Sustainable Architecture

Prof. Avlokita Agrawal
Department of Architecture and Planning
Indian Institute of Technology, Roorkee

Lecture - 19
Fundamentals of Climate Responsive Buildings-II

Good morning. Welcome to this lecture which is a continuation of the previous lecture on Fundamentals of Climate Responsive Buildings as part of the online course on Sustainable Architecture. In the previous lecture, we looked at how the climate of different place can be classified, what are the different climatic zones which are classified for our country India. The different five climatic zones, how do we define each of these zones and then we also looked at the passive design strategies.

The broad categories of the passive design strategies, then we moved on to see how can we identify based upon the climate of a given place, that what is the right strategy and we looked at two tools for that. One we looked at psychometric chart, where we could identify that depending upon the climate, the weather of a place what kind of strategy would be suited. For example, dehumidification or humidification or sensible cooling like that or.

So, this was a broad type of parameter, broad type of strategy that we could have used and then we went in more detail about looking at the building specific strategies with the help of Mahoney's table. So, after these two tools, today we will be looking at a little more advanced tool which is available in the form of free software which is called Climate Consultant.

So, today we will talk about the software Climate Consultant and how it helps us to identify the correct strategies. I hope you have already downloaded the software Climate Consultant and are ready with it.

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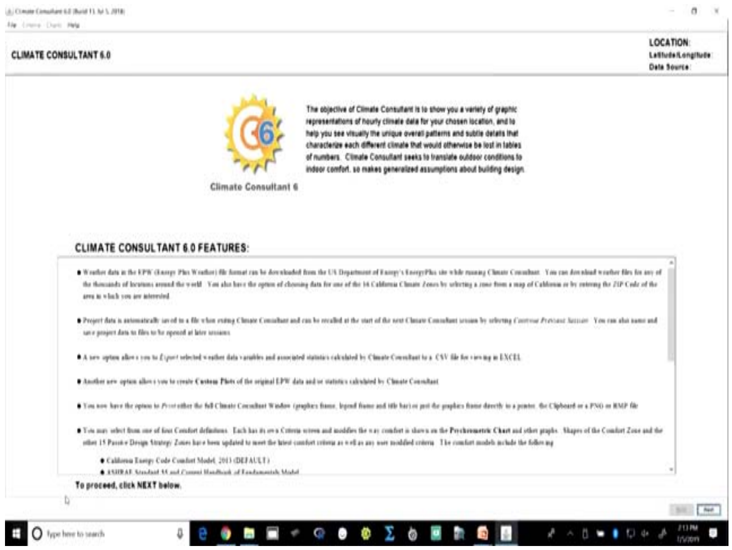

So, let us go ahead with understanding how the software works. Climate Consultant the recent version, most recent version which is available for you to download and use is Climate Consultant 6. Once you download the software, install it on your computers you will see a start up screen like this.

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So, we start a new project, suppose this is a residential project and we are choosing the metric units.

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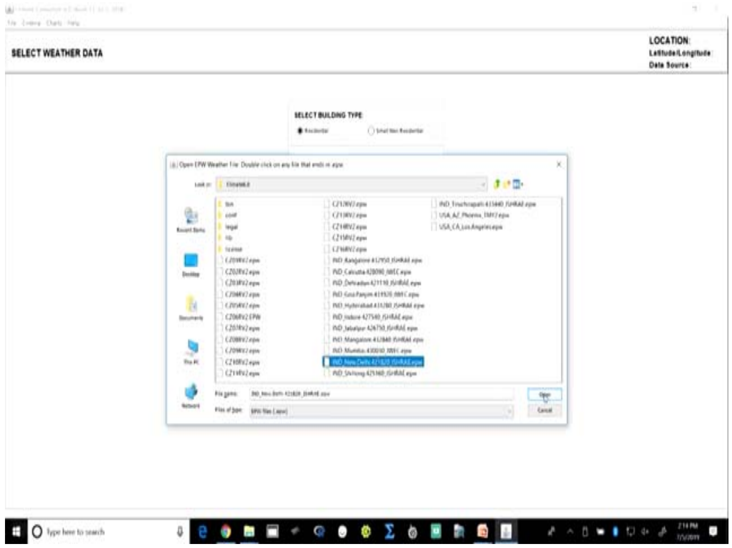

And we can open an existing weather data file.

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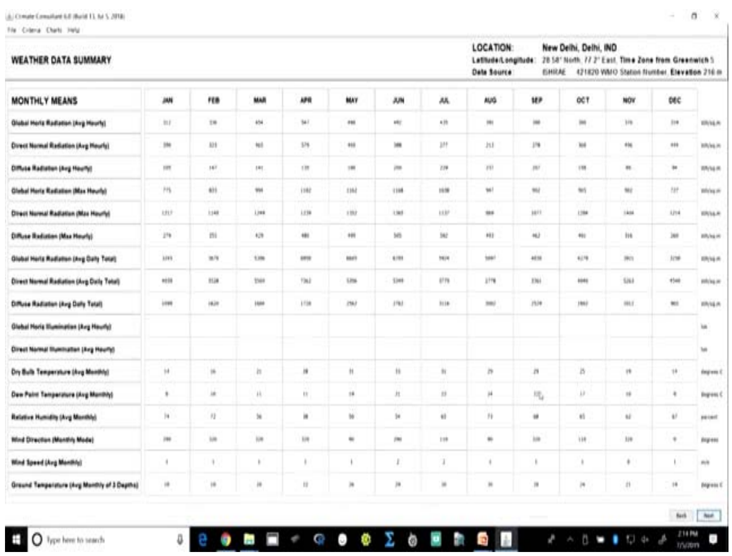

So, for example, suppose we are looking at New Delhi and we very clearly know that New Delhi is actually a composite climate, where it experiences the extremes of summers as well as the extremes of cold and it also has a monsoon season. So, there are three seasons that this climate experiences. So, once we open this weather data file, we would see that there is this entire data spread. So, we have global horizontal radiation, we have direct normal radiation for each of the months. We have diffuse radiation and global horizontal radiation which is maximum.

So, maximum, average and average monthly, average daily, average monthly, average hourly; so, this is what we have for the radiation besides that we also have illumination here. We have the normal illumination; we have dry bulb temperature which is average monthly, the dew point temperature. We also have relative humidity; wind direction and wind speeds and we have ground temperature which is the average monthly which is for 3 depths underground. So, this is the weather data which we have and this is the summary table which we see as the first screen after we have loaded the weather data file.

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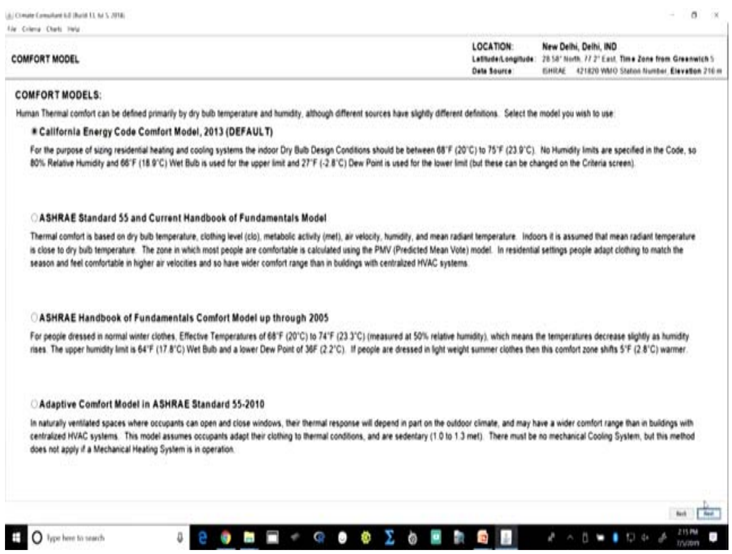

Now, once we have selected the weather data file, then we come to selection of comfort model. So, when we were talking about the thermal comfort, we have looked at the different comfort models which are there. If we look at this ASHRAE Standard 55 and the Current Handbook of Fundamentals Model, we are looking at PMV, we are looking at thermal comfort based upon PMV minus 0.5 to plus 0.5 is how we are defining it.

If we are looking at the adaptive thermal comfort model as per ASHRAE Standard 55, the 2010 version; here we will be looking at the adaptive comfort. And, then it is not the PMV based model, it is adaptive comfort model. We can choose either one of this; you can also try by varying these comfort models and then see what happens.

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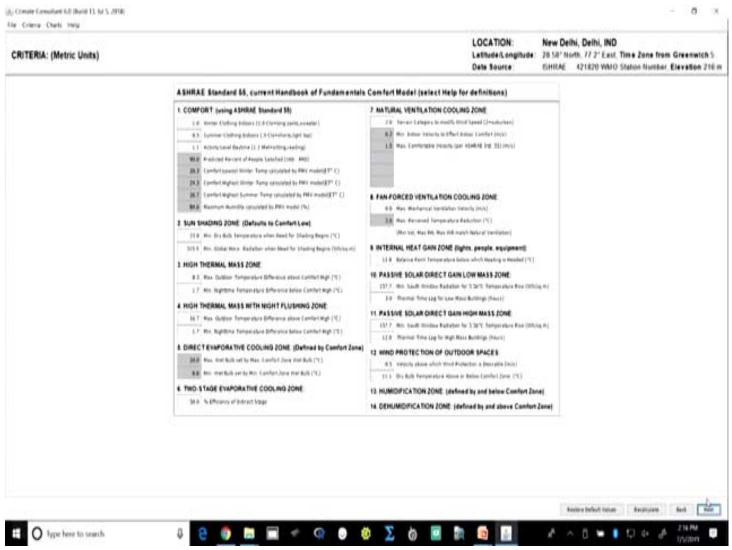

So, let us go ahead with say ASHRAE 55 for now, when we select ASHRAE 55 it gives us how the comfort is being defined, how the sun shading zone is being defined, thermal massing zone and the clo values. So, all of that is already defined based upon the comfort model as per ASHRAE 55. So, you can very clearly see that what is the model which is being applicable here which is being used here to define comfort. This is inbuilt; there is nothing that we can change about it. So, this is just for information a kind of annexure that we are using here.

