Energy Efficient Architecture

Lecture 3

Passive Heating

What is passive heating? Passive heating uses the energy of the sun to keep occupants comfortable without the use of mechanical systems. Passive heating is majorly used in locations which is experiencing more of colder climates and having prolonged winter seasons during which we are taking advantage of solar radiations and heating up ourselves to keep us warm and to meet thermal comfort. Heating the building through the use of solar energy involves the absorption and storage of incoming solar radiation, which is then used to meet the heating requirements of the space. What they are telling is it is completely passive design technique in which the incident solar radiation which falls on a building material is chosen in such a way it is capable of absorbing the heat and storing it and being used when it is needed to meet the requirement and not depending on any auxiliary heating devices. A successful passive solar building needs to be very well insulated in order to make best use of the sun's energy. If you are designing a building for passive solar heating it has to be well insulated because insulation is something which is going to protect you from harsh external colder temperatures. When you don't have insulation due to heat transfer obviously the hot indoor temperature is going to get wasted because of the conduction and convection process because of which the heat is going to go out and meet to the same temperature as the outdoor. You should not let it happen by it can be avoided by insulating your home.

History of passive heating: The Sinagua cliff dwelling known as Montezuma's castle was occupied between AD1100-1300 and is located inside a shallow south facing limestone rock shelter. As you see in this picture, The Sinagua cliff has been exposed to good solar radiation because it is located facing towards the south direction. As the sun moves, it moves from rises in the east and sets in the west. But the path it chooses to move is it rises in east and move towards south and then it goes to the west. the south is the direction in which the building will be exposed to longer radiation levels for locations in which for building locations in higher latitude condition. this is an example of the same which is faced towards the south which is using limestone and rock shelter which has good heat storage capacity because of which the heat which has been fallen on the southern face by instance or solar radiation is been trapped by this material.

The next is this round house which provides protection from heat, cold and wind. This proportion scale of each dwelling is also important. As you are observing this, these two images the proportion is very less because of which the volume of the space in which the heating is going to happen, the occupants surrounding is also restricted. So even a small amount of solar radiation also falls on this opening, the amount of air which has to be heated is very less and it

can be done quicker. There is no opening on this face because of which the heat loss can also be reduced.

Insulation: Materials that insulate well do so because they are poor conductors of heat. Having a home without insulation is doing just that leaving the house open year round. Insulation is something that protects the temperature of the inside and to make you feel warmer. It is mostly used in regions in colder countries in which they are trapping the solar radiation and to maintain the heat which is in the indoor. Without insulation it is like leaving your home opened because of the heat transfer it is obviously going to come equivalent to the outdoor temperatures. Ideally, you should insulate every surface between your house and the outside world. There are lots of choices for insulation from loose fill, batts of rolls of the pink stuff, to rigid boards and foam in place products. there is lot of different insulation material which is available in market which can be used in different shapes and sizes and even in different medium which also comes as spray insulation which can be used when your building shape is completely dynamic and you cannot go for regular block dimension as you find in the market. so there are different properties which can be used according to the needs and climatic region in which you are going to design.

A small recap of heat movement: heat movement is done by conduction, it is the way heat moves through materials traveling from molecule to molecule as we saw in the previous presentation how when a small end of the metal strip is been heated, the carbon atoms get activated by kinetic energy and the heat has been transferred from that one end to the whole strip that is the process by conduction and convection is the way heat circulates through liquids and gases, lighter, warmer fluid rises and cooler, denser fluid sinks. we might observe in day to day life like when you are in a room and in lower level, the air that you are experiencing around you is much colder but when you are in a upper floor, the air that is surrounding you is much hotter. this is because of the process of convection in which hot air, the density is very less because of which it rises in the cold air because of the presence of moisture the density is high and it comes down, Radiant heat movement moves through the air from warmer objects to cooler ones. This is how it moves from warmer object to the colder object like how we saw the example between Popsicle and a hot coffer, how it melts and the coffee colds down to meet the same room temperature is due to the radiant heat movement.

