Energy Efficient Architecture

Lecture 1

Passive Design

Passive design is a design that takes advantage of the climate to maintain a comfortable temperature range in the home. Passive design reduces or eliminates the need of auxiliary heating or cooling. so before starting any type of design we must understand the climate in which the project is going to take place and how the climate is going to contribute to the built environment because human can adapt and be comfortable only in the certain range of temperature depending upon their location and cultural experiences so to maintain the same band and to maintain the thermal comfort we must be aware of the climate of the locality and take advantage of the different aspects of climate to reduce the external use of heating or cooling which in turn benefits us by reducing our energy bills.

Importance of passive design. The importance of passive design cannot be overstated. Paying attention to the principles of good passive design suitable for your climate effectively locks in thermal comfort, low heating and cooling bills, and reduced greenhouse gas emissions for the lifespan of your home. when you consider the principles of good passive designs, according to your climate and traditional homes to the locality it helps to make sure that thermal condition within this built environment can be locked in and can be used by the users without using any type of external devices to keep the thermal comfort inside and which in turn benefits us by reducing our energy bills and also saving us from the climate change. Passive design utilizes natural source of heating and cooling such as the sun and cooling breezes. It is achieved by appropriately orienting your building on its site and carefully designing the building envelope (roof walls, windows and floors of home). A well designed building envelope minimizes unwanted heat gain and loss. when you started designing, you must know about local climate, temperature bands and how many people are going to use the space and what type of radiation, different device that is going into the space which is going to create and with all these theoretical information that we have in hand we can be able to place each and every detail correctly which will reduce the heat loss or heat gain. For example, if you are in a region which experiences longer winter, you want to trap in natural solar radiation inside because of which you must be orienting your building facing towards the south and the west which will benefit by the solar radiation which is falling. But on contrary to it, if you are in region with tropical climate, you want your building to be oriented for longer hazards to be facing north to south which will reduce the solar radiation which is coming in and shorter dimension should be facing east and the west. This type of orientation of the building and from that level to the usage location of wall tiles, wall thickness, everything should be understood by understanding about passive design. This is how the building will be oriented and this can reduce heat gain or heat loss. And importance of passive design. Maintaining the right interior temperature, humidity, and air quality often accounts for 30% or more of a building’s energy use. But you can do this passively,

without demanding purchased energy at all. To maintain a certain type of temperature, we are either using air conditioning building or room heaters which is accounting almost to 30% of energy use within the building. When you are rightly orienting the buildings and making use of all the passive designs principles which will be followed in the subject, we can be able to reduce the usage of external or completely ignore it. Designing passively means working with external weather condition instead of fighting against them. So this is not just finding flaws of the climate but taking advantage of the climate wherever you are located in. so how to achieve it? The most economical time to achieve good passive design in a home is when initially designing and building it. However, substantial renovations to an existing home can also offer a cost effective opportunity to upgrade thermal comfort. Even small upgrades can deliver big improvements. It is better to make your building completely passive design when you are starting your schematic plan itself but also for old buildings which are already built without keeping in mind of passive design, refurbishment can also be made to improve the quality of air, thermal comfort and humidity levels within the built environment. So even a small change in the decisions and principles that you are using can affect built environment extensively and can reduce energy demands. for example, there is a house which is already built like 30-40 years back and you want to refurbish it to help and reduce your energy built say it's located in a cooler area so there will be lot of cold air which is coming through the construction area between the window frame and the wall or the door frame and the wall. So there will be a certain air cage which is letting a lot of cold air to pass through the building and which in turn increases the efficiency of the room heater and it increases your energy bill. So to reduce that you can go for sealing your air case. This is one example for refurbishment. for best results, passive homes need active users – people with a basic understanding of how the home works with the daily and seasonal climate, such as when to open or close the windows, and how to operate adjusting shading. Even thought the architects are smart enough to create sustainable homes or efficient or intelligent buildings, end users must be the one who is going to use the space. So there is no point in creating all these principles in a space which is not being used at all. It needs active users and you must educate your clients to when to open the window and when to close the window, so how efficiently a window can be used. say for example, if you are located in tropical climate and there is lot of radiation on the west hazard and you are keeping different horizontal and vertical system lower systems for shading and the client doesn't even know how to operate it, there is no point in keeping such intelligent systems which again lets in solar radiation inside the building which makes the user to switch on the air conditioning to achieve the thermal comfort. The main aspect is you have to educate your clients to understand how the passive design principle works. A number of different and interrelated strategies contribute to good passive design. Passive design strategies vary with climate as explained in more detail in design for climate. The best mix of passive design strategies also varies depending on the particular attributes of your site. We will follow some of the points which will be explained in another topic design for climate in which we will cover the principles of passive design. Good passive design is critical to achieving a lifetime of thermal comfort, low energy bills and greenhouse gas emissions. It is not only going to benefit you or