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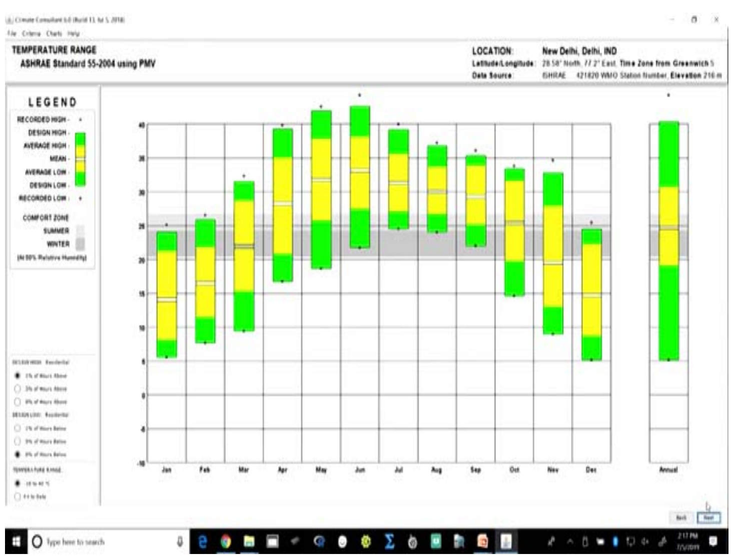

Now, we start looking at the climate of Delhi, here we are looking at the temperature range. So, this is dry bulb temperature and it shows the monthly range for New Delhi. So, for each month it very clearly shows what is the average highest temperature in a given month. This also shows the comfort zone which is for summer as well as winter.

So, it shows the comfort zone which is shown in gray here and this is taking a relative humidity at 50 percent. So, the comfort zone which is defined is at 50 percent relative humidity. Now, this shows how the temperature is varying it, this one shows the average annual spread of temperatures. Now, here we are looking at the design high and design low. So, we are looking at 1 percent of hours above the design high temperature which is here; suppose I change it to 0.5.

So, we see that only 0.5 percent of the hours will be above the design high which implies that we are designing for a temperature, where only 0.5 percent of the hours will lie above the design high temperature that we have taken. If we take it 0 percent; so, the design high temperature will be the maximum temperature that has been recorded ever in a given month; however, it is not a very good idea.

So, this percentage actually defines how much of the loading is going to be there in a building, the peak loading, but we should always understand that the peak loading is going to be there only for limited, few hours. So, the maximum temperature which has been recorded is going to be there for maximum 1 hour or 2 hour in an year. So, if we take it to be 1 percent of the hours above, we are taking only 1 percent of the hours which will not be brought to the comfort range with the design strategies which we are going to adopt.

The same is for design low. So, the lowest temperatures here have been taken as 0 percent of hours below.

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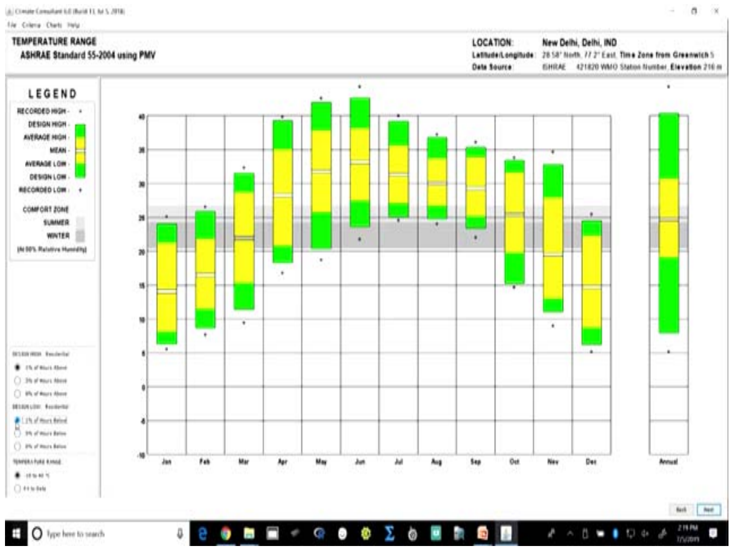

We can take it to 1 percent and we can see that we will not be designing for the remaining 1 percent which are below the design low temperatures, the set points.

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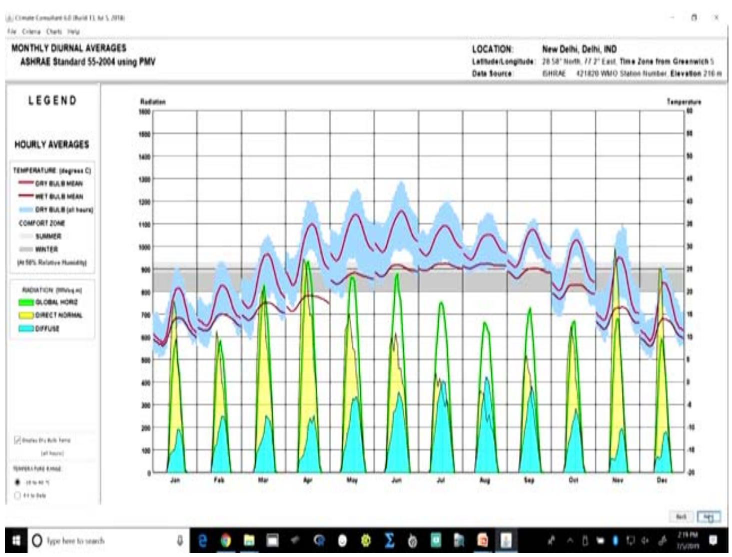

Similarly, we go on to see the diurnal averages, how the wet bulb and dry bulb temperatures are varying monthly. So, this is dry bulb mean, this is wet bulb mean, this is dry bulb variation for all the hours. So, this is the hourly data and this is actually the mean data. Along with this we also look at the radiation, the global horizontal radiations, the direct normal radiations and the diffused radiation. And, we see as the radiation goes on increasing the temperatures also increase, the ambient air temperatures also increase.

So, this kind of gives the summary of the dry bulb temperature, wet bulb temperature, the comfort zone of summer and winter both here and the how the radiations are varying.

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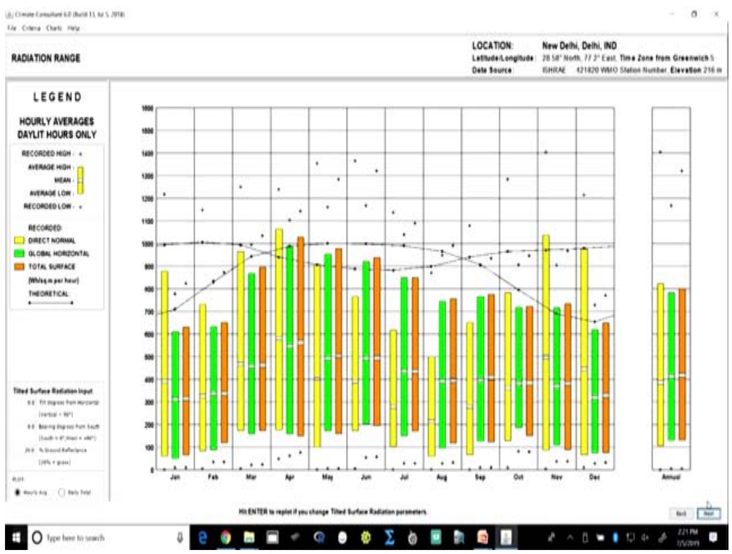

Then we are looking at the hourly average daylit hours. So, we are looking at the daylit hours which are direct which are receiving the direct normal, global horizontal and the total surface which is being lit. This is giving the variation for the high, mean and low, how it is varying for a month. And, this is the theoretical availability of the daylight throughout each month, throughout the year.

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So, illumination data for New Delhi is not available in the weather data file.

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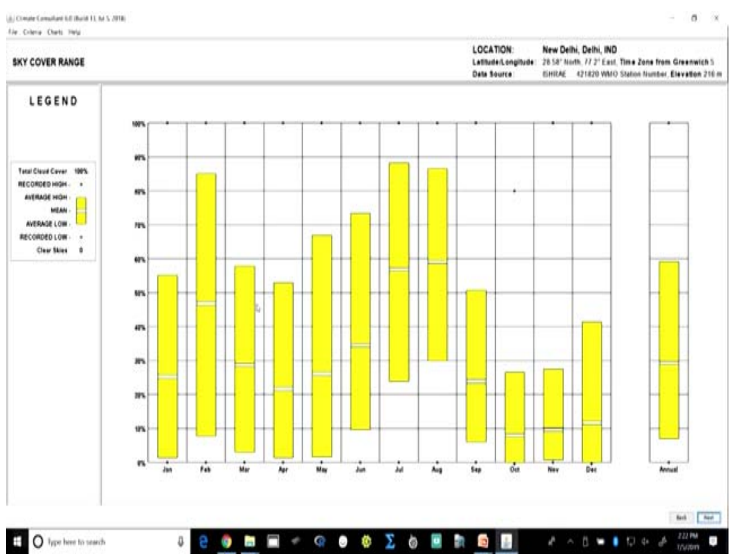

If we had we would have that as well, then this is the sky covering; the total cloud cover is assumed to be 100 percent. So, out of that how much of the cloud cover is there so, we can see that in July the cloud cover is quite high during the months of July and August which are the monsoon months. So, which implies that it is an overcast sky and in the months of winters: October, November, December even January the cloud cover is quite low. In the month of April and March also it is reasonably low. So, that is what we can see that what kind of cloud cover is available.

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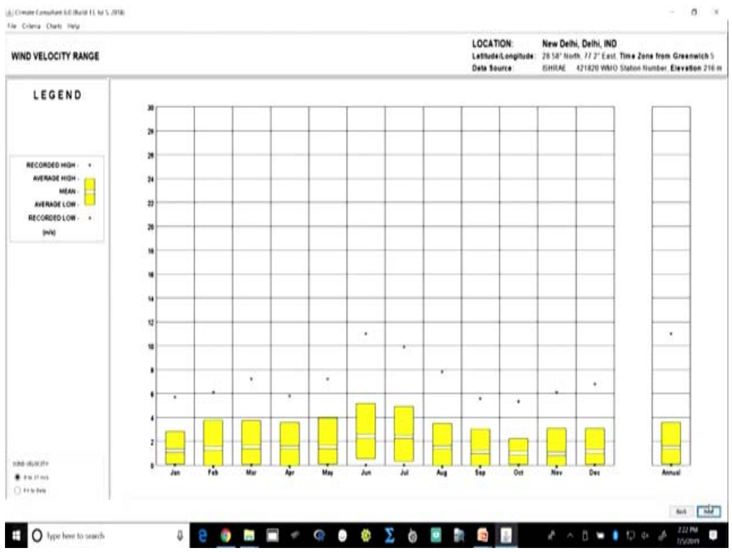

We can also look at the wind velocity range. So, what is the average velocity of the wind which is present. So, we can see again the average wind velocities increased during the rains, the monsoon period and slightly during the March and December. So, if you look at this we would also simultaneously while we are looking at this climate data, we are also going to make a mental note of what kind of strategies would be fitting; though the software itself suggests.

