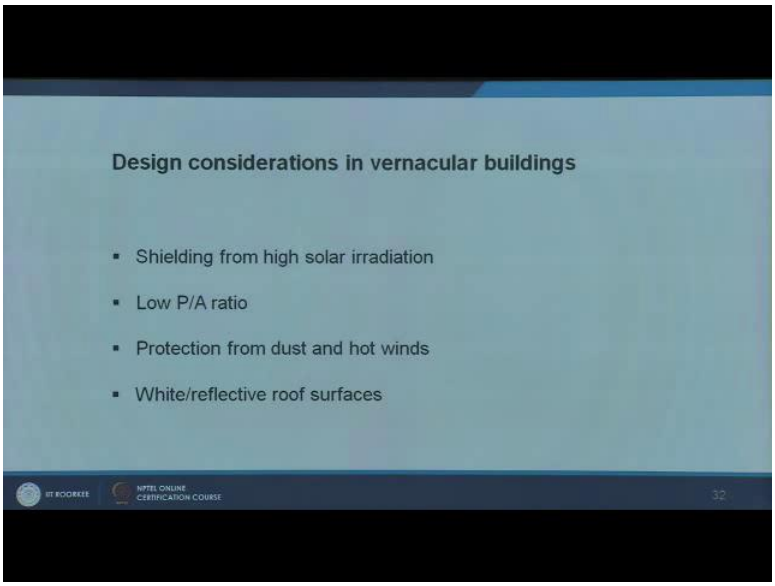
(Refer Slide Time: 22:24)



Let us go to hot and dry climate zone. I have taken Jaisalmer as an example. This is a spread of climate as you see, the distribution is quite far. It has a few humid and hot months, it has a few hot and dry months, it has warm and dry months, it has a partly moderate climate in about two months, January, February. Partly it has, little moderate climate, this is the distribution. If you compare, we still have more number of data points, within comfort zone compared to humid climates, whereas, you have more extremities. Temperature extremities go as far as, 46 degrees, versus about 3 to 4 degrees in winter, plus, you also have certain humid months.

So, the distribution is quite wide. So, what do we do, in terms of design? Primary thing is to shield a building from high solar radiation. Contrary to what people used to do in warm and humid regions.

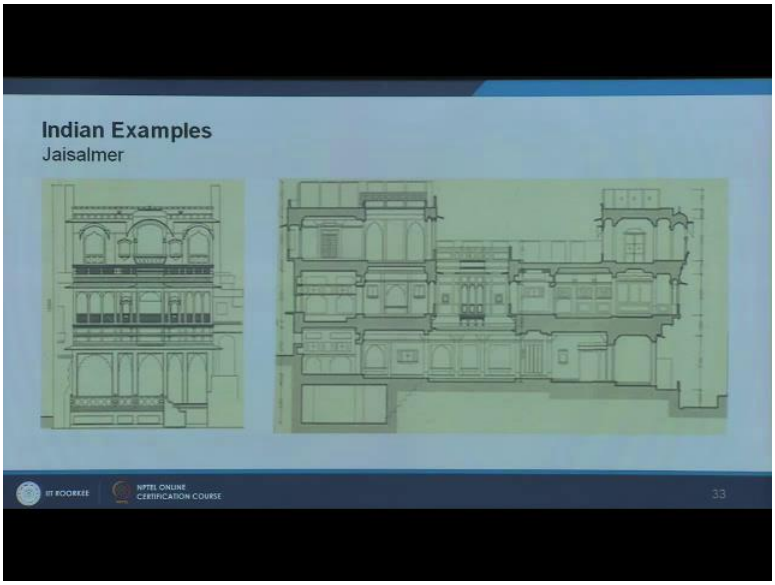
(Refer Slide Time: 23:08)



The P by A ratio, that is perimeter to area ratio, it should be kept low, or which is being, it was being kept pretty low in most of the vernacular buildings. I will show you a few examples. This typically means, the building plan form is more compact, protection from dust, and hard winds is another crucial thing, plus of course, white reflective roof surfaces are also preferred.

