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

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Week: 04

Lecture 02

Bioclimatic chart and Psychrometric Chart

Hello dear students, welcome back to another lecture on bioclimatic and psychrometric chart. So today we will see the bioclimatic and psychrometric chart. So what is a bioclimatic chart? Bioclimatic charts visualize the relationship between climate data and building design strategies for optimal comfort and energy efficiency, whereas psychrometric charts depict the thermodynamic properties of moist air, allowing us to analyze and improve thermal comfort. So, when we look at building design, these charts help us to understand how climate conditions impact building design choices such as window placement, insulation levels, and ventilation systems. Also, understanding these charts will help us to optimize building design for occupant comfort and energy efficiency, thus reducing the need for artificial lighting and cooling. These charts can provide us valuable insights for analyzing the climate data and making informed decisions about the building design and climate-responsive strategies.

Before we move into the construction and interpretation of these charts, let us familiarize ourselves with some key terms and definitions. Understanding these terms will help you to navigate the concepts and understand the relationships presented in the charts. The first is a bioclimatic chart. A bioclimatic chart is a graphical representation of climate data.

Showing the relationship between temperature, humidity, solar radiation, and wind. facilitating optimal building design strategies. The second is the psychometric chart. So it is a thermodynamic diagram that displays the properties of moist air, including temperature, humidity, enthalpy, and dew point, aiding in air conditioning design and analysis. Now let us look at what is dry bulb temperature.

The temperature of air that is measured by a standard thermometer is the dry bulb temperature. Whereas wet bulb temperature is measured using a thermometer with its bulb wrapped in a wet cloth and exposed to air flow. Relative humidity is the ratio of the amount of moisture in the air to the maximum amount it can hold at a given temperature. Enthalpy is the total energy content of air considering both its temperature and moisture content. is the temperature at which air becomes saturated with moisture and condensation begins to form.

Let us now look at what a bioclimatic chart is. So, the bioclimatic chart was developed by Olgay in 1950. It focuses on temperature and humidity to determine human comfort zones. It assists in identifying passive design strategies based on climate. The climatic elements around it are shown by means of curves, which indicate the nature of corrective measures necessary to restore the feeling of comfort at any point outside the comfort zone.

The components of a bioclimatic chart are temperature, which is on the y-axis, humidity, which is on the x-axis, the solar radiation, which you can find as lines below the comfort zone, and the wind patterns, which you can find as parallel lines above the comfort zone marking. So comfort zone per se is determined by passive strategies such as natural ventilation, shading, evaporative cooling, etc. Now if you look at the bioclimatic chart, you can see that. This is the zone. I will change the color.

This zone. Which has conditions pertaining to a specific air temperature Relative humidity Etc. It falls under Desirable comfort zone. These two zones fall under practical comfort zone. Now if the conditions of the room are beyond this, somewhere here, then somebody would feel too humid.

So it's a very humid zone. The zone below this comfort zone is cold. It's very cold here. It has low temperature which is uncomfortable whereas the zone above this is hot. It is hot or warm.

The zone here. What do you mean by zone here? The conditions of climate that exists here, which means a combination of this temperature and a combination of this humidity, say, for example, if we look at a temperature of 30 degree Celsius with a relative humidity of 10%, then it means that, this is a very dry zone. The person will feel very dry. Okay, and this is the tolerable limit for moderate intensity of work, whereas if someone is doing more work and not sedentary. Then beyond this, it becomes very warm and these are all hard surroundings; this is a very hard or a difficult environment, and beyond this is impossible to sustain.

Now if we look at what happens in this zone, which I call as the comfort zone, then it means that under these conditions one can sustain comfortably under these conditions of temperature and relative humidity. Then, when there is breeze movement of 0.1 meter per second, the comfort zone can extend itself and so on but at this point it will be too hot and There will be probable heat stroke. Again, these are required radiation ranges because below the comfort zone is a cold, very cold feeling. So in order to make it warm, you need radiation.

So when the climate parameters are in this zone, then you need radiation of 100 watts per meter square. At this point, you will need 800 watts per meter square. That is how you will read a bioclimatic chart. I am just teaching you how to read a bioclimatic chart to show that such charts were prepared way back in 1950 for us to understand which combination of temperature, humidity, wind speed, radiation can make us feel comfortable, warm, or cool. So above the comfort zone, winds are needed.

You need breeze above the comfort zone and this part becomes too dry. As I had already given you, the example of say 30 degrees Celsius and 10 to 15 percent humidity will make a person feel very dry. And this part will make a person feel very humid or sultry. At 30 degrees Celsius temperature and 95% humidity it's going to be extremely sultry. This is the limit for light work to do.