But, if you are looking at December and the wind speeds are increasing, we know that we have to block the wind during winter season say December and November. And, similarly when we are looking at June and July, that is the humid month in that period which is the warm humid climate kind of climate; we would require more of wind to be brought in.

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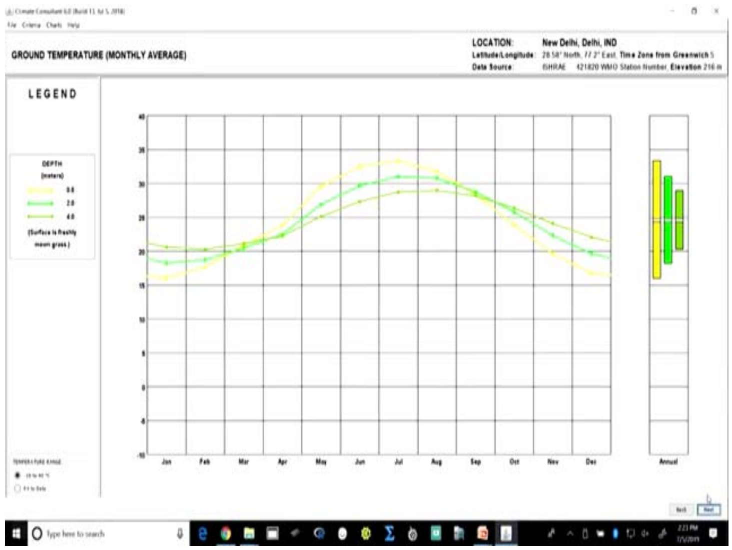

So, once we have looked at that we would look at the direction of the wind which will be available subsequently in the form of wind rows, but here we are looking at the ground temperatures at different depths. So, we are looking at the depth of 4 meters, 2 meters and 0.5 meters. And, we can see that the average temperature of the ground at a 4-meter depth remains largely within the comfort range, comfort zone.

So, in a climate like this earth air tunnel could be a great asset, it could be a very good passive design strategy. Because, if we overlap this graph with the dry bulb temperature graph, we would see that the dry bulb temperature actually varies quite large; if you are looking at an annual variation. So, it would go from somewhere close to 10 degrees and go up to 40 degrees during May, June and then come down to 10 degrees again by December. While, this earth temperature, the ground temperature will remain more or less constant at a 4-meter depth.

So, what is the depth at which we can still, but if you look at this at 0.5-meter depth we are still not getting comfortable temperatures say during summers, in winters it is fine, but during summers it is still not comfortable. So, probably going at a 4-meter depth for an earth air tunnel is what would be desired in this climate.

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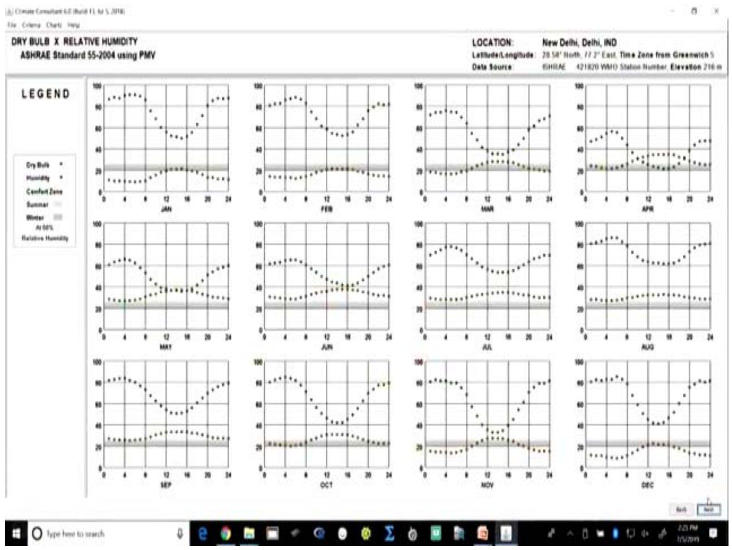

We are looking at dry bulb and relative humidity simultaneously. So, this green dot is the relative humidity, how it is varying for each month of the year and we are looking at dry bulb temperatures. So, we see that whenever the temperature is increasing in winter months the humidity is dropping, but overall if we look at the monsoon months, we see that the humidity here.

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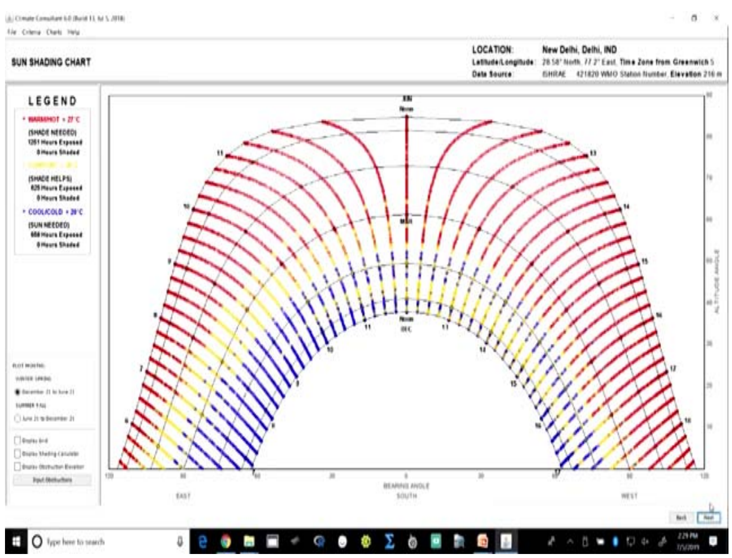

This part of the analysis in Climate Consultant shows how the sun path is varying. So, we can see for different months from December to June, how this sun movement is varying along with the temperature, the ambient air temperature which is given which is coded in three different colors. So, we know that when the sun is here in this zone in the month of say December, it is actually quite cold outside. So, we would want more sun during this period.

While, if we are looking at these red ones and the movement of the sun along this; so, we would want to block the sun, we would want to shade the sun. The ones which are in the comfort zone which is approximately 25 degrees centigrade, that is where 24, 20 to 27 degree centigrade that is where we would want to bring in. We may have sun penetrating inside the building and sometimes we may not require that depending upon the climate.

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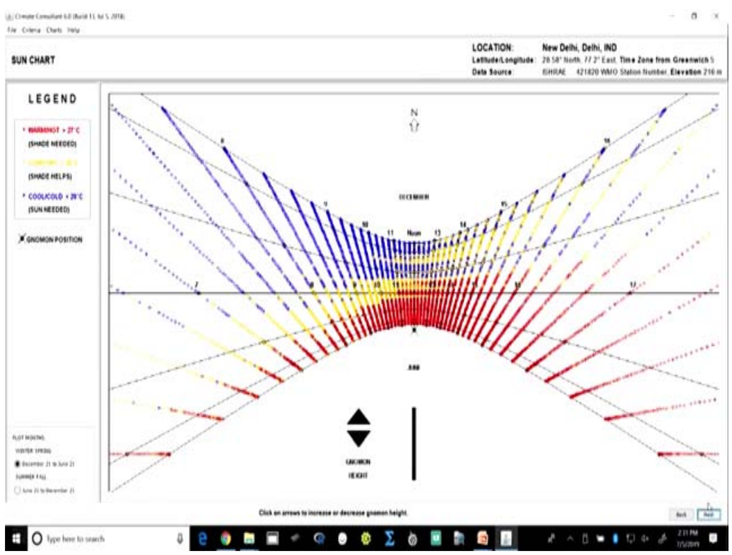

It is also showing the same sun path diagram here.

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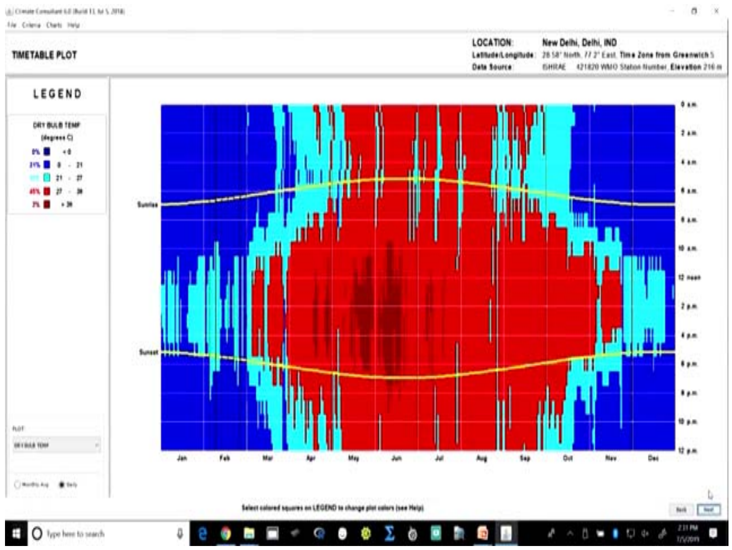

Here we are looking at how the temperature is varying at different time of the day; we are looking at different times of the day in each of the month and then we can see that what is the time of the day which is hot in an entire year. So, we are looking at hourly temperatures and we are also looking at the temperature profiles through color here.

