Sustainable planning and architecture
Lecture 1

Introduction to Sustainability

Sustainability can be divided into two main chapters; Planning level and Built Environment.

Sustainability can be understood by further dividing it, into 2 broad categories;

Planning Level: This includes factors such as;

> Sustainable Master planning

> Regional planning

> Water Calculation

> Catchment Area

> Landscaping and Ecology

Built environment: This includes factors such as;

> Thermal Comfort

> Materiality

> Energy Efficiency

> Indoor and Outdoor comfort

So it is basically whatever can help achieve thermal comfort within the built environment.

What is Thermal Comfort?

Thermal comfort is the state of mind. Ashrae states that “It is that condition of mind which expresses satisfaction with thermal environment." So thermal comfort is basically a state of mind. Different factors which affect the thermal comfort; *Environmental factors, Psychological factors and Physiological factors.*

Factors that affect Thermal Comfort:

> Dry Bulb Temperature

> Humidity

> Radiant temperature

> Air movement

> Solar Radiation.

Psychologically the human body's heat balance can be measured at steady state condition, which means by a moment of inertia and not after the human is involved in a vigorous activity. But human beings do adapt to their environment and their bodies can adapt to certain conditions to a certain extent.

These factors affect the person in the following ways;

> Health

> Productivity

> Comfort

> Energy Usage

> Awareness about surroundings

Psychological Factors:

Different activities that contribute to the user pattern with an environment also affect one's comfort zone: Sitting, standing, Exercising, Running, working, dancing etc. All these contribute to a variation in the heat levels in one's body which affect one's Thermal comfort. These activities can be measured in watts per meter square and this differs from each activity. For instance; sitting can produce 100 watts per meter square of heat, while dancing can vary from 700 to 800 watts per meter square, depending on the user's involvement.

Physiological Factors based on Clothing level: This can vary from nudity to being clothed completely (use of sweaters, jackets etc). This insulation property adds to achieving thermal comfort. We being in India, prefer cotton clothing while those in Canada prefer woollen clothing due to climatic factors, this also adds to one's psychological factor and this needs to be

taken care of while designing. Say for a school building, the amount of clothing as uniform needs to be calculated while considering a design.

Psychological factors:

> Adaptability: A body can adapt to circumstances and situations to environment which can be altered to achieve thermal comfort. This would call for one, to be more patient, not a fuss spot, more broad minded etc.

> Accumulation

> Past Experience: When you come from a very hot environment, even though the room is still a bit hotter, you feel comfortable because of the past experience you had from the outside environment. This cannot be altered, only one's perception to such past experiences can be changed.

> Time of exposure: If you exposed to an uncomfortable thermal environment for a short period, it doesn't have a significant impact on the user. Whereas, when exposed for a longer period, you do need to take into account other factors; length of exposure, how long does the person stay and factors that are affecting them.

> Culture: Basically from which background are you coming into this new environment, to adapt to these type of changes. So basically, comfort can be calculated by using these different factors like; comfort calculator, physiometric charts, which have certain adaptable ranges to show the comfort level a person can achieve, for different activity, different clothing and These are available online, in order to check both indoor and outdoor comfort levels. Basically, all these factors depend on climate.

We have a vast variations with regard to climate across different climatic zones. This not only depends on the climate but depends on the latitude, the longitude and the altitude, these factors define the climate one is bound to embrace. For instance; there is a big difference in the climatic conditions of both places; Chennai and Ooty, it is solely because of the variation in altitude.

Climatic Variables:

> Temperature:

Dry bulb, Radiant temperature, sky temperature.

> Humidity:

Relative humidity, moisture content, vapour pressure, wet bulb temperature, air movement

> Wind speed:

Wind speed, wind reaction, wind temperature

> Solar Radiation:

Global, diffuse, direct (horiz.), beam

> Illuminance :

Global, diffuse

These are different climatic variables that have adverse and direct effect on thermal comfort. While looking at temperature, we have to look at dry bulb temperature, Radiant temperature and Sky temperatures not just the indoor and outdoor temperature. All these have different effects on the user and the next factor is Humidity where you have to take care of; Relative humidity, moisture content, vapour pressure, wet bulb temperature, air movement, all these come under Psychometric chart and how different aspects affect the person's thermal comfort. Air movement can become a crucial factor for having good effect as well as worse effect, depending on the climate you are located in. So basically, on a warm and humid day, you would prefer a cool breeze to pass by but on a cold day, you prefer to not be exposed to such cold and humid conditions. The design aspects must consider the direction of the wind and the wind speeds, wind temperatures as well. For a hot and humid climate, it is preferred to be north-east and south-west wind direction for tropicals. Whereas, when you are considering a design for western climates, it is preferred not exceed 1m/s wind speed.