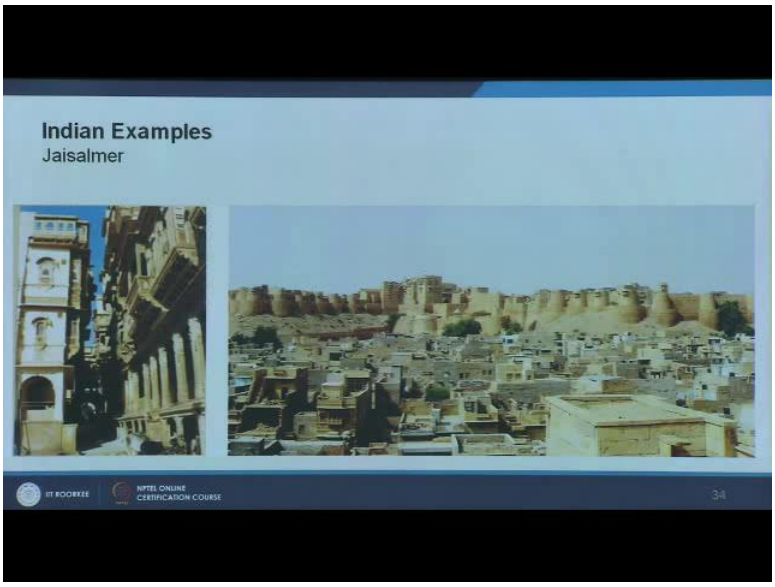
Classic example is the Haveli of Jaisalmer, which are more compact in plan, even when they do had courtyards for ventilation efficiency, they were more compact and shaded.

(Refer Slide Time: 23:40)



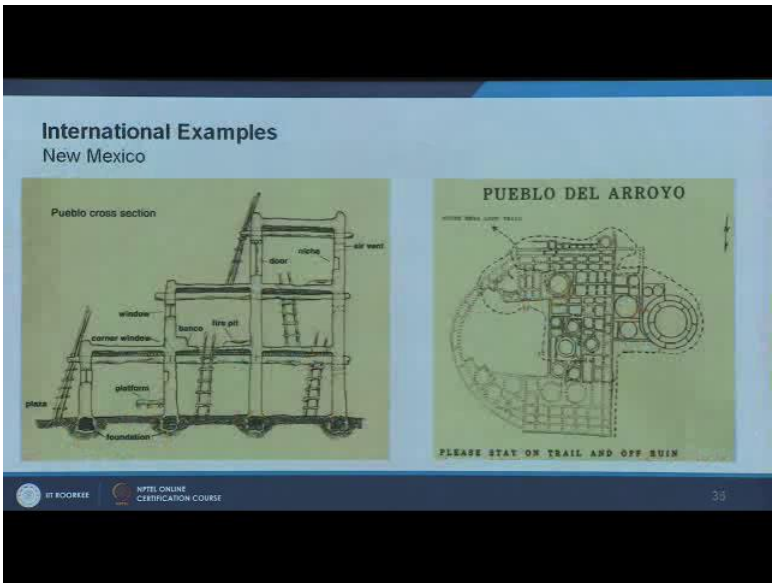
Narrow gallis, compact plan form, you will not find a loosely packed plan form at all.

(Refer Slide Time: 23:50)



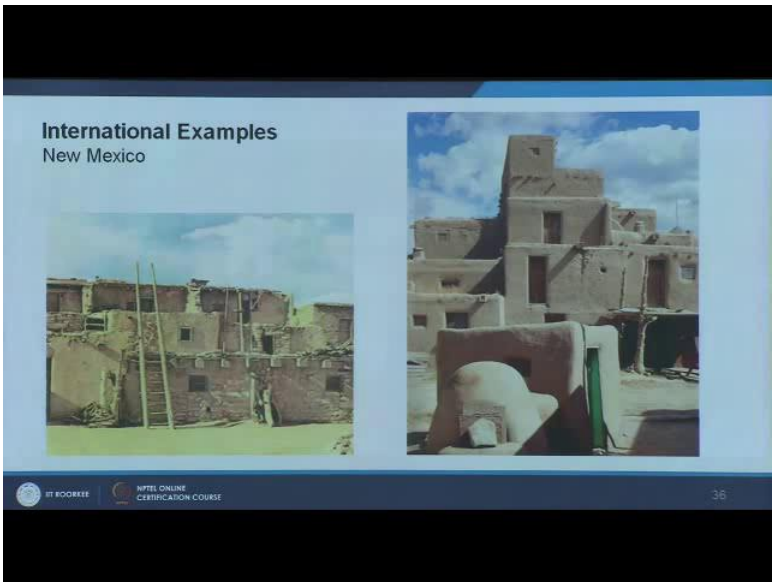
Not just Indian example, even international examples, where you experience hot and dry climate, the plan forms are more closely packed, the walls are more massive.