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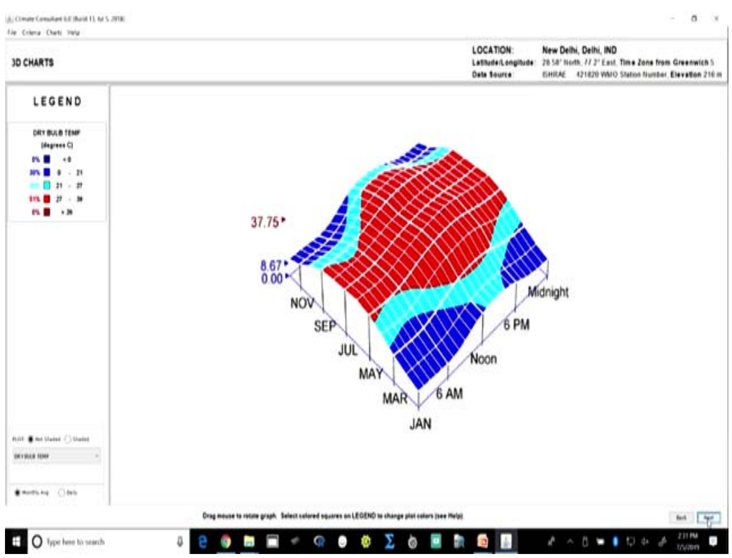

This is the same 3D representation of the same data.

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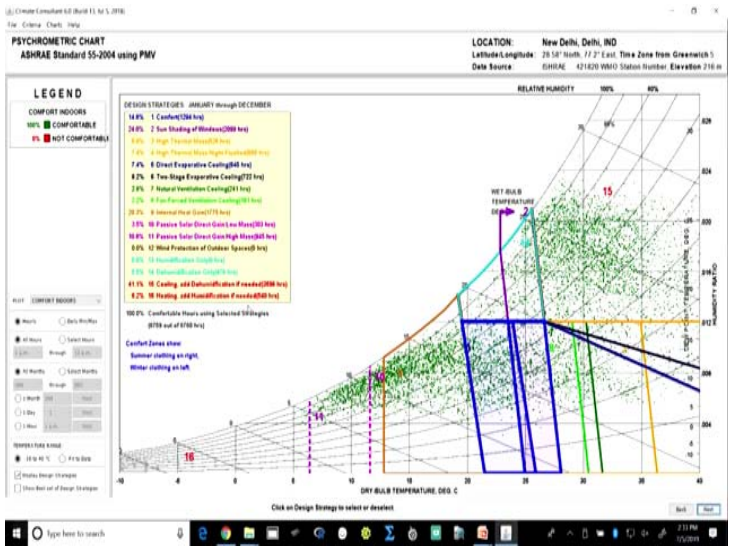

Once we have done this, once we have understood what the climate of the place is, we come to a screen like this. Now, this is critical and we have to look at this screen carefully and this is what tells us what are the design strategies. Now, if we look at all these strategies which can be employed to increase the hours of comfort. Here finally, with the employment of all these strategies which are given 100 percent of the time the indoors can be maintained comfortable. But, if we look at these strategies, we are looking at sun shading of windows, we are looking at high thermal mass.

High thermal mass which is also flushed during the night time. We are looking at direct evaporative cooling. We are looking at two stage evaporative cooling, we are looking at natural ventilation cooling, fan forced ventilation cooling. Now, all of these are not passive design strategies, some of them are advanced passive strategies. For example, the fan forced ventilation cooling. So, which means the simple ceiling fan is installed that is an active strategy, but it may also be coming under the advanced passive strategies; because of the kind of availability of strategies that we have.

We are also looking at say internal heat gain which is by heating up the interiors, this is again an active strategy, passive solar direct gain low mass and high mass strategies. We are looking at wind protection of outdoor spaces which is a passive design strategy. Humidification only, this is out and out an active strategy, dehumidification is also an active strategy. Cooling and dehumidification is air conditioning largely, HVAC and heating and humidification is again HVAC which we are adding.

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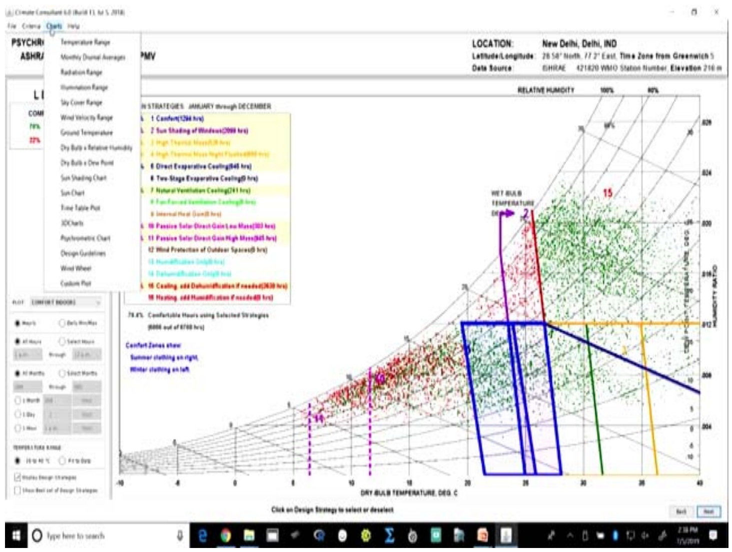

Now, if we are seeing that without doing anything, suppose I remove these strategies; I can take off these strategies. If I do not employ any of these strategies, I see that this is the period as per we have selected the PMV ASHRAE PMV model. So, this is the period under which the climate of New Delhi would experience comfort. So, only these many hours will fall under comfort here for the given climate; if we do not do anything, if we do not employ any strategy.

Now, through our understanding of composite climate we already know that what kind of strategies may work. So, let us look at the passive strategies first. So, suppose I add sun shading of windows. So, another 24 percent of the hours will be brought under comfort. So, we see that additional 24 percent of the hours will be brought in under comfort which is shown here so, this is the strategy 2. So, some of the hours around 2099 hours will be brought under comfort, if we provide for sun shading of windows.

So, that is a very highly effective strategy. If we look at the high thermal mass, suppose I add a lot of thermal mass; it will be able to add only 6 percent, bring 6 percent of these hours under comfort which is very less. If I night flush it, it will add around 7.4 percent of the hours and bring it to the comfort range. If I add natural ventilation, it will add to around 2.8 percent of the hours to the comfort range, comfort zone. Suppose, I add the passive solar heat direct gain; so, it will bring in around 3.5 percent of the hours during winters to the comfort zone.

If I add the high mass, it will add around 10.8 percent which is further during the extreme winters to the comfort hours. If I add wind protection of outdoor spaces, we are not able to bring any hour under the comforts so, let us take away that. Now, rest of these and also direct evaporative cooling; so, we are looking at evaporative cooling, now we are also looking at the humidity, low humidity levels. So, here we are looking at direct evaporative cooling where further more hours will be added to the comfort zone, other than these the rest are active strategies.

So, if we look at all these passive design strategies which are mentioned through the software, we would be able to bring in about 37 percent of the hours as comfortable range within the comfortable range. The 63 percent would still remain not comfortable, now the hours that we are looking at are the high humidity period. So, the hours which have high humidity lying between 25 to 35-degree centigrade temperature and high humidity, humidity of higher than 60 percent that is the warm humid season in a composite climate. So, we know that the extremely high temperatures and low humidity can be brought under comfort employing evaporative cooling which is like desert coolers.

The extremely low ones can be brought under comfort by adding direct heat gain, solar heat gain. So, that can also be partially brought under the comfort range, but the problematic period for a composite climate would be this warm humid period. And, that is where we would probably need cooling and dehumidification and we can see that 40 percent of these hours. So, suddenly the comfort hours go up to 78 percent and a large portion of this comes into a comfortable zone, when cooling along with dehumidification is done, added as a strategy; now that is an active strategy. So, we can look at the strategies, the design guidelines besides these.

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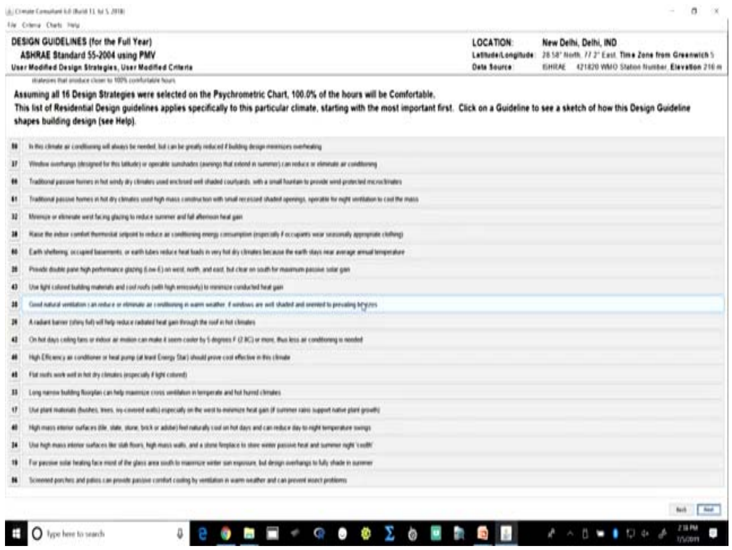

So, we can also see what kind of strategies are available for us, we can look at how the design of a building should be done to bring about to bring in thermal comfort. So, it says that the window overhangs or operable sun shades should be provided. They can reduce the need for air conditioning, the active air conditioning. The building construction it should have small recessed shaded openings.

So, smaller windows are preferred which are operable for night ventilation to cool the mass; so, night flushed. Then the minimization or elimination of west facing glazing to reduce summer and fall afternoon heat gain. So, each of these strategies can further help to increase the comfortable hours.

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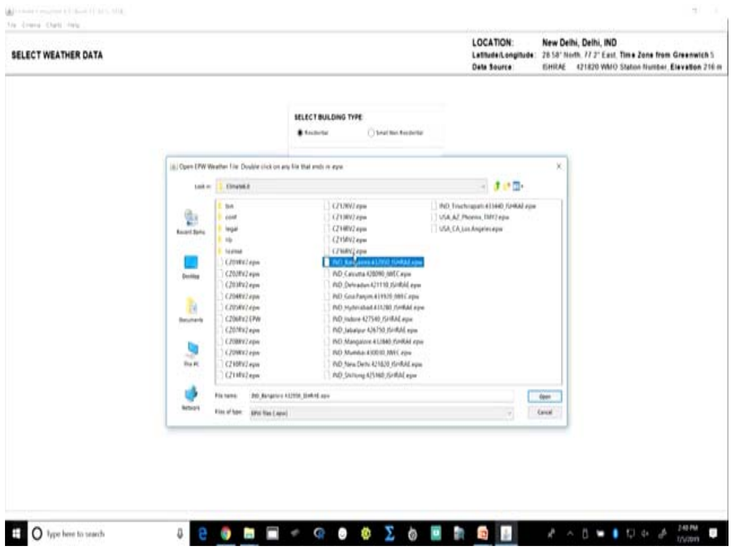

Let us quickly look at another climate, let us look at the climate of Bangalore which is a moderate climate.