Next is, Solar Radiation, is divided into; Global, diffuse, direct and horizontal solar beams, which apply same as wind speed. In hotter climates, you need to eliminate direct solar beams on all the surfaces as much as possible, whereas in western climates it is welcomed, how much ever is possible.

Illuminance - Global and Diffused, in India we have a good illuminance range from seven thousand to seventy thousand lux. So, using it in a very good effect, can produce the environment without going for any artificial illuminance and it can be completely used free of any conventional resources.

> Atmospheric pressure, cloud cover, precipitation etc.

We all know that climate has been changing for ages, from 1960 - 2060 - climate is to change drastically in places across the globe. There have been studies which has been carried out, which shows, 1960 - 2060 for about 100 years, this graphic shows different parts of the world which has different effects to the climate change. In India, we can see almost 3 - 4 degrees of temperature increase but whereas we can see adverse effects, close to Egypt, South America which will be very close to 7 - 8 degrees.

Is it only because of Global warming? It doesn't seem to be so.

Weather projections are based on emission scenarios input into General Circulation Models (GCMs) Different emissions which has been caused like, CO2, Carbon monoxide and phosphorus emissions from refrigerators and Air conditioners have caused adverse effects on the environment.

These are some of the charts that depict the rate at which emissions have been released over the years, right from the year 2000 to 2100. CO2 concentration per ppm and emission scenarios which also affect the temperature increase. We can also, There is an adverse increase by the end of 2100 due to all these emissions as well as the climate change. The question is, how to achieve sustainability? So, Sustainability is not just the usage of material, but it also accounts; Climate, Envelop design, User comfort, Occupant Typology, Micro climate and User pattern .

Why Sustainability is needed?

Generally, if you would take a look around, all the buildings are simply heat producing machines, they simply produce tonnes of carbon dioxide and carbon monoxide on a daily basis. This is what buildings are telling us and what do we have to respond to it? So, all these buildings produce tonnes and tonnes of carbon dioxide and carbon monoxide.

The Issues and Viscious Circle

Urban warming from AC = Demand for more AC issues and Vicious circles

When the heat is on, in Chennai, we all resort to air conditioners which accounts for more electricity generation, which is equal to more power stations. Today it has become a must even for ATM booths to be equipped with air Conditioning. You would find almost every building with an air conditioner.

More Air conditioning systems, more electricity generation which only brings up the need for new power stations to supply electricity to all households across the city/state/country.

Electricity generation is the basic release of carbon dioxide into the atmosphere and other nuclear issues as well. Due to the adverse effects of supplying electricity in the form of carbon to households, people in Chennai are now trying to resort to nuclear energy which can also have terrible effects on people if anything goes wrong. So this whole 'AC culture' is an obstacle for sustainable design. Architects must have a larger vision and construct likewise, such that we don't need AC's, or even if we do, it should be allowed in certain cases only.

There is this article from the Times of India that reads that, there has been 15 hours of power cut in Trichy city, which is leading to low performance in academics of students, which has to be taken care of since it affecting the next generation as well. Such is an instance; that only goes to show, that if we are irresponsible users of such natural resources, the next gen will have nothing left to hold together in the coming days. So architects and designers, we must be sensitive to the environment that is around us.

'With the increase in mechanical systems carbon emission is increasing which results in global warming and non-renewable energy depletion. ' - how do we avoid such a situation ?

> By beginning to understand the climate and the user.

> Using passive design strategies to improve your energy bills.

> By learning to curb the use of mechanical systems that have adverse effects on the environment.

So we need to look back into our past and implement the essence of it, into our lives today for a better and safer environment.

> Increasing global temperatures

> Melting of Himalayan glaciers

> The increase in dependence on air conditioning systems

> Worsening Micro Climate effect

All these indicate that we are moving in the wrong direction and we need to take more measures to make our environment more sustainable and eco- friendly buildings. So sustainability is nothing something that can be taken for granted, it can be assumed by putting some material that you have achieved sustainability to the maximum percentage.

How can we be sure if what we are doing, contributes to sustainability or not?

It is fundamentally a matter for architecture, being an outcome of programmatic, formal and operational choices made (or ignored) by design. - Sirnos Yannas. Sirnos is trying to imply that, the eco-friendly changes you try to make to a building should be a process to the design and not an added layer to your design.