any individual it is also going to impact on the environment, on the biodiversity condition, it is going to help them grow by reducing its effects.

Design for climate. Good passive design ensures that the occupant remain thermally comfortable with minimal auxiliary heating or cooling in the climate where they are built. Each of six main climate zones in India has its own climatic characteristics that determine the most appropriate design objectives and design responses. When you are designing a building of passive design and with the principle of passive design it cannot be relocated from one location to another location which is completely different region and different climatic conditions. So each and every design you make using this principle will be very unique and it can be adaptable and it is used only to that particular site because it is using the surrounding benefits and the climate and the weather and climate aspects of the site. Identifying your own climate zone and gaining an understanding of the principle of thermal comfort helps you make informed design choices for your home. Again India is divided into six main climatic zones each of which has different passive design principles so wherever you are designing you need to understand that particular climate and what type of design principle has to be used and which can be modified according to certain site condition which will be beneficial on a large scale. These are different climatic zones. the top as you see is cold, the middle strip is composite, the areas such as Rajasthan and Gujarat usually experience hot and dry climate and this light green is monsoonal climate and here downside is usually warm and humid because we fall usually in the band of tropical and tropics.

Orientation. Orientation refers to the way you place your home on its site to take advantage of climatic features such as sun and cooling breezes. For example, in all but tropical climates living area would ideally face north or as close to north as possible, allowing maximum exposure to the sun and easy shading of walls and windows in summer. As we said before orientation becomes a main or basic aspect of passive design in which you need to place your building according to our specific climatic zone to get beneficial out of the climate. So if you are in colder region, the building for longer hazard must face the south and when your climate is like tropics your longer hazard must be facing towards north so it reduces the solar radiation which is coming inside the building which eventually reduces the air conditioning usage. Good orientation reduces the need for auxiliary heating and cooling and improves solar access to panels for solar photovoltaic and hot water. Your home is thus more comfortable to live in and cheaper to run. when you are orienting the building properly you will also understand about when you are using PV cells to trap solar radiation to get benefited out of electricity or even for using just for hot water or solar hot water systems, you have to orient them according to the sun path diagram of your location so it will be more benefited. For example, for tropical region, your solar system or PV cell must be facing towards the west because solar radiation is very harsh when it is setting. So there will be lot of heat and light which has been trapped inside the cells which in turn use renewable energy to create electricity. it takes account of summer and winter variations in the sun’s path as well as the direction and type of winds. So orientation is not just about the radiation, it is also about the wind pattern. when you are making design decisions you also should refer to windows pattern in

which you will be informed the prevailing wind directions and towards which you should or should not orient your building, the same if you are in colder region you would not appreciate a colder gush of wind coming to you and when you are in tropical region wind breeze is much appreciated and much expected. So you have to orient according to the wind directions which you can be informed by windows pattern of your location. How sun path is moving on different dates. June 21st is summer solstice which is longer summer day and December 21st is winter solstice which is shorter summer day and sun path is completely different so you have to make a design decision according to your climate wherever you are located. say if you are in colder climate you have to make sure your colder months are more benefited by passive solar design but when you are in hotter climate you have to orient your building in such a way it is benefited by mutual shading your building is not exposed or inviting more of solar radiation inside. this is example of windows pattern and as you see this building is an example, this side is more prevalent winds even though there is wind on all the directions, the most wind direction is towards the north east actually. These windows are oriented according to this direction to invite the cool breeze inside.