Only under conditions of this below this light work can happen. Above this is unbearable. Whereas below this part you need sunshine, you need solar radiation. Because below this line you need to counteract low dry bulb temperatures. Say below 21 degrees Celsius.

So this is the way that a bioclimatic chart is depicted. Let us now look at the psychrometric chart. Now how do we understand the psychrometric chart? The psychrometric chart is a powerful tool for understanding the thermodynamic properties of air, especially its moisture content, and how it affects human comfort and human performance. It helps us to analyze and control indoor air quality. It optimizes air conditioning systems and ensures comfortable living conditions.

So in a psychrometric chart, the dry bulb temperature the chart displays the dry bulb temperature on the horizontal axis. So this is the dry bulb temperature. The humidity ratio, or specific humidity, is mentioned on the vertical axis, and it represents the amount of moisture in the air as expressed as a humidity ratio. So this is the specific humidity on the y-axis. The relative humidity; the chart features curves.

representing constant relative humidity values. So these are the relative humidity values, which are shown as curves or curved lines on the chart. The saturation or dew point- This temperature is indicated on the chart, representing the temperature at which water vapor will condense. So this is the dew point represented on the chart. Let us now understand the individual components of this chart.

The first is dry bulb temperature. So the dry bulb temperature is the temperature of air measured by a regular thermometer exposed to the air but shielded from moisture and radiation. It is called dry bulb because the thermometer is not influenced by the moisture content in the air. The important thing about dry bulb temperature is that it is the most commonly used temperature measure and is crucial in determining comfort levels in the built environment as well as in heating, ventilation, air conditioning design, and performance analysis. The second component is the wet bulb temperature.

So, wet bulb temperature is the lowest temperature air can reach by evaporative cooling. It is measured using a thermometer with its bulb wrapped in a wet cloth and exposed to air flow. It gains significance because wet pulp temperature reflects the cooling effect of the evaporation and is critical for assessing humidity levels and the effectiveness of cooling systems like evaporative coolers. Third is absolute humidity. So absolute humidity is the total mass of water vapor present in a given volume of air regardless of temperature.

And it is usually expressed in grams of water vapor per cubic meter of air. Then its importance is that it is a measure of the actual amount of moisture in the air. And it is useful for detailed analysis of air properties and HVAC system design. The fourth one is the relative humidity. Now relative humidity can be defined as the percentage of moisture in the air compared to the maximum amount of moisture the air can hold at a specific temperature.

It is expressed as a percentage. It becomes important because it is key in determining thermal comfort. High relative humidity means the air is holding a large amount of moisture, which can make the environment feel warmer and more uncomfortable. This you would have noticed in the incident that happened in Chennai during an air show where the air that day was extremely humid and warm, resulting in high heat stress amongst people. So the dry bulb temperature is denoted as on the x-axis through these vertical lines. The wet punt temperature is along this curved line and has to be read in this manner, whereas the absolute humidity is along the horizontal line on the y-axis And the relative humidity are these curves, which are more or less aligned along the wet bulb temperature line, curved lines.

Then we will understand what a dew point is. Dew point temperature is the temperature of saturated air. And saturated air is the air full of water vapor. That is called saturated air. So the temperature of saturated air is called the dew point temperature.

The saturation line is where the humidity is 100%. So the wet pulp temperature line and saturated line is used to measure the dew point. The dew point temperature lines are not to be plotted on the psychrometric chart. How can you find the dew point temperature? If dry bulb temperature and humidity ratio are known, then you can easily find the dew point temperature. For example, if you have a dry bulb temperature of 28, say 28 degrees will fall here.

And a humidity ratio of 0.013, 0.013. Then, at the point of intersection, you draw a horizontal line towards the wet bulb temperature like this. In order to find the dew point temperature. So this will be the dew point temperature which is approximately 0. 19 degrees centigrade. Specific volume is the amount of air in per unit gram of dry.

Its unit is meter cube per gram. So specific volume is the volume per gram of dry air. Enthalpy is if you have 1 gram of air, then how much heat is present in 1 gram of air is called enthalpy. And its unit is joule per gram. The enthalpy lines are very similar to the wet bulb temperature line, but these lines are extended towards the enthalpy scale. For example, this is the specific volume line and these are the enthalpy lines.

So, I am showing each of the components of the psychrometric chart separately because the complete psychrometric chart will look like this and it can be very confusing. That is why I had deciphered each of these separately and shown them to you. So this is how a complete psychrometric chart looks. You don't have to really bother too much about drawing a psychrometric chart or anything like that. I am explaining what a psychrometric chart is and its components because when I teach you a simple tool to understand climate and arrive at passive strategies for a particular climate type, you will have to deal with a psychrometric chart.