Climatic Factors

While creating the design itself, one must consider the climatic factors, the micro climatic effect, the level of thermal comfort to be achieved/ maintained, typology, the use of the building, the future scenarios etc. The Sustainability of a building can be tested with the help of tools and softwares that measure, temperature, wind speed, surface temperature and lux level as well; Day - SIM, GECO, Envi Met, Energy plus, Soft computation, Illuminance, WIN - AIR, Ecotect and TAS can give basic intuitions to you as to how much you need to work on your envelope design to achieve thermal comfort. There are some modelling softwares which can be used to test your designs basically; DAY-SIM, GECO, ENVI-MET is used to test micro climate effects and ENERGY PLUS, SOFT COMPUTATION or all softwares which is used to test the thermal comfort, the temperature which is achieved within the built environment. ECOTECT which we we all know is environmental software which can be used to test the sun path and wind by WINAIR plugin, ILLUMINANCE for daylight studies. Basically it is like a vicious circle which goes back;

So you have sustainable passive principles, which can be used and adopted to create a building. It can test the principles, thereby producing a result that aids the user by 90% and these results can give a closer view to the user as to whether it suits the thermal comfort or not. You can now go back to your principles, to tune them accordingly according the needs determined from the results earlier, in order for it to become an effective principle. This is a process that one must go through in order to achieve an effective principle. As we discussed earlier, now we are going to look into few of the comfort calculator tools which are available online, which can be used to test the thermal comfort.

Tools that can be used to measure Thermal Comfort:

> Comfort Calculator:

Down you can see this link that can be used to download this website, which can be used to measure the thermal comfort.

This calculator takes into account; Air temperature, Radiant temperature (the average temperature of different surfaces surrounding the person. Eg: walls ground or a roof if the

subject is within closed walls etc.) , Relative Humidity (amount of water that is present in the air), Air velocity (measured in meter per second), Activity Rate (the type of activity the user is into) and Clothing Level. The air temperature can be measured using different tools from historical data's and the radiant temperature is average or mean temperature of different surfaces surrounding the person. For example, inside a built environment, it will be walls, ground and a roof. But outside it can be different planes which are surrounding the person, even colour can account to the radiant temperature. If a person is standing surrounding a wall of cool colours, the reflectance will be very less and he will be actually having a very less radiant temperature compared to the actual temperature. So, the Radiant temperature is very important. Also, the temperature on which the occupant/ user is resting. We are exposed to a wet stone environment, the radiant temperature is much less when compared to a hot, concrete surfaces. Relative humidity is the amount of water vapor present in the air. Air velocity is measured in meter per second, it accounts the air direction and the speed of the wind. Clothing level is the cloth, the user is using. It has to take into account all the clothing, the person is wearing, this will generate by using different factors, it will provide the 'Predicted Mean vote' which is the state when the bunny is happy and the 'Percentage of people dissatisfied' is zero as well. Usually the percentage of people dissatisfied can be acceptable when it is within 20- 30% and if it is more than 30%, you need to redefine your environment and the different factors that are affecting the thermal comfort.

The next tool is;

CBE Thermal Comfort tool

This takes into account; *the air temperature, the mean radiant temperature, Air speed, humidity, metabolic rate and Clothing level.* This is more accurate since it takes into account, use of more operative temperatures and it also works under adaptive thermal comfort mode, which is the dark blue shaded area depicts the temperatures in which, thermal comfort can be attained, while the light blue indicates the thermal comfort that can be achieved with a slight amount of dissatisfaction, which is however satisfactory.

CASE STUDY

The graph above depicts the climatic range for trichy, the comfort level temperatures were calculated by Nicol and Roaf in Pakistan back in the year 1996, which depicts the adaptive and cultural behavior in Pakistan is similar to that to the Indian context, the clothing, the surface etc which is all same.

The formula to calculate the neutral temperature; Tn = 17.0 PLUS 0.38 x To.av (this is the mean average temperature for the month). It differs from January to December where there is a

neutral temperature for each month, which has to be multiplied by 0.38, and added with 17, which will give the average temperature throughout the year in every month. Based on this relationship, that shows the neutral temperature in relation to the mean monthly dry bulb temperatures. A comfort band is then plotted using a plus/ - 3.0 K difference for 90% acceptability of the occupants.

Having a closer view of the graph of the climatic variations, from January to February and from November to December, it is usually a rainy season and the roads get flooded which in turn increases the relative humidity in the air temperature. Whereas from the month of April to mid-August, it is completely dry and the rivers get very dry, so the air temperature to be very high and the relative humidity very less. You can feel the skin is very dry. All these considerations, seasonal variations, must be taken into account in the design of the building.