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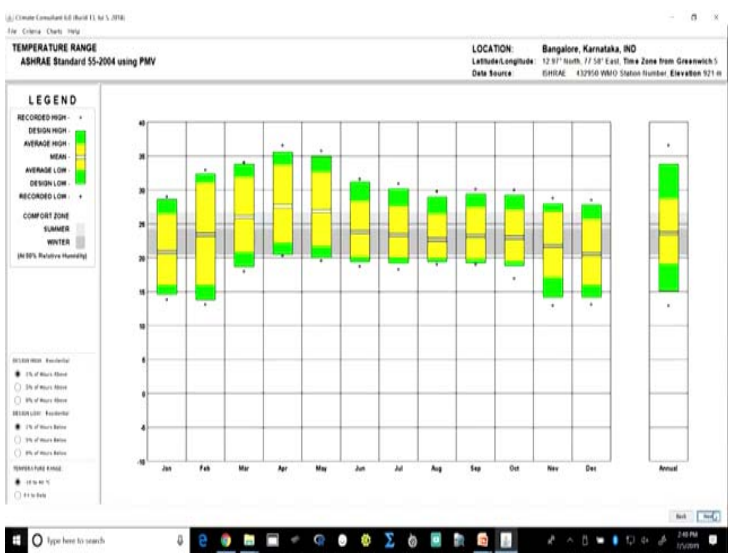

And if we look at the data, look at the temperature range; so, while the temperature range in Delhi was quite high. Here we see that the temperature range is closed to the comfort range.

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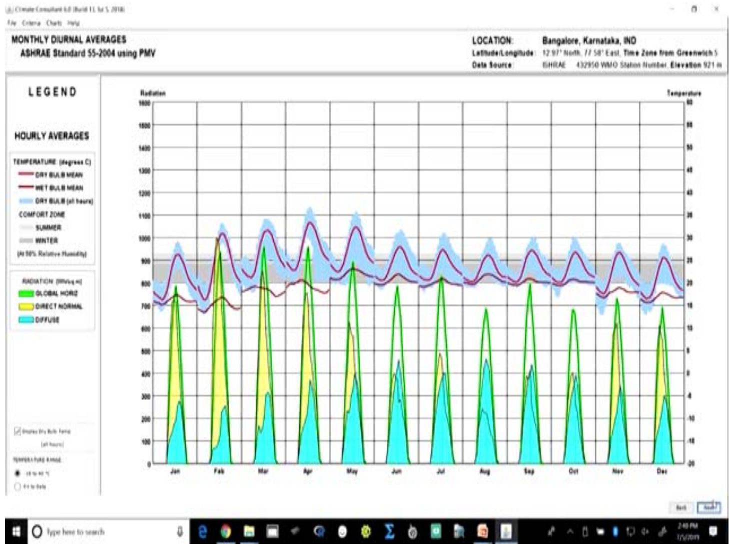

Similarly, here we can see this variation coming in which is very close. We can see that the radiation is quite high even in the winter months, while for the climate of New Delhi based upon its latitude, the solar radiation received during winter month was quite low. And, during the summer and monsoon months it was quite high, that is what is available in the form of the radiation range as well.

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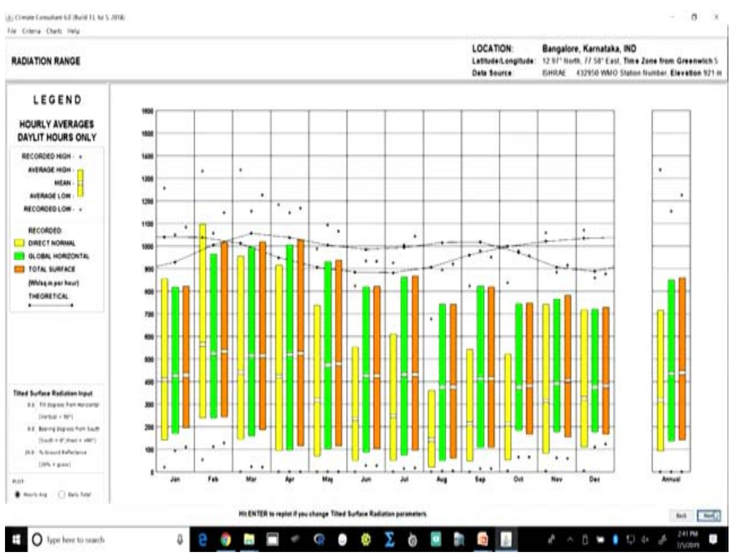

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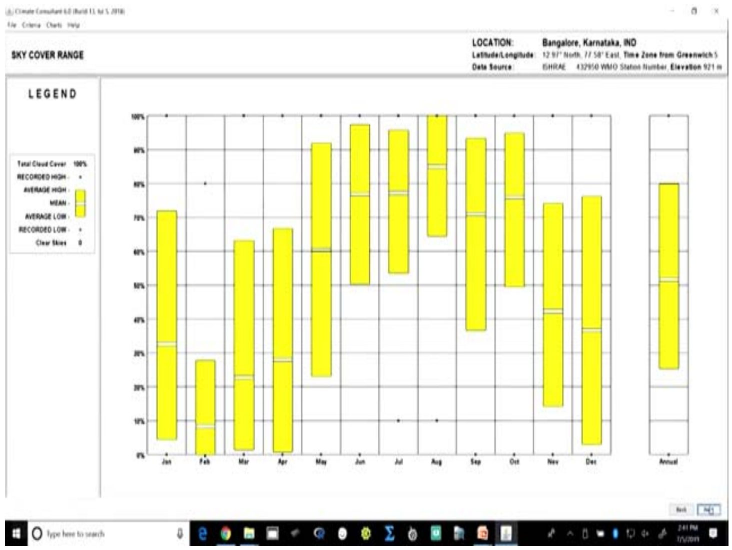

This is the sky cover range and we see that the sky cover is quite high in the monsoon months here as compared to the Delhi climate.

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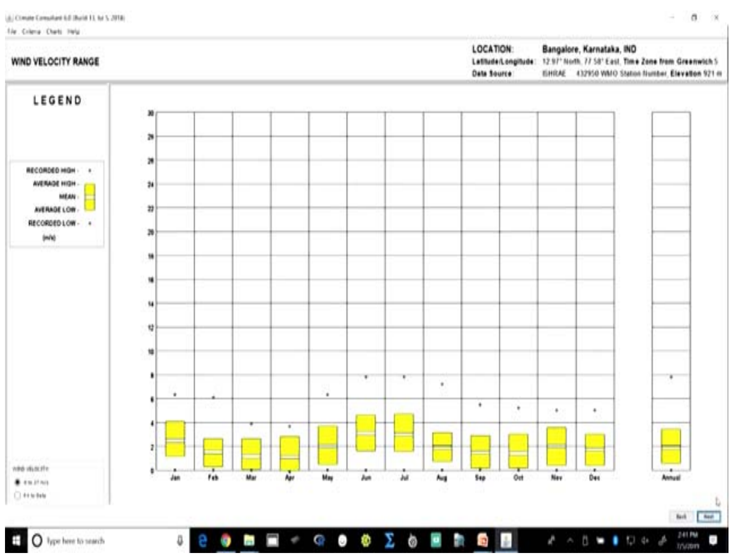

If you look at the wind velocity range more or less it remains the same.

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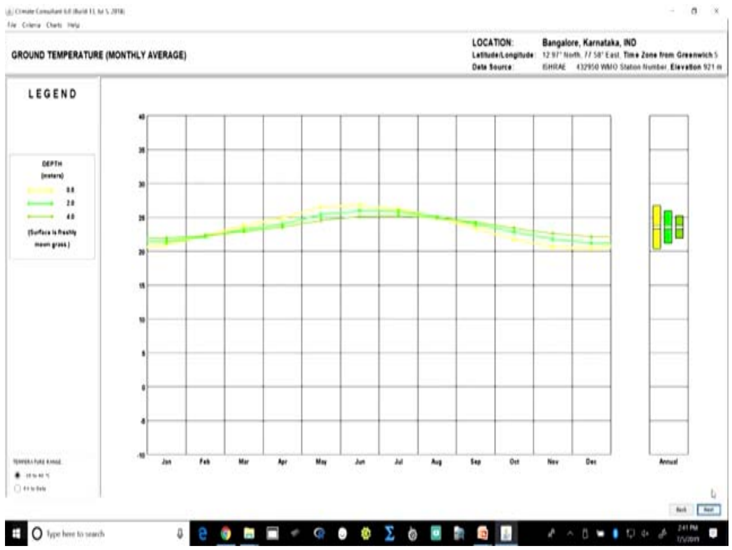

And, if we look at the ground temperatures if you remember the Delhi ground temperatures, we saw that it was going a little higher for 0.5 meter depth and it was crossing the 30 degree centigrade limit, while here we see that it is almost limited within the comfort range. So, we do not need to take our earth air tunnel down below up to 4-meter depth, but even a 0.5-meter depth would serve the same purpose.

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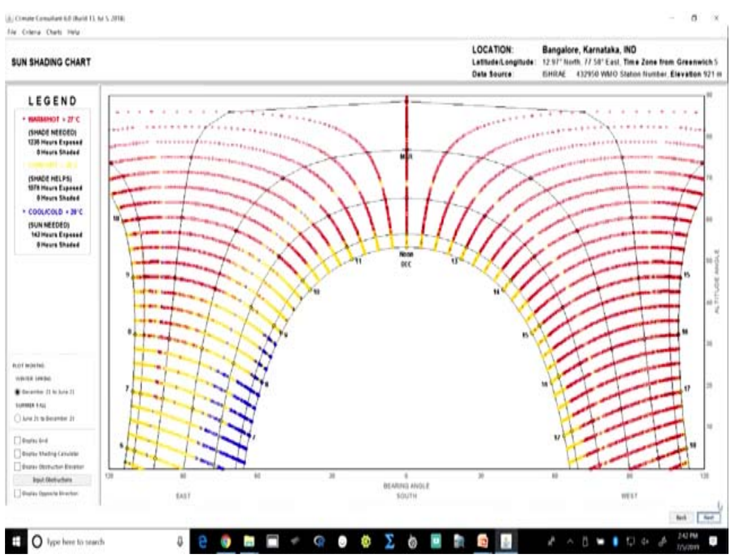

If you look at this sun shading chart, we would see that for large part of the year it is spread in the warm temperatures under the warm temperature.