Five elements of passive solar design are aperture (collector) is the large glass window area through which sunlight enters the building. So aperture means the opening basically the openings for windows and doors that you are going to give should be ideally located by which the passive solar heating can be encouraged and no heat loss by the same. so you have to orient your aperture so accordingly to the sun path of your specific location if it is much more solar radiation on your west face, it is appreciated to have good openings on your west or if it is on the south it is good to have good amount of openings on south to get more solar radiation. Then absorber, the hard, darkened surface of the storage element. When the solar radiation is falling on a surface. it can be made into dark or hard element or it can be chooses with the material with good high heat storage capacity which when incident solar radiation falls on the surface, the time for which the

heat has been trapped inside the surface is longer and it can be used even during night when the outside temperature is much colder. Thermal mass, the material that retains or store heat produced by sunlight. Thermal mass as we saw in previous presentation as well. This is the material which has good heat storage capacity. Example: concrete, bricks, tiles which can be stored good amount of heat and it can be used for passive solar heating of your home. And distribution: the method by which solar heat circulates from the collection and storage points to different areas of the house. One example is carpet. When you see western residents you will find all the flooring to be made in carpet which is because of the room heat or room radiator or due to the incident solar radiation, the property of carpet has the good ability to trap the heat which is falling and to equally distribute throughout the space wherever it is used. One such material is carpet as far as this type of heat transfer method. Control, roof overhangs can be used to shade the aperture area during summer months. when you are doing for passive solar heating you should also keep in mind if the summer is very harsh or summer radiation should be completely neglected because of which you have to roof hang or over hang the shade according to your summer solstice and sun angle and because of the winter solstice the sun being at lower level it should still send in the solar radiation during the winter months.

The different type of gain is direct, indirect and isolated. as you see in this image, the direct gain is just by an aperture, opening an aperture solar radiation is falling inside your built environment, whereas indirect gain is a small space which is been added to the residents which by the solar radiation it falls on the first surface and then gets heated up. The heated up air is being used to make your built environment cool. this is called indirect gain and isolated gain is like almost adding a separate room completely to trap the solar radiation which is incident on space and which can be used as separate isolated space and it can be heated up and the hot air can be used for different parts of the house through ducts and exhaust system that can be taken and transferred to the different parts of the built environment.

Direct Solar Gain

Now moving on to direct solar gain, the most common passive solar system is called direct gain. Direct gain refers to the sunlight that enters a building through windows, warming the interior space. A direct gain system induces south facing windows and a large mass placed within the space to receive the most direct sunlight in cold weather and the least direct sunlight in hot weather. the direct solar gain is mainly used to colder regions so prolonged winter seasons in which they are saying to use facing towards solar radiation say south face should be given more wall to window ratio in order for the solar radiation to come in and directly fall on your floor which will be heated up and that heat will be transferred throughout the space or the built environment by heating up the air. So this is called as direct solar heat gain and it should also be kept in mind to eliminate the solar radiation during summer months by providing good amount of shading and over hangs. Direct gain systems are probably the least costly passive system. When you are doing this type of direct solar gain system. this initially done while designing itself will reduces lot of cost because after building you might realize that you are actually using study

table where there is no sunlight or solar radiation and you would really appreciate if there was a window which can let in solar radiation to trigger your activity. So this type of design decision must be made even during the initial stages of design. day time, the scenario is when you open a window or even if it is a fixed glass, through glass, solar radiation comes in and during night it gets absorbed even if it is completely closed, the observed radiation gets emitted on the surroundings which is used to maintain same air temperature as it was during the day and reduce the auxiliary heating effect.

Massing and Orientation for heat: Massing and orientation are important design factors to consider for passive heating. Consider these factors early in the design so that the surface areas exposed to sun at different times of the day, building dimensions, and building orientation can all be optimized for passive comfort. As you see in this picture, sun rises in the east and sets in the west and so the path it chooses is to go alongside of the south. As you see here, the longer side of the building has been oriented towards the southern face. So the incident solar radiations are prolonged solar radiation exposed towards the southern direction by placing the building also according to the same. Also make sure you take advantage of this passive incident solar radiation and it contributes to passive solar heating techniques and it will really reduce the energy bills. This is applicable for buildings you are designing in colder climates.

Thermal mass is a material's resistance to change in temperature. Thermal mass is a material which has resistance to change its temperature; it usually maintains the same temperature and just because the outside temperature is very hot it doesn't quickly changes. It reduces the peak hot temperature or peak colder temperature. It usually acts on the same level of temperature Inspite of the outer being very hot or very cold. Objects with high thermal mass absorb and retain heat. Thermal mass is crucial to good passive solar heating design especially in locations that have large swings of temperature from day to night. As we said before, in examples of country or regions like Rajasthan when the days are really hot like 40 degree and the night goes very close to or lesser that 10 or 5 degree Celsius, thermal mass can be used to reduce the peak temperature. so when you observe there are lot of ancient building which are built in stone which is also god thermal mass or concrete which reduces this type of fluctuations during day and night or it maintains the same constant temperature inside the built environment. in this picture, this is an indirect gain example here this is a thermal mass wall and this is a glass through which the sunlight is been lent in and this space is been heated up and the warm air rises and it goes inside this space and people who are using it will be benefited by air which is preheated in this space. Whatever the cold air that is coming through different windows will be lighter and it will be stored here and it will be having small opening given here and due to temperature difference the air usually moves here and again it usually gets heated up and then again it gets circulated. So this is the process by which thermal mass can be used for passive solar heating technique.