But right now you don't have to understand to draw a psychrometric chart or something like that. It's a standard that is already given. I am just explaining the components of the standard chart. Now how do we find the parameters on this chart? So suppose you have a dry bulb temperature of 30 degrees centigrade. What should you do? You should mark the dry bulb temperature point here.

And suppose the wet bulb temperature is 25 degrees Celsius. So the 25 degrees Celsius is here. You need to find the relative humidity and the specific humidity dew point. And specific volume, say.

Then what you should do is. You should draw parallel lines. On the given values of the parameter. Dry bulb temperature.

30 degrees Celsius. Wet bulb temperature. 25 degrees Celsius.

You find the intersection. So. This is 20. This is 30. So this is 20. So this is the. intersection. So now you find the relative humidity. Now draw a parallel line along the relative humidity curve.

So this is the relative humidity curve. You draw a parallel line like this. Where is it? It is somewhere between 70 and 60 but closer to 70. So we will say Approximately it is 68. Relative humidity is 68.

So suppose you have to find the specific humidity. You draw a parallel line along the specific humidity line like a horizontal line. That line should start from the intersection point till the end where the values are from here you draw till the end and this value lies between 0.

018 0.018 and 0.020. So sorry, 0.015 -this is 0.015. So this point will be say 0.017- So the specific humidity is 0.017. Like this, we can find various parameters, climatic parameters based on what is already existing in the chart for various combinations of dry bulb temperature, wet bulb temperature, relative humidity, and so on. We are not going to find this actually because you don't need to find this in today's world because there are a lot of softwares and I will be teaching you all that.

So now why we learned, why I taught you all that is on the psychrometric chart, this comfort zone is marked. It means under these conditions of dry bulb temperature, wet bulb temperature, relative humidity, wind speed, etc., people will feel comfortable. Now if the room is not having these conditions, then what strategies must be adopted to make the room comfortable? So in order to do that, what all should be done? First we will see, this is the thermal comfort zone. So without doing anything, if the room condition lies within the climatic parameters as shown within this boundary, the room will be comfortable.

But if it is not so, if it is somewhere here, if this is the climate parameter, then what happens? You need comfort ventilation. Comfort ventilation is a strategy that uses natural or mechanical ventilation to maintain air quality and comfort. It's most effective in climates where outdoor air can be used to cool the indoor environment without the need for air conditioning. So if somebody designs a room that is beyond the thermal comfort zone, which is indicated here, where the humidity temperature range is beyond this range, then comfort ventilation can be a good strategy. Then internal gains; if the condition falls on this side, what happens? heat generated by internal sources such as people, lighting and equipment.

These gains can help keep spaces warm in cooler climates and contribute to overall comfort. Then we have high thermal mass. So in this zone, in this zone, an effective strategy can be high thermal mass with night ventilation. So high-thermal materials like concrete or stone store a lot of heat during the day and release it at night. Coupled with night ventilation, it helps in cooling down buildings during hot days, which is a passive cooling strategy.

Each of these strategies I will be dealing with separately in detail. But I am telling you how to relate the psychrometric chart with the comfort conditions, and if the conditions are not comfortable, what strategy can be used as depicted in the psychrometric chart. The strategy per se I will deal with it separately and teach you each of the strategies separately. Next is evaporative cooling. So if this is, if the condition lies in this boundary, then evaporative cooling can be a good strategy.

So this technique lowers air temperature by evaporating water into the air, which is effective in hot and dry climates. The chart shows its cooling potential as temperature rises. Then we have passive and active solar strategy, which happens in this zone. So solar radiation is used to heat spaces either passively through building design or actively through solar panels. This strategy is effective during colder months when solar gain can reduce the need for conventional heating.

Or conventional heating or cooling can also be a strategy beyond this point. So this is where conventional heating or conventional techniques of heating, when natural methods are not sufficient, mechanical heating in cold climates or air conditioning in hot climates becomes necessary, and in this chart it is represented where extreme temperature conditions occur outside the comfort zone. Then this is conventional dehumidification and air conditioning. So for humid climates, dehumidification is crucial as it reduces excess moisture in the air, ensuring thermal comfort. This typically involves mechanical systems like air conditioning units that cool the air while removing humidity.

when there is no comfort- when the conditions lie within this zone, I will change the color. Yeah, within this zone, high thermal mass with night-ventilated cooling is a good way to make the indoors comfortable so each of these I will be dealing with separately Showing all the working principles and so on. So we have seen now the psychrometric chart.