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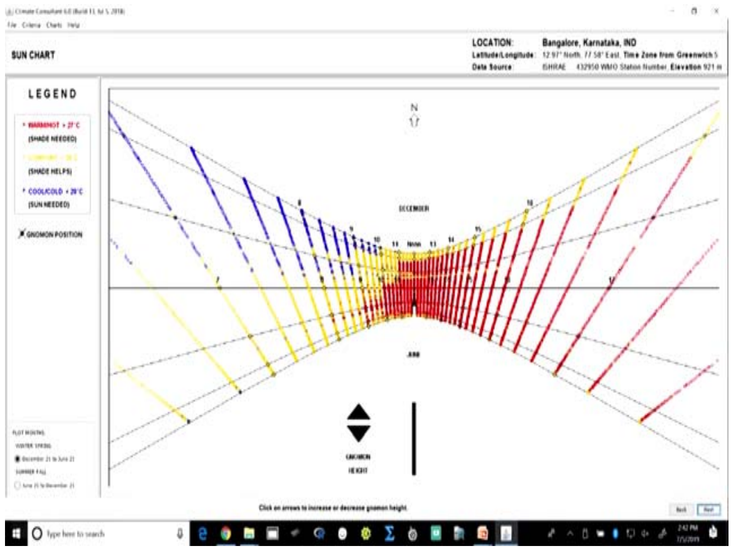

So, shading might be a very good strategy.

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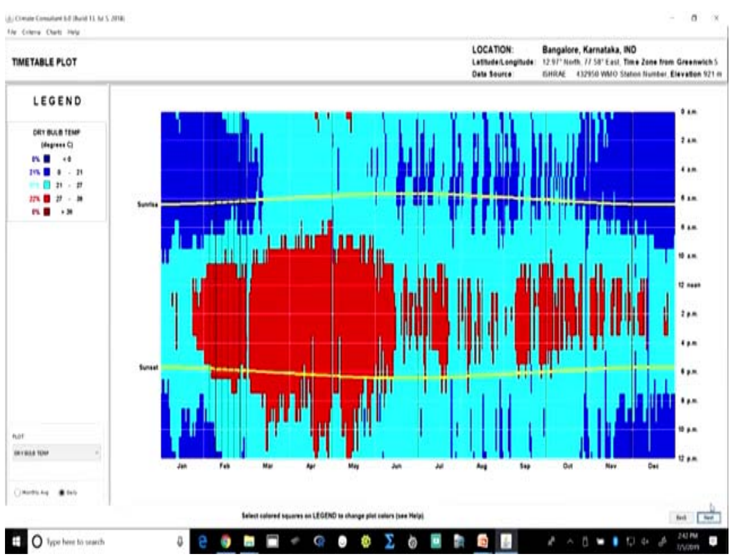

And, the same thing we see that the extremely high temperatures above 38 are not there at all and we have the hotter months are actually March to May, while in New Delhi climate we saw that the hotter months were somewhere in June, July, August, the most problematic months.

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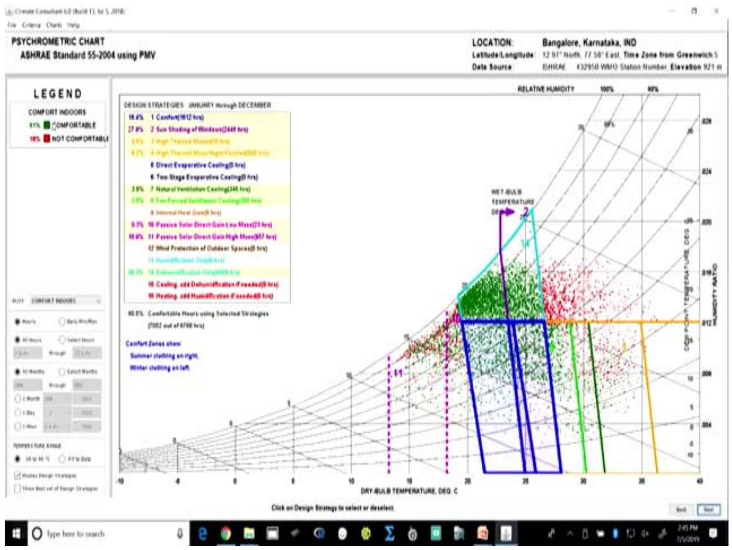

Now, we come to this. So, if I take off all these strategies, we can see that without doing anything the climate of Bangalore has around 18.4 percent hours as comfort, but we can also see the spread. We see that there is no extreme winter climate here, there is no extreme summer climate here where the temperature goes above 35. There is range where the at higher temperatures there is no high humidity. So, we have high humidity at a temperature range which is within the comfortable range.

So, if we do not do anything, we have around 18 percent of the hours falling under comfort. And, if I add just sun shading so, around 27.9 percent of the hours are added to the comfort hours. And, if I look at the natural ventilation around 3.9 percent of the hours here are added to the comfort and if I add fan forced ventilation another 3.5 percent here are added to the comfort. If I look at passive direct gain and passive gain high mass then almost all the hours which are towards the lower temperature ranges are added to the comfort range.

And, if I add the high thermal mass and high thermal mass which is night flushed almost the entire of this high temperature ranges are also brought within the comfort zone. Now, the problem in this climate Bangalore climate is also the high humidity temperatures, where higher temperatures with high humidity. And, here if we add only dehumidification because it is anyways within the comfort range of temperature, but the humidity is high. So, if I just dehumidify the environment, I would be able to bring in about 46.3 percent and that makes 81 percent of the times of the year, hours of the year as comfortable. And, here only if I add humidification there is no change; so, there is no humidification needed, because it is anyways quite a humid climate. And, if I add cooling along with dehumidification, it may not really serve the purpose.

So, I can see that for with these strategies I can bring in about 81 percent of the hours in an entire year as comfortable.

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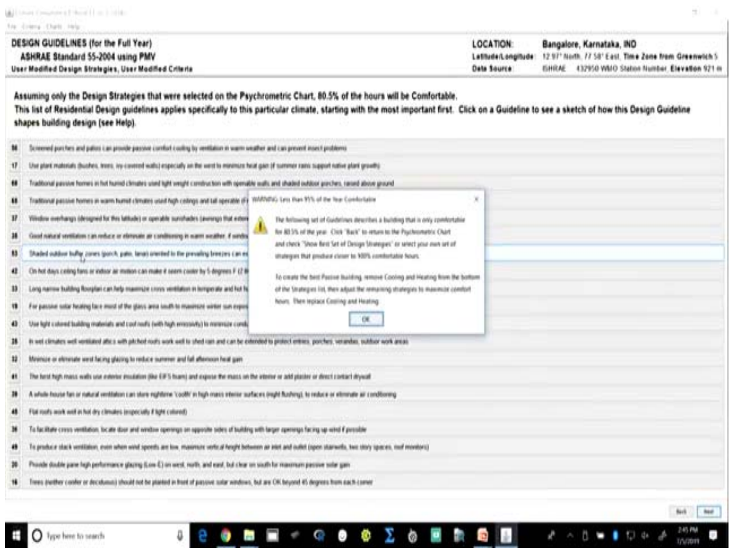

So, if we compare the two climates and look at the design guidelines, we can actually see what kind of strategies works. So, use of light-colored building materials and cool roofs which was also a strategy for Delhi climate, then minimize or eliminate west facing glazing. So, all these design strategies will then become available to you.

With the help of this kind of a tool we can do preliminary identification of strategies that what kind of strategies would work, what kind of strategies should be taken ahead. And, along with that a knowledge of what kind of passive design strategies are available, we can make a judicious choice of what kind of strategy we should be using.

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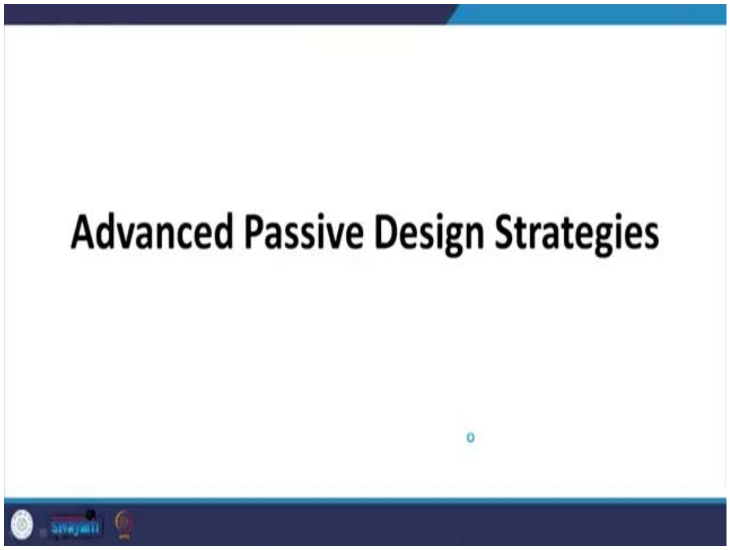

Now, once we have done this, we also have to know a little bit about some of the advanced passive design strategies besides the ones that we have already seen.