Aperture for heating: windows and other apertures bring in heat from sunshine, but can also lose heat by radiant cooling and by conducting heat better than most wall or roof constructions. Apertures and shading must be intelligently placed to take advantage of the sun's heat in cold

locations and seasons, while not overheating in hot seasons. What they have explained is it is important to keep good amount of windows when you want good solar radiation. But if you are having lot of windows there will be radiant cooling effect which is also happening during the night because of which you are losing your heat energy which is being trapped during the day by the same aperture or window opening. You need to create a balanced ratio of wall and window you are choosing in order to maintain the same equilibrium.

Shading for solar heat gain: Shade can keep the heat and glare of direct sun from coming through windows. They can also keep direct sunlight off of walls or roofs, to reduce cooling loads. when you are considering all these different strategies for passive solar heating we usually tend to forget what happens during summer months, because during winter months is the month which is given more priority or more specifications on regions with colder climate or prolonged winter months but during summer even these radiations for example in western countries like London, radiation is very harsh due to the high level of UV radiation that is present in the sun. So you would really appreciate there is good amount of shade under you when you are exposed to sun. You should be considering the same and different shading. If you see this picture, there is removable shading devices which can pull out during summer months and this place can be completely shaded and even during winter it can be pulled up and this space can be used with good amount of solar radiation.

Direct gain system rules: A heat load analysis of the house should be conducted. Heat load analysis is how many people are going to use, which space, what is the volume of the space, and how much air it is getting in and what are the different equipments they are using and what are the internal gains and internal losses they are going to make, and all these accounts to heat load. Do not exceed 15cm of thickness in thermal mass materials. as we said, thermal mass reduces the peak temperature and night cooling temperature and it maintains constant temperature but you cannot keep on adding the same material because after a certain point, it almost reaches its limit and after which even if you add, the amount of effect which is going to act on the thermal comfort is going to be very less. As a thumb rule, it is better to keep the thermal mass thickness limited to 15cm. Do not cover thermal mass floors with wall to wall carpeting; keep as bare as functionally and aesthetically possible. There is no point in keeping good thermal mass which can be used for trapping solar radiation and then covering it with the carpet or some other tiles which there is no point in keeping it. The thermal mass won’t even be acting on it. So it is better to keep as bare as, as raw as possible. Use of medium dark colour for masonry floors, use light colors for other lightweight walls, thermal mass walls can be any colour. Whichever the surface in which the solar incident radiation is going to fall. It’s better to keep it in darker shade so the solar radiation which is falling be trapped because of the darker colour and thermal mass acts Inspite of this colour which we are going to use on the wall. For every square foot of south glass, use 68kg of masonry or 18l of water for thermal mass. as water is also a good thermal mass which can collect good amount of heat, it is also one of the way in which you can store heat by

keeping huge gallons of water and trapping the heat and then radiating it during the colder night period.

Indirect Solar Gain

In an indirect gain system, thermal mass is located between the sun and the living space. The thermal mass absorbs the sunlight that strikes it and transfers it to the living space by conduction. Using a Trombe wall is the most common indirect gain approach. What indirect gain is, as we saw in direct gain it is just having a window and letting in solar radiation inside but this indirect gain is having a small space which is connected with built environment and that place first gets heated up and that hot air is used to heat your remaining space? This is called indirect gain and Trombe wall is one of the good examples and Trombe wall is wall which is constructed with thermal heat storage capacity material and it is painted in black which we will be discussing later on. The wall consists of a 20 to 40 cm thick masonry wall on the south side of a house. A single or double layer of glass is mounted about 2.5cm or less in front of the wall's surface. Solar heat is absorbed by the wall's dark colored outside surface and stored in the wall's mass where it radiates into the living. This exposed Trombe wall exposed to the outside radiation should be painted in black because of the darker surface. The solar radiation gets trapped in and the trapped in energy which is stored inside the Trombe wall gets transferred as heat transfer from the Trombe wall to the inside built environment to make it to equilibrium. There are two types of indirect gain systems: thermal storage wall systems (Trombe walls) and roof pond systems.