(Refer Slide Time: 23:56)



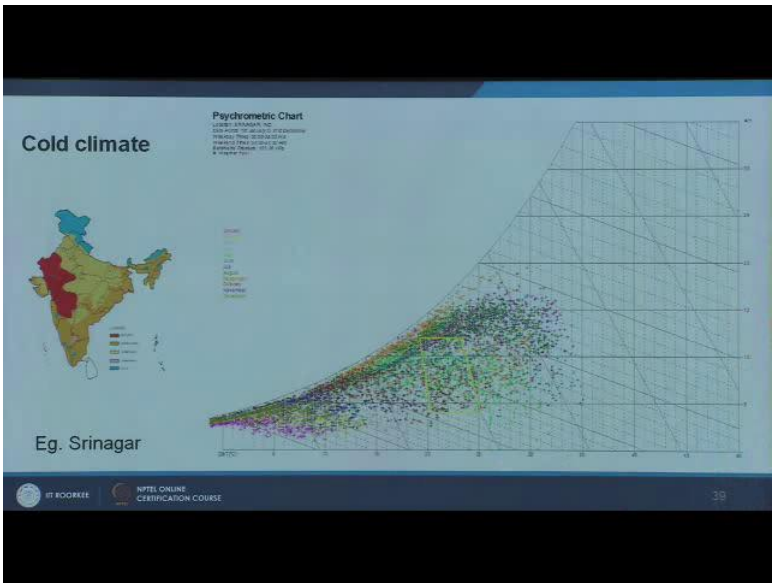
We will talk about the building envelope, in that part, we will talk more about thermal capacity, and the type of wall envelope, which is being used right now. These are massive walls, which has more thermal capacity, are damping in technical terms. Some views of these buildings, the massing is more or less resembling, a typical hot dry region.

(Refer Slide Time: 24:20)



Next is cold climate. I have taken the example of Srinagar. I could not get the climate data for Leh, which is you know, which will be further more onto the left side, for further more lower temperatures. This is for Srinagar.

(Refer Slide Time: 24:25)

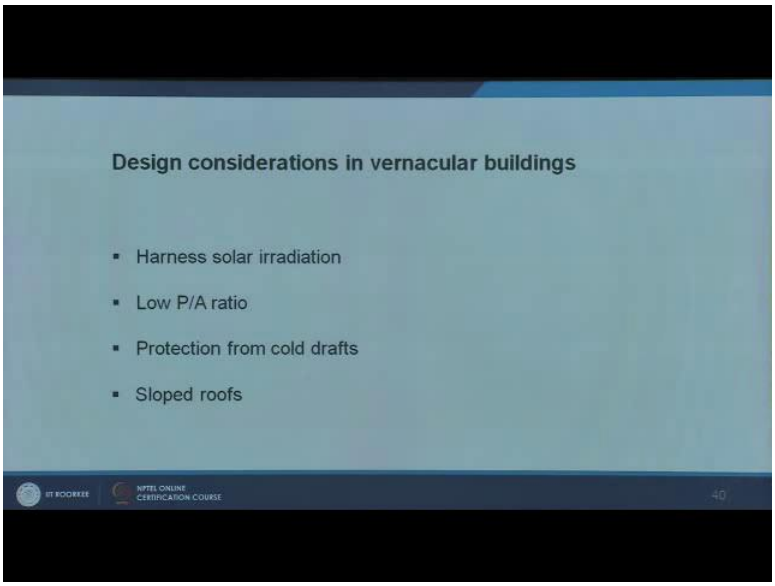


It starts from one extreme, it goes all the way to warm and humid in one of the months, plus, more or less, it lies in moderate, as well as cool, and it extends down to pretty cold seasons. This is how the distribution of data is. It goes below 0, for a few part of the year,

some climate data points are say in December January even part of November you will find data, which is sub zero.

