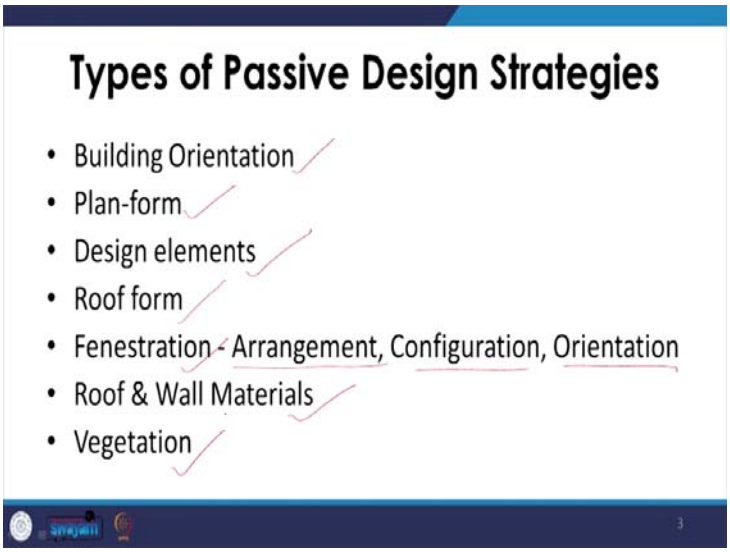
Sustainable Architecture
Prof. Avlokita Agrawal
Department of Architecture and Planning
Indian Institute of Technology, Roorkee

Lecture -18
Fundamentals of Climate Responsive Buildings – I

Good morning. Welcome to this lecture for the online course on Sustainable Architecture and previous lecture in the previous lecture we were discussing about the tools for understanding the response of the building to the given climatic context. And then we had talked about the by climatic chart and we learned how to use Mahoney's table to identify the appropriate design strategies for the given climatic context which was based upon the understanding of air temperatures, humidity, rainfall and wind data.

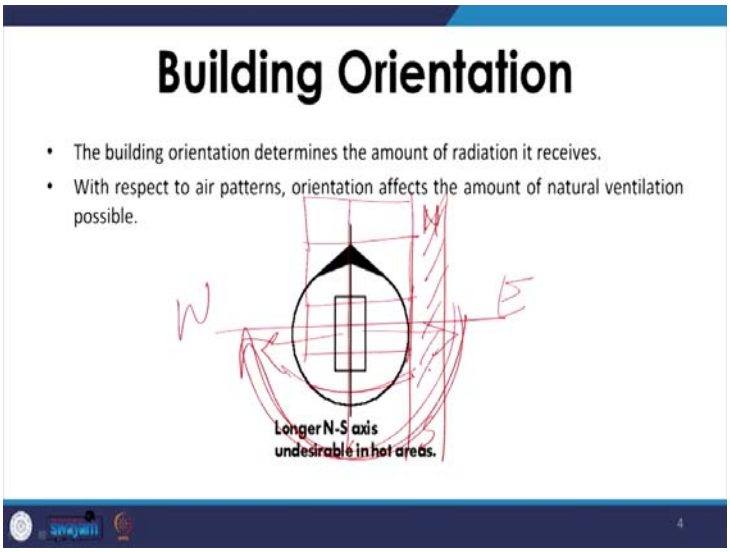
Today before I move on to use another tool, we would very quickly understand the design strategies which were proposed through which was suggested through Mahoney's table. So, let us quickly look at those passive design strategies which are proposed in Mahoney's table go over each of them one by one.

(Refer Slide Time: 01:32)



So, the type of passive design strategies that we are looking at our building orientation, plan form design elements, roof form fenestration, where we are talking about arrangement configuration and orientation all of these roof and wall materials and vegetation.