The psychrometric chart. How to read it. Strategies. If the indoor conditions that you design fall outside of thermal comfort conditions, and in forthcoming classes I will also teach you in detail all the strategies. So detailed strategies I will teach you in these lectures. Now this is important because when I teach you the software, this is the kind of psychrometric chart you will get. You don't have to do anything. The software itself will generate this psychrometric chart, so you should understand what it is.

So when we use the software that I will be demonstrating, which is called the climate consultant software that uses the psychrometric chart. So when you download the climate data for a particular location, you can study and attach the file of the climate consultant software, and automatically you will get the psychrometric chart plotted for that specific site location. Design strategies are beautifully represented by specific zones on this chart. The chart itself is divided into 16 design strategy zones, and the percentage of hours that will fall into each zone is also shown. This helps us to derive the most effective passive and active design strategies for that particular location.

The software is then given detailed design guidelines for each specific zone and comfort level. This chart provides a very clear strategy based on this current one that you see is based on Kolkata's climate data to improve thermal comfort through passive and active measures tailored for various times of the year. So here you have the comfort zone. So this is the comfort zone, and where you will find people who stay in this kind of climatic condition to be having 100% comfort. So it shows the dry bulb temperature and humidity level where people will feel thermally comfortable without active cooling or active heating.

The color-coded design strategies to achieve comfort include each of these. You need to have comfort ventilation, you need to have sun shading of windows, you need to have high thermal mass, high thermal mass with night flushing should be there, direct evaporative cooling, and so on. Comfort ventilation 44.5% of the year can be made comfortable by increasing natural air flow for Kolkata. Sun shading of windows 25.

5% of the year reduces solar heat gain and keeps indoors cooler. High thermal mass: 2%. See you can see this return here. 2% is returned here. So 2% of the time high thermal mass can absorb heat during the day and release it at night to maintain comfort.

Evaporative cooling. So you can see here evaporative cooling. Direct evaporative cooling. forms 2%, and it involves cooling air by evaporating water effectively in dry climates. Dehumidification helps reduce discomfort from high humidity by 16.8% hours. There are other parameters also, but then I'm not going to go into each of these strategies.

What happens when you use each strategy, for example, cooling and dehumidification? If you apply that strategy, then 28.7% of the year can be comfortable. All the green dots represent one hour of the year when it is comfortable. And if it were not comfortable, that dot would have become a red dot. So what it basically means is if we apply all these strategies, then throughout the year Kolkata will be comfortable for certain conditions.

What are these conditions, this data input like comfort model, hours, days, months etc. All this I will teach when I teach you climate consulting. Now suppose I remove some of the strategies. So the psychrometric chart highlighting adaptive comfort ventilation as the dominant strategy accounts for 44.5% of the year, which is 3895 hours of the year, can be made comfortable By having adaptive comfort ventilation. What is adaptive comfort ventilation? It means using natural or forced ventilation to enhance comfort by taking advantage of outdoor air conditions.

It adapts to varying temperatures using outdoor air when conditions are favorable to reduce the reliance on mechanical cooling. In Kolkata's humid climate, this strategy helps maintain indoor comfort by optimizing air flow, especially during moderate temperature periods. If I remove the other things like sun shading, high thermal mass, and high thermal mass with night flushing, if I am not going to follow all that, then what happens? The red dots they come in. The red dots They fall outside, suggesting hours where intervention is needed.

So red dots are hours of, hours in a year of discomfort. Every dot is one hour of the year. So only here there is comfort because I have followed the evaporative cooling adaptive thermal comfort adaptive comfort ventilation I have followed; therefore, this alone is green. If we want to make this red as green, we have to follow some of these strategies. So that is what this software will eventually lead us to, and that analysis of what all strategies must be used for a particular climate in order to have how many hours of comfort can be read from a psychrometric chart. And that is the reason why I have taught you the psychrometric chart in detail.

You don't have to be scared by seeing all those lines that I showed you. You don't have to be scared that you may have to end up drawing that or learning that. I have shown you all that because eventually, when we learn about the software, you will use the psychrometric chart, and you should know what it means. Then eventually in that software we will get one list of design guidelines and how much comfort hour will be contributed by which design condition, which condition that we use will also be there. So, how typically houses were built—you know, thermal mass, use of it, use of vegetation—everything will be there in this software, and we will see that software in the next class or one of the next few lectures, and that will be quite interesting.

So, today we saw the bioclimatic chart; we saw how the comfort zone boundaries are there. Then we saw what the psychometric chart is. Again, in that the comfort condition boundaries are there. Then we saw what all the elements are that are there in the psychometric chart. And we saw why it was useful for us. What strategies will work if your indoor condition is beyond the thermal comfort zone? So with this we will stop today's class. And we will continue with another class in the next lecture. Thank you.