Shading

Shading of your house and outdoor spaces reduces summer temperatures, improves comfort and saves energy. direct sun can generate the same heat as a single bar radiator over each square meter of a surface, effective shading which can induce eaves, window awing, shutters, pergolas and plantings can block up to 90% of this heat. when you are in hotter climate with lot of solar radiation, it is ideal to use huge windows to invite wind but whereas when you are having huge windows you are also inviting harsh solar radiation, so for that you must eliminate the direct solar radiation by using different type of shading system according to your climate and you can benefit only the prevailing wind directions according to the specific location. Shading of glass to reduce unwanted heat gain is critical, as unprotected glass is often the greatest source of heat gain in a house. However, poorly designed fixed shading can block winter sun. Again it is about seasonal climatic variation which has to be considered from schematic design development. So making anything fixed which cannot be operated is actually a bad kind of design because it is actually letting in sun but you cannot have the ventilation out of it. So it is just a glass which is inviting sun inside. So we must make adapt to opportunities to user to change their environment according to the changing need and changing climatic conditions around them. By calculating sun angles for your location, and considering climate and house orientation, you can use shading to maximize thermal comfort. If it is located in harsh sun radiation climate, then sun path ahs to be analyzed properly to understand from which direction sun is coming and how it can be blocked. Without knowing sun path diagram whatever the shading design you are doing might be over engineering or under engineering also because you don’t know exactly where to stop your shading. You will be giving 10m of shading whereas it just needs 5m or 5.8m something like that. So understanding sun path diagram is also very important aspect of shading design. This is an example of tinted glass which is been treated with some coating which reduces and reflects

radiation and this is different sun location according to different dates. As you see, the December winter sun is usually low lying and as we go from March to June, the sun level increases and during June or summer months it is usually very high and the solar radiation is also a lot. For example, building orientation, overhangs and other features can be designed to capture the sun's heat in cold times and avoid it in hot ones. So it's not just for one climate, you can make your design to change according to your seasonal variations also. say for example, European countries like Greece or Spain, the summer temperature goes up to 40 degree Celsius whereas winter temperature goes even to -3,-4 degree Celsius then you have to come up with different strategies which will work better for during winter months to gain passive solar heating and also to gain summer months when it will neglect solar radiation completely. As you see, this is the winter aspect and summer aspect. so here in this picture, if you observe, the sun's location is different in two different images because this is winter month and sun path is very low and when it is a summer month, sun path is higher, so the sun shade is designed according it will block only the summer radiation and it will let in the winter radiation.

Passive Cooling

Moving on to passive cooling, it is the least expensive way to cool your home. To be effective, passive cooling techniques need to cool both the house and the people in it with elements such as air movement, evaporative cooling and thermal mass. Passive cooling design techniques can be applied to new homes as well as renovations, across a range of different climate zones. Passive cooling is similar to passive heating. Passive cooling is just focusing on cooling effects which can be adapted for tropical such as warm and humid and hot and dry climate. this type of climate can be used to reduce the air conditioning bills in which it takes advantage of ventilation and windows pattern, prevailing wind directions, etc and eliminating this solar radiation by knowing the sun path diagram as well. These are different type of passive cooling techniques which will be dealt later. The sun heats buildings, especially on dark roofs and pavement. When you want to adapt to passive cooling your building will be located on tropical region or wherever the sun is very high. When the sun is very high, the incident solar radiation that is falling on horizontal surface such as roof is very high. So you need to consider the roof material should not be darker colour and it's more encouraged to use reflective surface to reflect back the incident solar radiation. You can minimize unwanted heat gains by choosing more reflective surfaces or vegetation. As you see in this picture. This is for passive cooling. so different surfaces as we know this horizontal surface is going to absorb a lot of solar radiation, so here you have to avoid dark roofs like this and you have to use more of reflective roof or vegetation.