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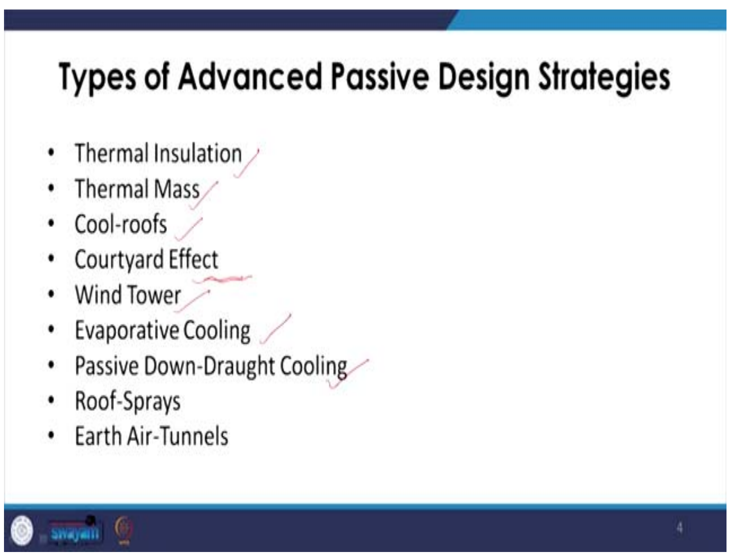

So, some of those I have listed here, there are many-many more. The new ones are being developed and researched, but these are some of the identified and established ones which are also commercialized and popular. So, here we will look at thermal insulation, thermal mass, cool roofs. Courtyard effect has already been taken as a passive design strategy, but it is advanced passive design strategy if we club it with a little bit of mechanical ventilation, forced ventilation. Wind tower is an advanced passive design strategy, evaporative cooling, passive downdraught cooling which is very similar to wind towers, roof sprays and earth air tunnels.

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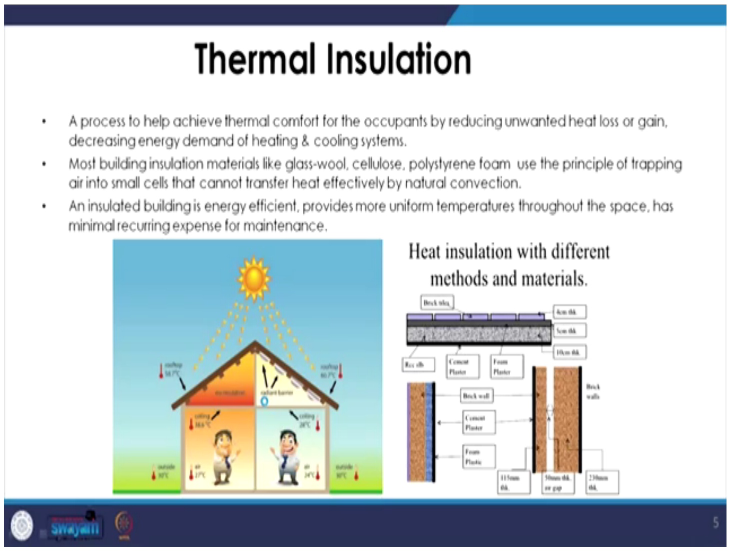

So, when we are talking about thermal insulation, we are talking about adding a material which has extremely low u value or adds a lot of heat resistance to the transfer of heat and that is added to the regular building construction. So, it could be added to the walls, it could be added to the roof. Now, depending upon the direction of heat transfer the insulation would be added. So, suppose we are talking about an air-conditioned building in a hot climate, there the heat is actually coming from the outdoors and there is air conditioning which is happening inside.

The insulation that may be provided in such a case would be in between the in between two brick walls, where the insulation would be slightly towards the indoors. While, in an extremely cold climate where the outdoor temperatures fall extremely below much below the sub-zero temperatures, the insulation may be towards slightly towards the outside, but both the sides being covered with building materials.

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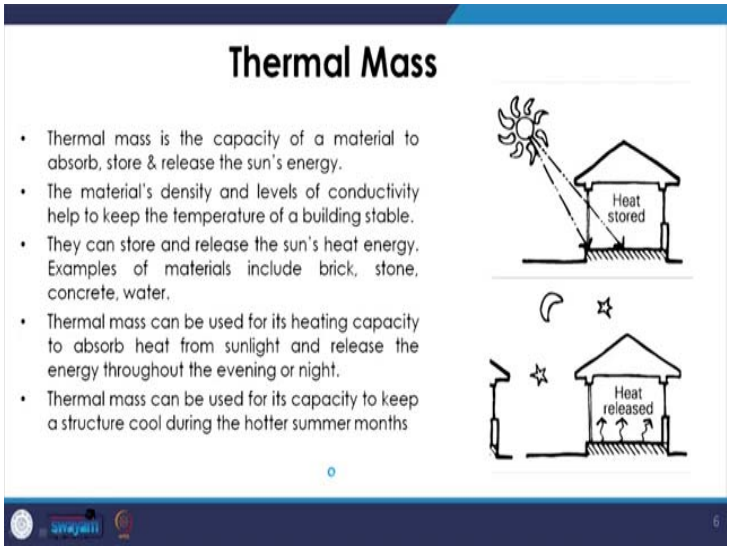

If we are looking at the thermal mass as a strategy, here the mass will absorb the heat and it will re radiate it during the night time or the time when the temperatures fall down, fall below the surface temperature of the material. So, this strategy is often utilized as a very popular passive design strategy when we are designing for extremely high temperature variation, high on heat or high on cold.

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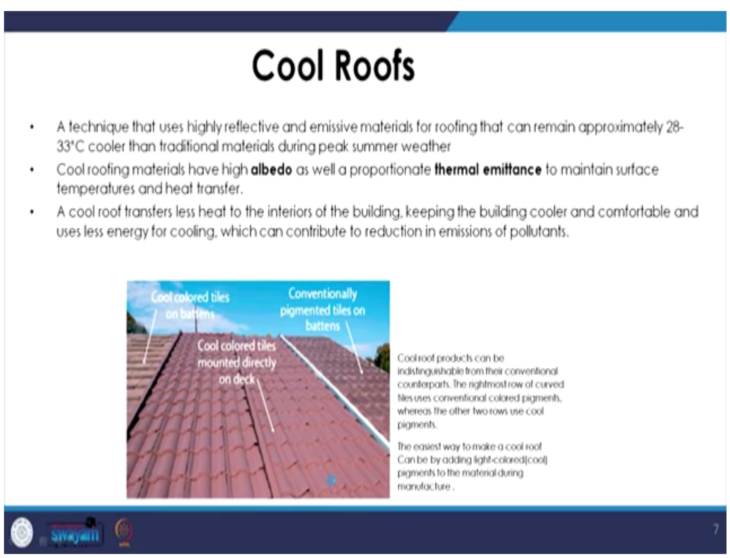

Cool roof is a new kind of concept, a passive design strategy where the albedo of the roof is high which implies that the roof reflects a lot of heat which is incident on it. The remaining portion of the heat which is absorbed by the roof is also emitted, almost 100 percent of it is emitted during the night time.

So, there is very little amount of heat which is transferred to the indoors, largely reflected rest of it re-emitted; the ones which is absorbed and very little portion of it is transmitted inside that is what the overall functioning of cool roof is. So, there are cool roof paints available, there are cool roof materials which are available and it is becoming quite popular across the world.

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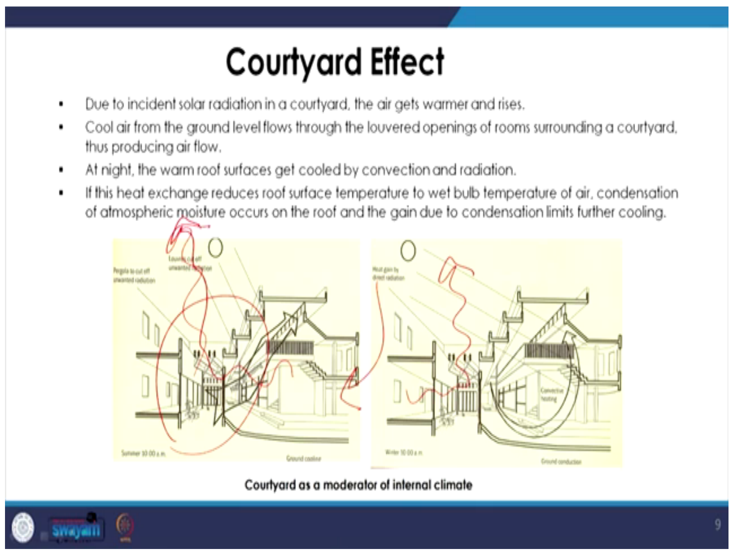

Then we have courtyard effect, we have talked about courtyard as a passive design strategy earlier also. Now, what courtyard does is that it shades the indoors from getting heated, the interiors from getting heated and this open to sky courtyard; this open to sky courtyard facilitates the night ventilation.

So, the heated air from the indoors is ventilated through the courtyard during the night and that that is the time when the temperatures outdoors fall below. So, it allows for the structure to bring in air from the outdoors during night and release it through the courtyard during the night, that is what the fundamental functioning of a courtyard is.

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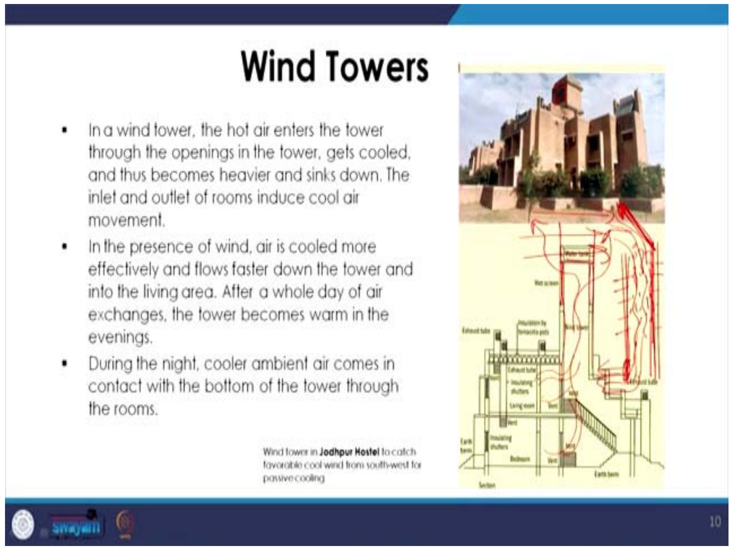

Then we have wind towers. Now what is the wind tower? It is a tower which is slightly raised, it has openings on towards the above end. So, suppose this is the wind tower; so, it will have an opening here. Now, through this opening, the wind it works two ways. So, it acts as an exhaust. So, there is hot air which is rising up; so, this acts as an exhaust and the hot air rises up and goes out. In other times of the year, it may also help to bring in; so, there are improvisations to the wind tower. So, there are wind towers which have a shape like this, where the this is the prevailing wind direction.