(Refer Slide Time: 01:49)



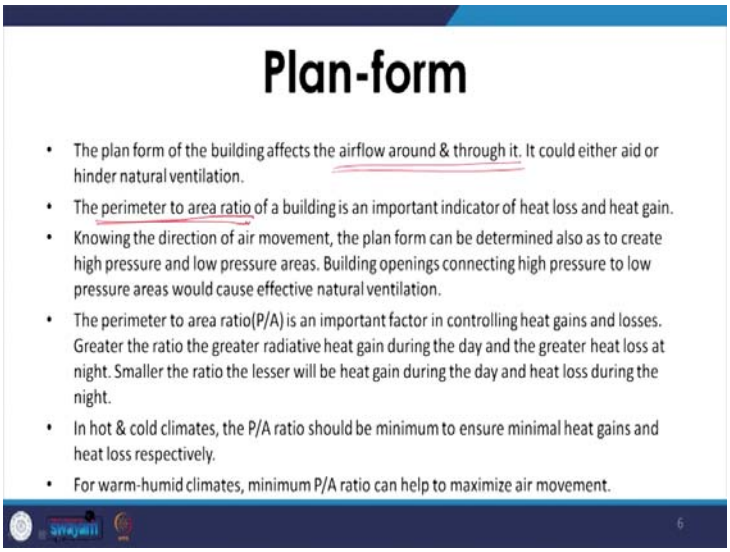
Starting with building orientation first. So, the building orientation mainly determines the amount of radiation which the building is going to receive. Since we very clearly know that the sun moves from east to west in the northern hemisphere we are talking about India in this case. So, it is rises from the east and sets down in the west. So, predominantly this is how the sun path is going to be.

So, an orientation where the north south axis is larger which has more exposure towards east and west is not preferable for hot climates and large part of a country has warm, hot or tropical climate. So, this orientation is not preferred. Also, the reason is because when the sun comes to the south it is at a very high altitude and the solar radiation can very conveniently be cut off by using horizontal shading. So, it is always preferable in hot areas to have your building oriented in such a manner that it has a longer east west axis.

Here when we are talking about building orientation it automatically affects the orientation of the street. So, if we have more buildings oriented with their longer axis in east west direction, we automatically know that we have streets which are in the north south direction and in such a case the streets also remain shaded for most time of the day.

So, the preferable street orientation is north south which facilitates the buildings like this and it helps the streets to remain shaded for large part of the day.

(Refer Slide Time: 03:52)

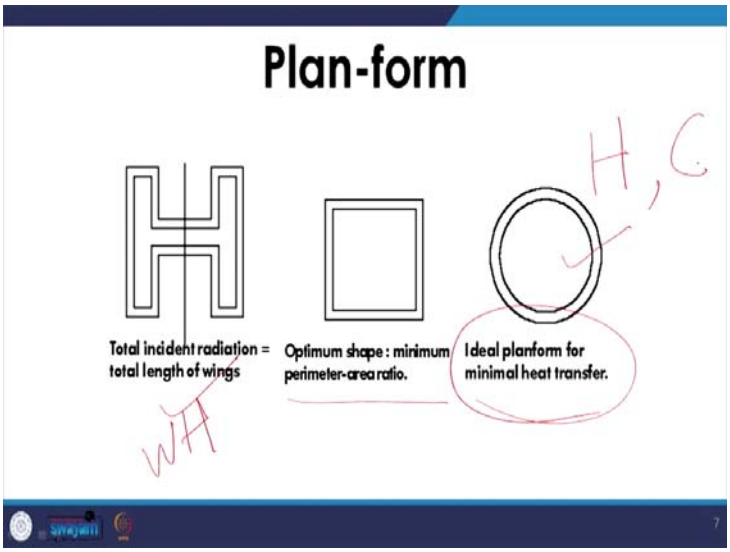


Now, we are talking about the plan form. When we talk about various arrangements for plan form, we are talking with respect to certain parameters. One we are talking about the air flow around the building plan and through it. The second thing we are talking about perimeter to area ratio. Perimeter to area ratio also leads to surface to volume ratio not directly, not exactly the same, but directly proportional.

So, we are looking at the perimeter to area ratio because it is an important indicator of the heat transfer it could be loss or it could gain. So, these are the 2 reasons because of which we talk about the plan form. Now when we are talking about the hot or cold climates, we should reduce the perimeter to area ratio to minimum.