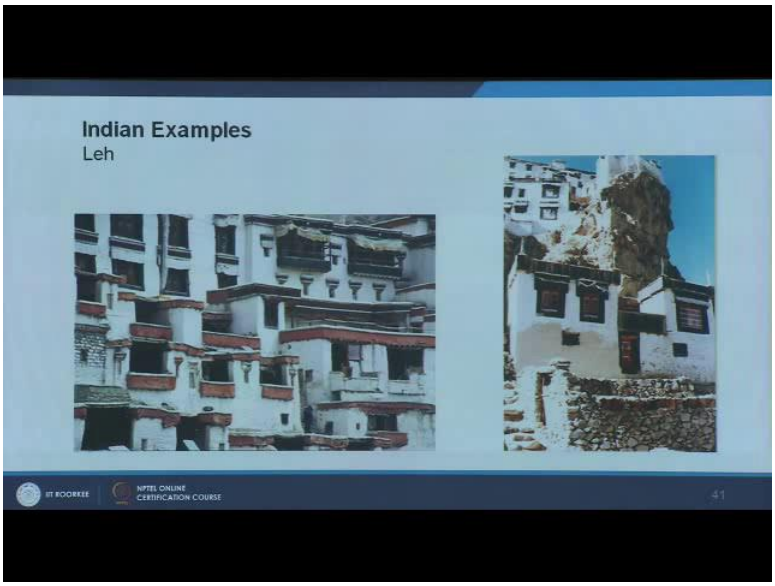
Most part of the data is in cold. Then you also have little bit of moderate and warm humid temperature data points as well. Mostly, the part of the year, that is, about 4 to 5 months, you will have, in and around comfort zone, or the warmer time of the year. What do we do here?

(Refer Slide Time: 25:24)



First is, harnessing solar radiation is very crucial. Number two, there is a resemblance between this particular climate cold climate, and the hot dry climate, in terms of the P by A, that's perimeter to area ratio. Both of these things will have low perimeter to area ratio, or more compact plan form for in architectural terms. We need protection from cold drafts, similar to that, we had from hot winds. Roofs are sloped, because we have precipitation in the form of snow sometimes.

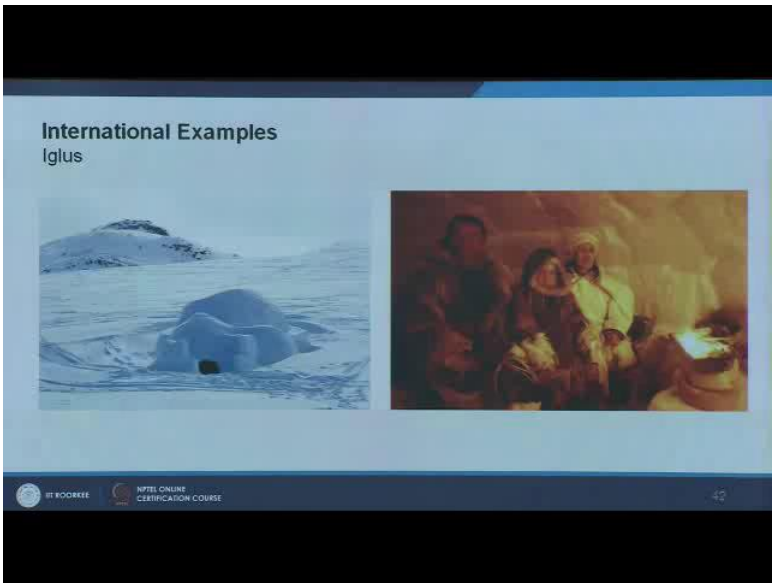
(Refer Slide Time: 25:53)



Some examples from Leh compact plan forms, except that the buildings are located in the cold climate.

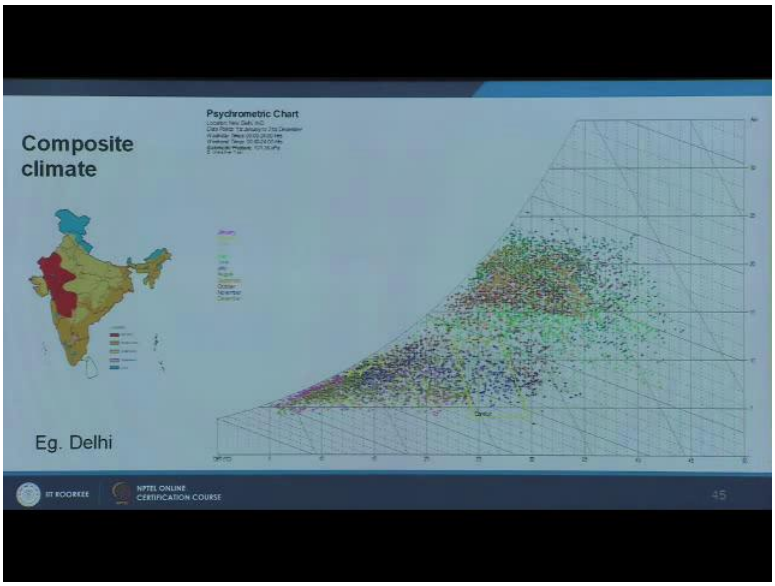
The plan forms resemble these two extreme climate regions.