The most important factor for a hot climate; is the wind speed. Having a tropical climate, The city faces two wind directions; which follows wind speed in the north east during the months October to April. While May to September, the wind hits south west. These are different wind speeds that occur that show 4 - 5 meter per second of wind ranges that are predominant in the city and can be very advantageous for the projects to be designed over there. This only goes to show that wind speed can be made use of, on a larger scale.

This is Psychometric chart for the city Trichy, which shows different monthly variation in achieving thermal comfort. The orange line depicts the neutral comfort zone developed according to ASHRAE, the blue lines depict the comfort levels that can be achieved with access to ventilation during the months; Hot seasons vary from March to September in which you need indirect adaptive cooling to elevate the comfort levels. These green lines depict the different wind speeds with which comfort levels can be elevated as well.

Next field work, **CASE STUDY 2:**

Kerala Kalamandalam - Thrissur

It is located a latitude of 10.5 and a longitude of 76.2 which experiences a typical warm and humid climate. Taking a look at the climatic ranges of kerala, it experiences 6 months of monsoon as we already know. Summer to june, is a typical summer. It is a campus setting in which it is a school for dance and music. The site is oriented towards the north. The site experience north east and south west wind, depicting the thermal comfort that can be achieved and this is the sun path diagram.

This is an open campus which caters to different needs between users, students and it also has built environment and semi covered environments. These blue spaces are the teaching environments which is located very close to the wind flow directions, which has to be taken into account while zoning the site. These orange ones are the dance classrooms that are also considerably close to the outer edge, which will have an unobstructed wind flow from both, north east and South west. Now moving on to on particular building which is called 'Koothambalam', which is the space to perform dance, it is like an auditorium. Zoning of the auditorium you can see the changing room at the rear end, the performance space at the center and the audience space at the front. You can see the use of solar screens on both sides and the how the roof blocks all the solar energy, you can see how the solar screens work and there is no solid wall that covers the building, thereby causing the room to be cool with the access to good ventilation from both sides due to the solar screens. These Solar screens cut down the radiation completely and promotes airflow throughout the building. These solar screens are like a buffer space. This is the audience space which is used of seating and this wooden space is used for performers. These snaps were taken at 12 in the noon and you can see even during high solar radiation, there is no sunlight falling in the audience space, you can see the two zones. This is a typical makeup room that uses artificial lighting during daytime, this accounts for heating of the environment which has to be taken into account. One more interesting factor is that, people in the auditorium, view performances by being seated on the floor, that has significant temperature reduction, thereby being used to achieve thermal comfort.

The picture below, depicts the different spot measurements were made at different points, horizontally on the on the koothambalam which shows different air temperature. So it is interesting to note that even though air temperature does not fluctuate more, the surface temperature of the floor has significant reduction which can be used to achieve thermal comfort. There are different lux levels which have been measured at different points, there is a lux level of 82200 lux, which can cause a significant amount of glare which is blocked to a maximum extent by the solar screens and inside, it is brought down to 300, which is perfect for viewing the dance programme and also the account of dressing was taken where the uniform used by girls are loosely fitted sarees and the boys are clad in semi naked clothing where the lower body is covered with a towel and a pyjama which both allowed the wind to move in and the sweat to escape. So, a small interview was conducted with the students which show that their classroom was comfortable but their lack of space and light, we like to have classes outdoor in the evenings, this scenario is basically because of high solar radiation that takes away the realive humidity and and makes the air dry. So when it is under a tree and due to transit operation, it feels more comfortable. These are different tests which have been adopted by Tasts that show different 30% of opening with window to wall ratio and 50% window to wall

ratio even though the temperature slightly is higher. 50% window to wall ratio has good effect and percentage of acceptability is higher compared to 30%. These are two dates in which the auditorium was studied more in detail; the school begins at 9 o'clock and ends at 5 o'clock, in which the space was used for different activities. In the morning it was used for teaching, from 11 to 12 30 - they had a performance with 150 - 200 students sitting and from 1 - 2 it was lunch break and from 3:30 - 4:30 it was once again a dancing activity. So as we can see, when there is an increase in the number of people from 80 - 150. There is a slight increment of 0.7 degree Celsius. So, what this says is; the envelope is designed in such a way; where it is easy to release the heat that has already been accumulated, even though there are many more people adding to the space. Even though they are eighty people dancing with a metabolic rate of almost 500 watts per meter square to almost, 700 watts per meter square, the temperature increases just to 1.2 degree Celsius, which can be neglected because of the wind flow throughout their body. So, these are different factors that have to be considered while designing and the flexibility it gives for the project. The same study was carried out for the consecutive day, which showed, the same one degree of increment when they are 80 people dancing in the classroom, with respect to outdoor temperature.