So, as to ensure minimum heat transfer because larger is the perimeter, larger would be the surface area and more would be the surfaces available for heat transfer. In warm humid climates for on the other hand we should have larger perimeter to area ratio because larger is the surface larger is the possibility for heat transfer and air movement air ventilation.

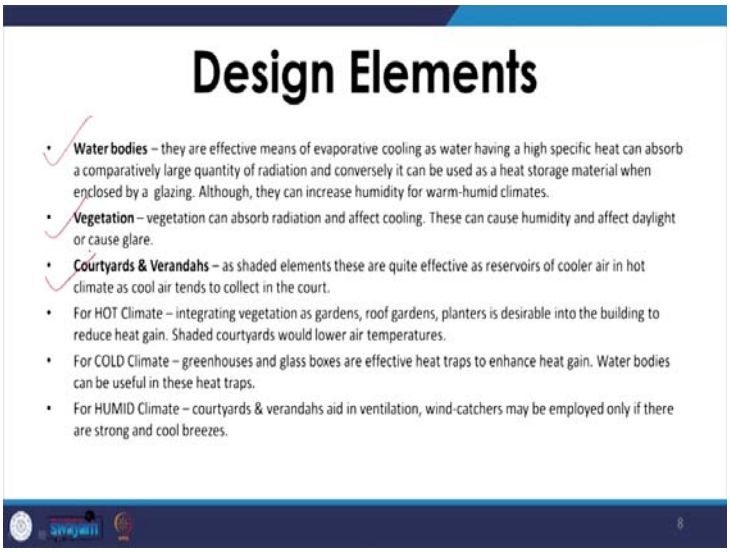
(Refer Slide Time: 05:13)



From this perspective if we look at different planforms, we would see thus that the best platform which is suited for minimal heat transfer is a circular form and that is why if we look at majority of the traditional building platforms in hot dry climates we would find that they are often circular.

You look at bungas of Rajasthan, we look you look at huts from Cameroon, huts from Kutch we would find that they are usually circular in plan. That minimizes the perimeter to area ratio. The optimum one is a square and a building platform which has a lot of wings coming out and a lot of penetrations a lot of punctures in the plan form will result in a building which has very large perimeter to area ratio and that kind of a form would be suitable for a warm humid climate and these ones for hot and cold.

(Refer Slide Time: 06:21)



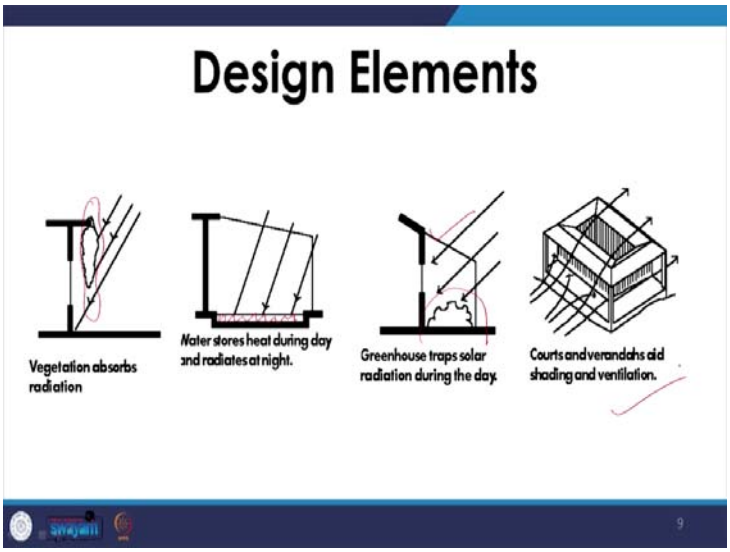
Next, we come to the design elements. When we are talking about design elements, we talk about the water bodies where should they be placed, we are talking about vegetation. Now each of these design elements has impacts on temperature, on humidity, on air. So, vegetation can absorb radiation and it can affect cooling. It can also channelize the air.