(Refer Slide Time: 26:04)



We also talked about the surface area to volume ratio, the example of igloo, it is a hemispherical structure, and we have more volume accommodated in the minimum exposed surface area as possible. Take a look at composite climate, Delhi is a classic example.

(Refer Slide Time: 26:20)

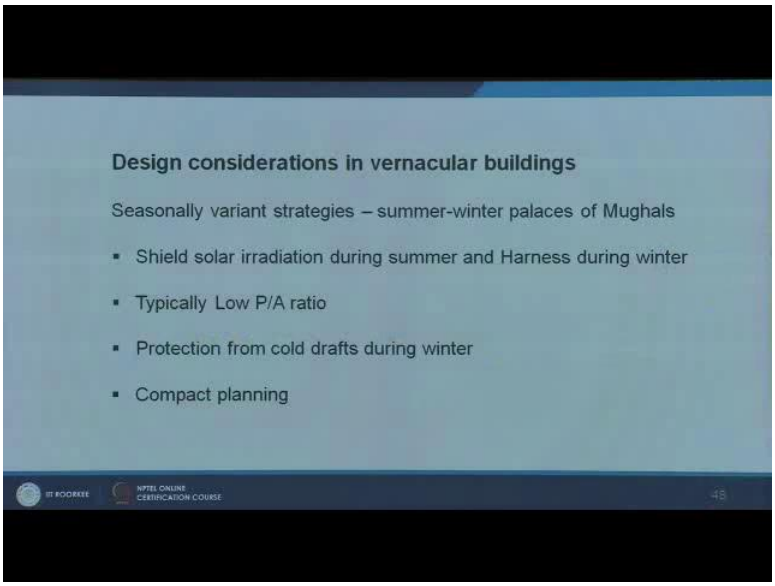


You have climate data spreading in at least 4 to 5 different climatic regions. It is hot and humid, during the monsoon season, it is hot and dry, during summers, it gets to warm and humid. You have warm and dry and moderate season, some part of the year, this is how that climate distribution is. It is little complicated in terms of the climate occurrences, or the weather occurrences, it spreads as far from, the hot and dry, goes up to hot and humid, and goes all the way to a cold climate.

So, there is no specific climate type, which is occurring for more than 3 months. So, this is called composite climate. Another example, Hyderabad, this also has pretty good spread of 5 different climate zones, starting from moderate on one side, hot humid, warm humid, warm dry, and hot and dry. This is how the spread of data points is. It is not as extreme, if you note closely, as Delhi. The temperature points are not going as far, as it went in Delhi, but still the distribution is quite wider. What do we do in these types of things? It is more challenging, in terms of designing buildings, in these particular climates.

What people used to do, simple thing, they had seasonally varying strategies. Simple example is the Mughal summer, winter palaces, they used to switch where they were living. Climate responsive living patterns, they adopted summer palaces, winter palaces, they had Hawa Mahals for specific seasons, and they occupied these buildings.