This is the thermal storage wall or Trombe wall and this is double glacing. as you see the winter glacing will fall here and it will heat up this space, due to small air gap that is present this surface will be painted in black which will absorb good amount of solar radiation and presence of two vents which will supply hot air in the top and will take the cold air on the bottom. This is how it is going to act during day time and night time. During night time, this ventilation will be closed and whatever the preheated air in the morning which was circulated will be used during the night time to maintain the thermal comfort.

Main functions of Sunspaces: Auxiliary heating, to grow plants and living area. some of the main aspect is we can reduce the external usage of room radiators or room heaters and the energy bill will go down obviously and that can be used as extended glass space which can be used to grow plants. You will be like you are going to have your own greenhouse effect within your own residents and to keep it as extended living area. During winter months, if it is very cold you would really appreciate if there is direct solar radiation which is heated which might hit on your body. Having this type of space will encourage such type of an activity.

Main considerations: sitting- a sunspace must face south. Due solar south is ideal, but 30 degrees east or west of due south is acceptable. When you are designing, this wall has to face true south which is perpendicular to the 0 degree of the south or it might be tilted 30 degree to east or west is also acceptable to trap in more solar radiation. Heat Distribution- warm air can be blown

through ductwork to other living areas. It can also move passively from the sunspace into the house through doors, vents or open windows between the sunspace and the interior living space. We are going to keep this indirect solar gain connected only to one of the external wall. so how do we distribute the heated up air to rest of the house is by keeping different types of vent and duct systems throughout the house, we can take up the preheated air from the sun space and it can be distributed on different spaces and it can be taken advantage according to the usage and user comfort or usage pattern. Glazing – Sloped or vertical? Although sloped glazing collects more heat in the winter; many designers prefer vertical glazing or a combination of vertical and sloped glazing, sloped glazing loses more heat at night and can cause overheating in warmer weather. Vertical glazing allows maximum gain in winter, when the angle of the sun is low and less heat gain as the sun rises toward its summer zenith. the shape of the glazing that you do is also very crucial that is on a location which has longer colder months or on western country which has more colder seasons in which you have to place your windows vertically in which the sun is very low and it will trap in more solar radiation for longer number of days rather than having it on horizontal surface which will trap only for a shorter duration of the time.

Building as thermodynamic system: in a building, where energy input, outdoor climate, fuel supply network, heat up and internal source of energy which is human being light and other sources and heat is stored in different building surfaces and different materials by its storage capacity and energy output. This is called first law of thermodynamics which is an addition of outdoor climate plus fuel supply network and energy and power which is internal energy resources which is equivalent to heat stored in building and energy output.

Function: Different spaces for a variety of activities, some sedentary. When you observe these two images, the kids are wearing different type of clothing for same type of location because the activity pattern they are involved in is completely different. When they are playing they are doing more metabolic activity which will produce some amount of heat because of which they are choosing much lighter clothes whereas when they are studying they are mostly in a sitting position so they prefer thick clothing levels.

Occupancy: it also depends on how many people are using one space. Number of occupants can vary from high to low or even to none. Different activities require different environmental conditions. As you see the volume is different and the surrounding is different. so this is how it has been calculated when there is low metabolic level, the clothing rate is lower which can be acceptable for 23 degree Celsius +/- 2.5 degrees and when there is high metabolic level say 3.5 metabolic level, clothing rate is reduced by 0.5 which is comfortable or neutral temperature is 12 degree Celsius +/- 2.5.

Occupancy pattern and generation of thermal heat gain: depends on internal gain and the number of occupants they are using and their clothing. As you see in this picture, the presence of occupants results in a rise in room temperature above the outdoors. The occupants produce heat by metabolic process, use of appliances and use of artificial lights. These are collectively known

as internal heat gains. They can raise the temperature about 5-10K above outdoor. So in this picture as you see, there is lot of people using lot of appliances which is going to add up to the heat source. These are all should be considered as heat load even for basic schematic design process.

Occupancy patterns and indoor air quality: Occupancy also determines the need for fresh air to maintain indoor air quality. One person needs 5-10l of fresh air per second which is equivalent to 18-35m3/hour per person. The window should be kept open able as you see in this picture to maintain to this type air quality. For a classroom of 150m3 volume with 15-30 occupants, this works out at 300-1000m3 fresh air required per hour which is equivalent to 2.0-7.0 ach. When there are lot of occupants the windows has to be more open able to meet in to the air exchange per hour requirement.