Similarly, water body if it falls on root the air from where the air is entering into the building in the direction of wind it can pick up the air can pick up humidity moisture from the water body and add to the moisture. So, in a hot dry climate a water body planned in the route from where the wind is entering the building is preferred while in a cold climate it is it may not. Then we are also looking at courtyards and verandahs as design elements.

Now courtyards and verandahs are required are used for shading for cutting off the direct solar radiation in buildings. So, they are more preferable in hot dry climates in warm climates. Courtyards and verandahs also facilitate movement of air because of the differential heating because of the shading which is there. So, the indoors remain cool, the verandas and courtyards are at a moderate temperature and the outdoors are at a higher temperature.

So, it induces air movement because of this differential heating and that is why verandas and courtyards are also the highly preferred design elements for warm humid climates because it induces the air movement.

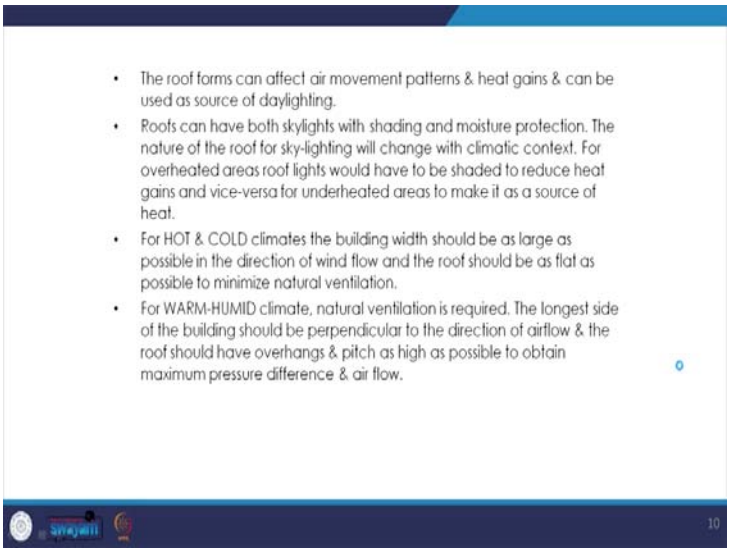
(Refer Slide Time: 08:15)



They help in absorbing. So, we are looking at vegetation it helps in absorbing radiation. In case we are looking at water body it stores the heat during the day and it releases it at night.

We can also combine the vegetation along with a green house. We are looking at courtyards and verandahs which help not just in shading and, but also ventilation which is what we just discussed about.

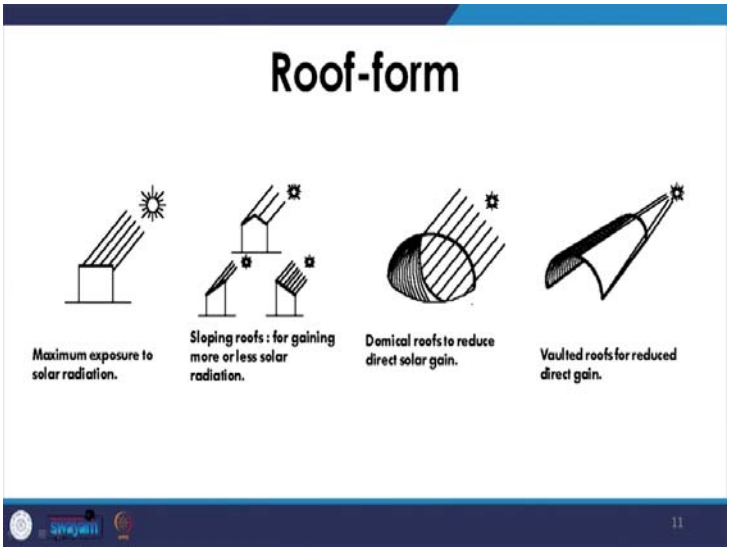
(Refer Slide Time: 08:41)



Besides the air movement and solar radiation and controlling the air temperature, these elements also help in controlling the daylight. Suppose we plant deciduous trees towards south.