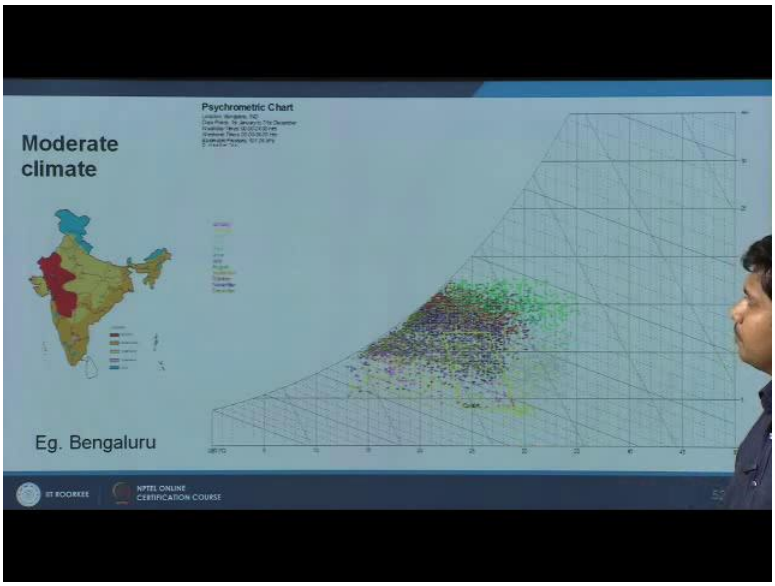
(Refer Slide Time: 27:59)



So, some kind of adjustments, they were able to do, within themselves. Common thing which people do is, shield solar radiation during summer, and harness during winter. Typically, the plan form is compact, though, some seasons are pleasant. Considering two extremities, both pretty hot summers, as well as pretty hot winters, the P by A ratio is kept low. The protection from cold draft during winter, and hot winds during summer, compact planning was adopted. I am coming back to the same graph, which I showed you here. I would like to highlight, there is quite a good distribution, among the macro climate, that is localized macro climates, within the composite climate itself.

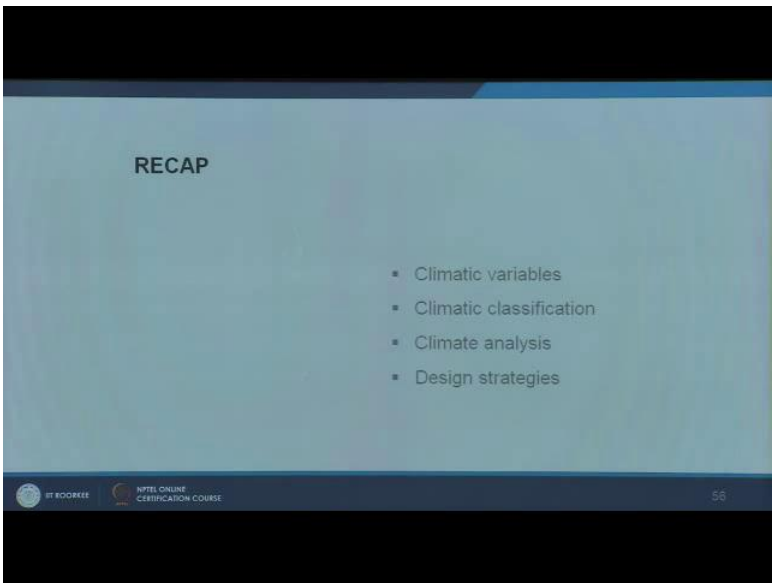
I would recommend you keep this in mind, because just take 20 locations, the distribution is quite significant, in terms of both summer and winter. So, when you design a building with one city, with respect to the other city, though there are standards which prescribe certain building envelope characteristics, we will look at them, but whatever climatic recommendations are there, we also need to consider the localized macro climate within, when designing for climate responsiveness. Only then the design would be more successful, and regionally representative.

(Refer Slide Time: 29:12)



Next, is a moderate climate - it is a pretty, you know, comfortable climate rather, example is Bangalore, which I have considered here. Partly, it is in warm and dry, warm humid and spreads to moderate. This is a spread of data, a lot of data points, lie within the comfort zone, lesser number of heating and cooling degree days, typically the harness solar radiation which is focusing on winter, you can have lot of shaded outdoor activities, and constriction can be less massive. Thermal capacity, very high thermal capacity is not expected in this climate some international examples as well.

(Refer Slide Time: 29:48)



To conclude this session, we started with climate variables; we looked at what are the different parameters, which we need to consider. What are the climate classifications, we looked at 5 major classifications, apart from the international one. We took a look at how climate analysis is done. We looked at how it is read in a psychrometric chart, then how do we interpret and get design strategies what people were primarily doing. These were historic examples, which I was trying to site.

Following sessions, I would be talking more about, how we infer for our specific design, what strategies to use, and how successful they might be, in our own design. I will be demonstrating this, with a specific set of software tools, which you can use.

Thank you.