So, if this is the prevailing wind direction and there is a sloping structure on the top of wind tower, the wind is forced to come inside the wind tower. Now, this wind tower will have a high thermal mass and while the air moves down the heat is absorbed by the structure of the wind tower. And, by the time it reaches down and it is brought into the area, the air has already lost some of its heat and it has cooled down. And improvised version of the wind tower is where with the help of a water tank as shown here or some sprinkler system, where moisture is added.

In the process of this, the evaporative cooling happens and the air becomes cooler it loses its heat and by the time the air comes down it is cooled down totally. So, if you look at some of the old forts; if you go to Gwalior fort, if you go to some of the Haveli's in Rajasthan and some of the forts; wind the concept of wind tower and thermal high thermal mass around wind tower has been exploited very well.

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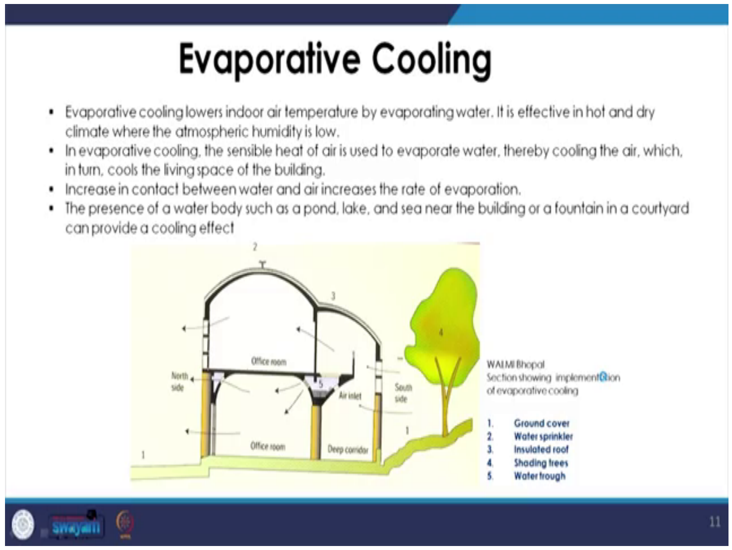

We are also talking about evaporative cooling here, now what we do in evaporative cooling is what I just explained as part of the advanced wind tower, where moisture water is added and the air cools down evaporatively. So, in some of the places where water bodies are added in the path of the wind when it comes inside. So, when it passes over a water body it picks up the moisture, it loses heat and it is cooled by the time it enters the interiors and when it gets heated up again it is exhausted out.

So, evaporative cooling is a very effective technique, but unfortunately most of the regions which are very hot are also dry and there is a scarcity of water. So, often the evaporative cooling is not possible because of the scarcity of water and it cannot be employed. But wherever it is possible, evaporative cooling should be looked at the first option for cooling down the air.

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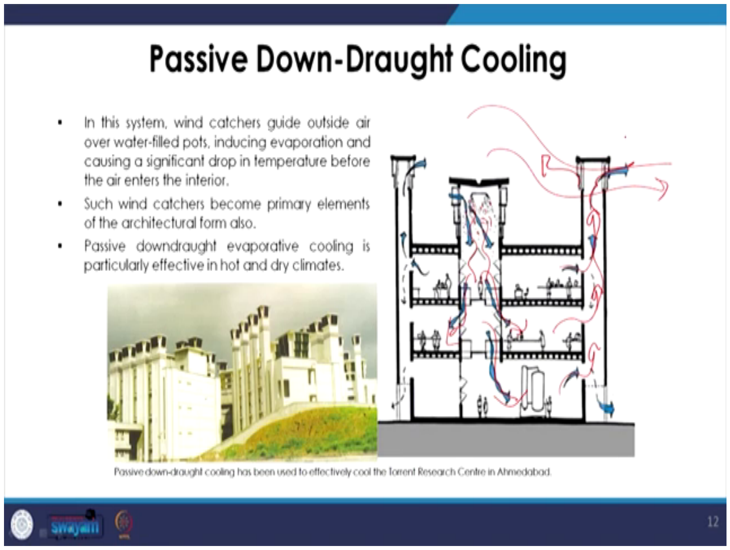

Passive down draught cooling, I have recently explained as an improvised version of a wind tower, where the moisture, the water is sprinkled on the air and subsequently the air cools down. And, when it enters into these areas, the habitable areas; it becomes quite comfortable, it comes at a comfortable temperature. And, then it is clubbed with these wind towers where the exhaust air which is then the hot air, the heated air is taken out through these wind towers. Now, these wind towers are provided in such a manner that the prevailing wind takes away, exhausts this hot air for large part of the year and no mechanical exhaust is required.

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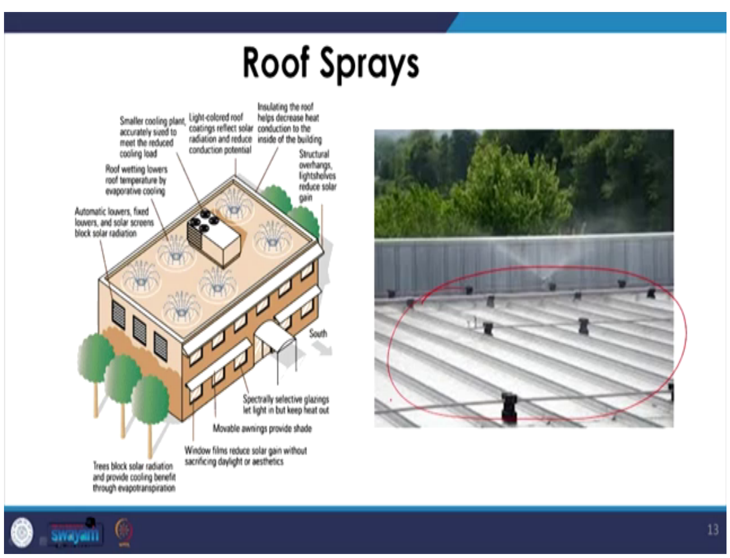

Here another strategy which can be employed which is often employed is roof sprays, again it requires water and it cannot be used in areas which are draught prone or which have less availability of water, but it is primarily evaporative cooling. So, the roof which gains a lot of heat throughout the day and the surface becomes heated. So, during the evening time when the outdoor temperature starts to fall, the evaporative, the roof spray will help to evaporatively cool the roof, cool down the surface of the roof.

If you remember that was a very common practice in our traditional residential buildings, homes where people would often sleep outside on the terrace during night time. And, during the evenings water would be sprayed on these roofs and in the process of this evaporation the water takes away all the heat which has been absorbed by the roof faster. So, it will anyways re-radiate it, but it takes away all the heat and the roof becomes comfortable for people to sleep on; so, that is the same concept of roof sprays.

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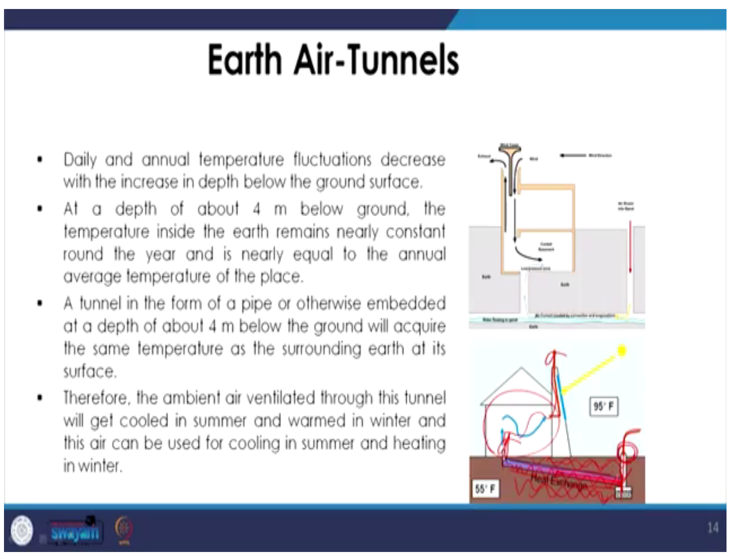

And, the last one for this advanced passive design techniques is earth air tunnel. So, what we do in an earth air tunnel is that there is a tunnel actually a tunnel, masonry tunnel which is constructed below the ground. So, what is that depth? Depends upon at what depth do we get a uniform temperature throughout the year. So, if we look at in the case of Delhi, this earth air tunnel should be at least at a depth of 4 meters. While, if you are looking at a case of Bangalore then the earth air tunnel could also be constructed at a depth of 0.5 meter.

This is looking at the heat or energy perspective; however, looking at the soil characteristics and groundwater table, the depth may also vary. So, what we do is we create, we construct an earth air tunnel. We take in the air forcefully and let it pass through this tunnel and since the ground which is surrounding this tunnel is at a constant temperature which is usually the average annual mean temperature which is what the ground temperature of a place is. So, for a place like Delhi, it would somewhere be around 23, 24 degree centigrade which is the average mean temperature which is usually in a comfortable range, comfort zone.

So, when we pass the air through this tunnel, the tunnel and the mass which is around the tunnel absorbs the heat or provides it with the added heat in case of winters. And, then this air is taken inside the habitable space and the space gets cooled and when it get hot, it is exhausted out. So, it is not absolutely passive because we require fans, we require pumps to bring in that air from outdoor into the earth air tunnel to take it into the room.

So, there are exhausts required and there are some associated problems with earth air tunnels, where rodents like rats and insects they enter the earth air tunnel. So, how to manage, how to maintain the entry of air into this earth air tunnel, how to maintain the cleanliness. So, there are some associated problems, but the earth air tunnel is a very effective means of cooling indoors. So, besides the passive strategies, that we saw in the previous lecture, yesterday's lecture along with the advanced passive design strategies which we have just seen.

And, with the help of tools like Climate Consultant, Mahoney's table, as a very first step for designing any sustainable building we should have understood the climate of the place, we should have identified these strategies which should be utilized for designing the building. So, with this we have concluded the first step, the first step of the process of designing sustainable buildings and from next lecture onwards we would look at the further design of sustainable buildings and how do we take it forward.

Thank you very much. See you in the next lecture.