So, in summers these deciduous trees would shade the building and control the direct radiation and also the day lighting while in winters when they shed their leaves, they allow a lot of sunlight and daylight to penetrate inside the building. So, together these elements control a lot of environmental parameters

(Refer Slide Time: 09:21)



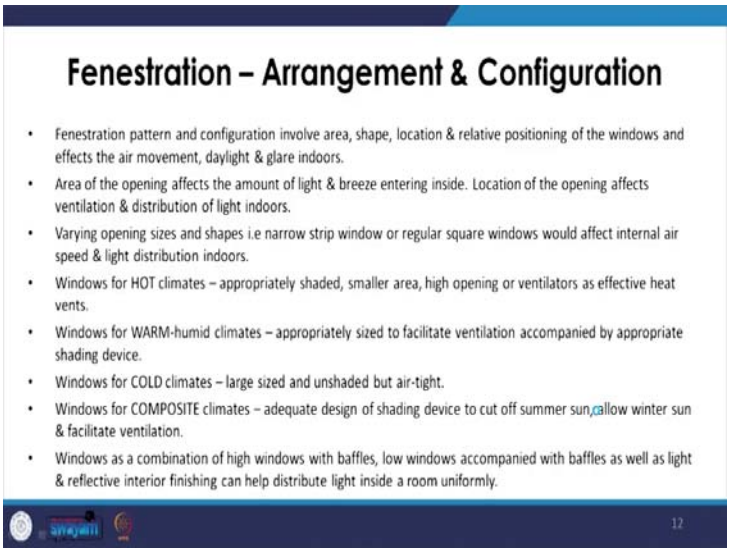
The next we are looking at roof form. So, if we have a flat roof, it gives maximum exposure to the solar radiation. It is exposed for a longer duration of time because it is flat and receives sun almost throughout the day. While if we have domical roofs half of the dome would at any given point of time be shaded by its own. Same is with vaults if it is properly oriented. Now for this reason you would always find that in extremely hot climates domes are the preferred route form.

So, it is not by chance that that the use of domes was more in the middle east and it evolved from there. It was the necessity which led people to understand to realize research that dome is the most preferred form. In besides the direct solar radiation it is also it has also to do with the amount of precipitation which is received.

So, if there is very high amount of precipitation the sloping roof is preferred of course, that is a very common understanding. So, domical roofs are good for areas where we want where there is very high amount of solar radiation, but we want to cut it off. Sloping roofs would be good for cutting down on solar radiations partially and also to facilitate managing the rainwater heavy rains and flat roofs are good for cold areas because we want maximum amount of solar exposure on to these roofs.

That is why in majority of the cold climates either we would find roofs sloping where the exposure is largely towards the south or we would find flat roofs where in cold climates where there is no precipitation or very less precipitation, we would find flat roofs. So, in Leh Ladakh, Spiti valley which is cold dry we would find these cold flat roofs in cold regions while in the northeast states where it is cold and humid where the rain is also there we would find sloping roofs and in Rajasthan in extremely hot climates where we would find structures such as bungas we would find these domical roof forms.

(Refer Slide Time: 11:47)



Next, we talk about the arrangement and configuration of fenestration. Now fenestration in today's times becomes one of the most important element of building because it allows it affects the movement of air and hence the temperature indoors. It allows for light. It also controls the amount of air which is coming in and going out.