Passive solar heating: it is the least expensive way to heat your home. Put simply, design for passive solar heating keeps out summer sun and lets in winter sun while ensuring that the building envelope keeps that heat inside in winter and allows any built up heat to escape in summer. Orientation, thermal mass, sealing and other elements all contribute to the design of a house those benefits from passive solar heating. So passive solar heating, as we saw in passive solar cooling, this is how to heat your home, when you are building a home in a much colder

region or prolonged winter months. so if you are in composite climate say for example if you are in a place in which even the winters are very harsh and even the summers are very harsh, the design must ensure letting in the winter sun and it is making sure even the external heat has been built up during the summer. it is having proper provisions to the heat to escape. as you see, the shading and window location has been made according to the winter sun. So the winter sun can get in but the eves are been projected out in such a way that it's blocking the summer sun to control. So you have to provide controls on this window and it should not be made as a completely fixed glass because when the summer heat is built within the space you need some ventilation or opening for the heat to relieve or escape outside. Only then, you will feel equivalent to outdoor temperature or else your home might be even very much differential temperature towards outer and inside temperature. Different material like thermal mass and distribution pattern like internal gain can be used which will be discussed later in the next unit. Energy also radiates in and out of buildings through windows. You can make windows work for you by optimizing the window to wall ratio on each side of the building, and choosing windows that optimize how much energy passes through as infrared, visible light and higher frequency radiation. when you are designing windows, you should consider wall to window ratio, sat for example if you are designing for passive solar heating, having lot of window must be very good if it is letting good solar radiation but on a disadvantage to the same point you can also have lot of air leakage which is making the cool air from the outside which is penetrating through the air gap and it is coming inside. So we have to come up with an optimum balance to lock the thermal comfort within the built environment and not to allow the solar radiation inside but to reduce the heat loss and energy efficiency.

Thermal Mass: it is the ability of a material to absorb and store heat energy. A lot of heat energy is needed to change the temperature of high density materials such as concrete, bricks and tiles. These materials have high heat storage capacity and are therefore said to have high thermal mass. Lightweight materials such as timber have low thermal mass. When you are looking buildings for colder climates, thermal mass becomes very crucial because thermal mass of the material which will have high heat storage capacity. What is heat storage capacity is when there is heat which has been produced within a space they capacity of the material must be high to trap and absorb and protect this heat within. And it should not be light or low heat capacity. If it is a low heat capacity material then it will automatically whatever the heat has been coming and falling on the material, it will automatically gets transferred to the outside. as you see, how thermal mass works is in this picture, day time when the winter sun is low it falls on different surfaces and all the surfaces is made of thermal mass. This thermal mass makes sure this incident solar radiation will be absorbed on all these different surfaces. when there is during the evening or night time when you are using heating, you are going to close your window completely and protect your window so whatever heat that is been absorbed during the day time will be emitted out and it will make sure the built environment is kept in comfortable temperature and it reduces the usage of room heaters. Use of materials with high thermal mass throughout your home can save significantly on heating and cooling bills. But thermal mass must be used appropriately.

Poor use can exacerbate the worst extremes of the climate, radiating heat on a hot summer night or absorbing all the heat you produce on a winter night. Good use of thermal mass moderates indoor temperatures by averaging day-night temperature extremes. Choosing what type of thermal mass and heat storage capacity is very crucial and it depends on location to location. as you see in this picture this graph shows, this yellow is the outdoor temperature which is very high when you are using light timber framed building, the indoor temperature is shown by light green but when you are using heavy building with external insulation which will be good thermal mass, the temperature is this. This is how the temperature will follow. As you can follow, the peak of temperature is reduced and even the colder temperatures are maintained because the heat that is trapped in during the day will be emitted during the night and these are different examples of thermal mass.

Glazing: glazed windows and doors bring in light and fresh air and offer views that connect interior living spaces with the outdoors. However they can be major source of unwanted heat gain in summer and heat loss in winter.