So, controls the ventilation requirement. If you look at the physiological objective in extremely hot and cold climate, we do not want an interaction of the outdoors with the

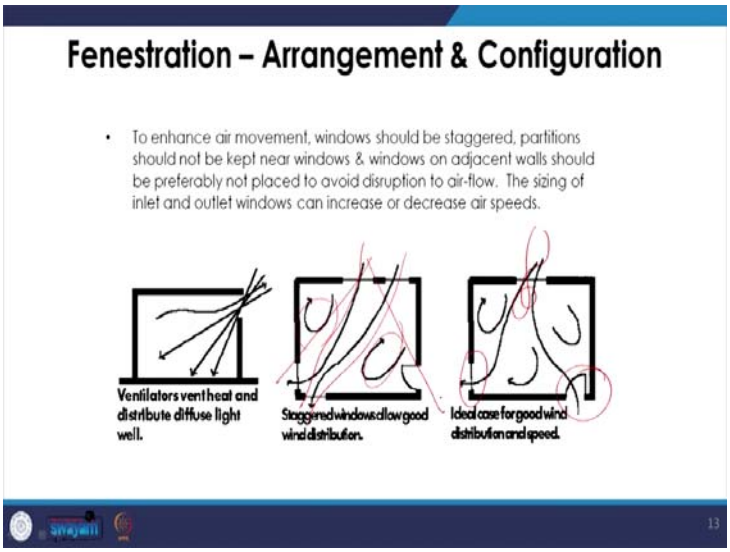
indoors as far as heat exchange is concerned. So, in both these climates, hot dry and cold we would prefer smaller windows very small windows were not much of heat exchange through convection is happening. That is what windows facilitate fenestration facilitates.

However, in one humid climate we would want a lot of air movement to happen because that is what brings in the comfort. So, in warm humid climate the size of the fenestration is preferred to be large. So, huge openings are preferred in warm humid climate. Now when we are talking about hot dry and cold climates the kind of material that the fenestration should have will also matter.

So, if we have insulated glass clear glass double glazed window which allows a lot of radiation to come in, but blocks the air that would be preferred in cold climate. So, fixed glass windows which will allow a lot of sun to penetrate in. So, the window should be oriented towards the direction of the sun. So, south facing windows and also inclined at a certain level. So, that a lot of sun can penetrate in that is an ideal arrangement in a cold climate.

However, if we look at hot climate, we do not want direct solar radiation, we do not want a lot of daylight because it is anyways very clear and bright. So, very small amount of opening would do and we also do not want any air movement. So, in hot climates traditionally you would find wooden shutters. So, wooden shutters would control all these 3. That is how the fenestrations have been designed as far as the material is concerned. If we look at the arrangement the arrangement determines the amount of air flow inside the room.

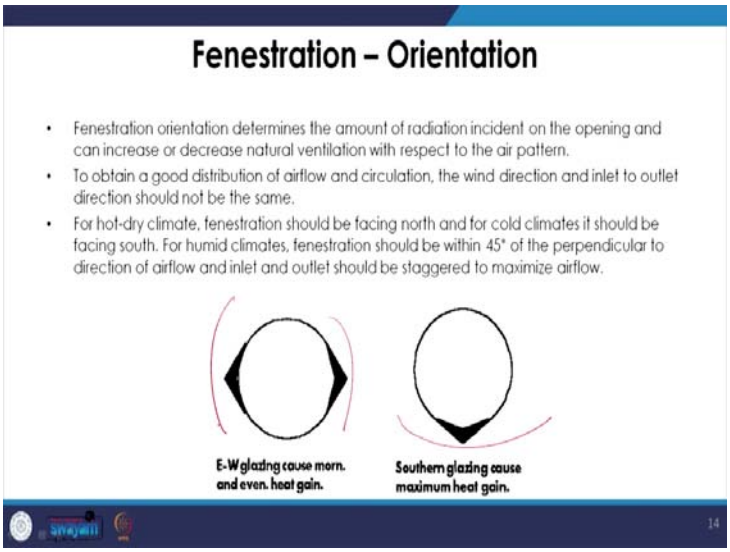
(Refer Slide Time: 14:32)



So, if you look at SP 41 where a lot of arrangements of windows have been proposed. This is in plan that we see. So, if we have windows arranged in opposite corners on opposite walls of the room it will allow almost the entire room to ventilate properly. However, if we have if we do not have these windows these openings there the wind would just not circulate through the entire room.

So, for enhancing the air movement it is preferable, it is advised that the windows be provided on the openings be provided on the opposite walls and preferably the corners. So, that the entire room remains well ventilated.

(Refer Slide Time: 15:24)

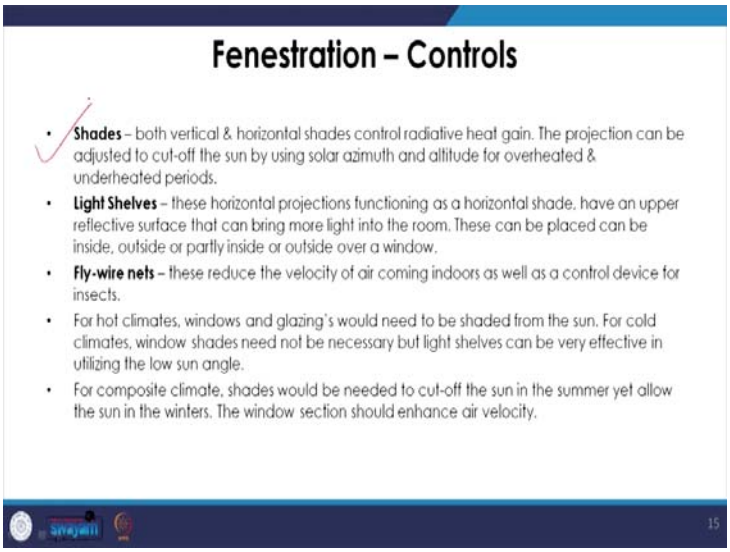


When we are talking about the orientation as I have just talked about the southern glazing which is oriented towards south would maximize the heat gain and hence it would be preferred in cold climates.

While if the window is in is towards east and west it would maximize the heat gain during morning and evening. At that time morning and evening the sun might be at lower temperature specially mornings not necessarily evenings. But we must also keep in mind that it is extremely difficult to shade these windows because of the low altitude of the sun.

So, if we are providing windows in east and west in most likely cases the sun would penetrate inside the building. So, the windows have to be properly oriented, the fenestration has to be properly oriented in order to control. In addition to designing the size, orientation and arrangement of fenestration we can also add controls or fenestration along.

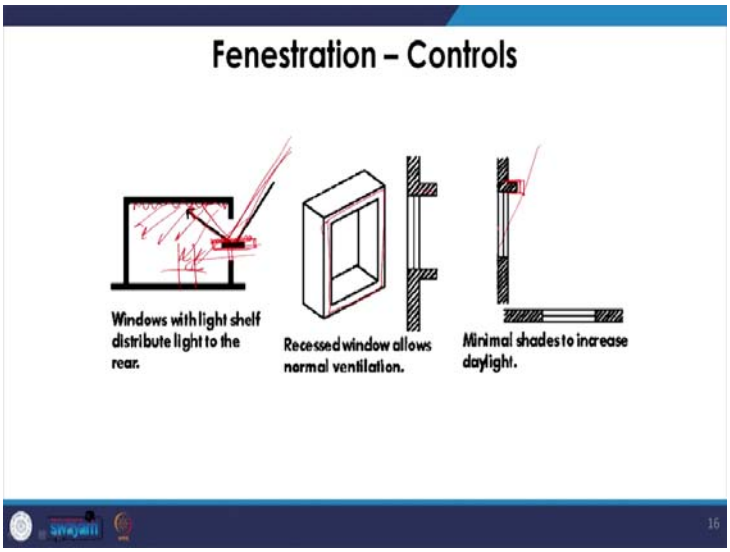
(Refer Slide Time: 16:31)



So, we have different types of controls that we can take into account. One most common and popular is shading devices shading devices could be both horizontal and vertical and I am sure in your climatology you have already read about the sun path diagrams and how to design shading devices, how to understand the movement of sun and how to cut it down using horizontal devices as well as vertical devices.

Now, in today's times these shading devices are of multiple types not just the fixed ones. We have moving ones, we have the outdoor ones which are moving, we have the indoor blinds which are moving and so on. In addition to that we have light shelves.

(Refer Slide Time: 17:18)



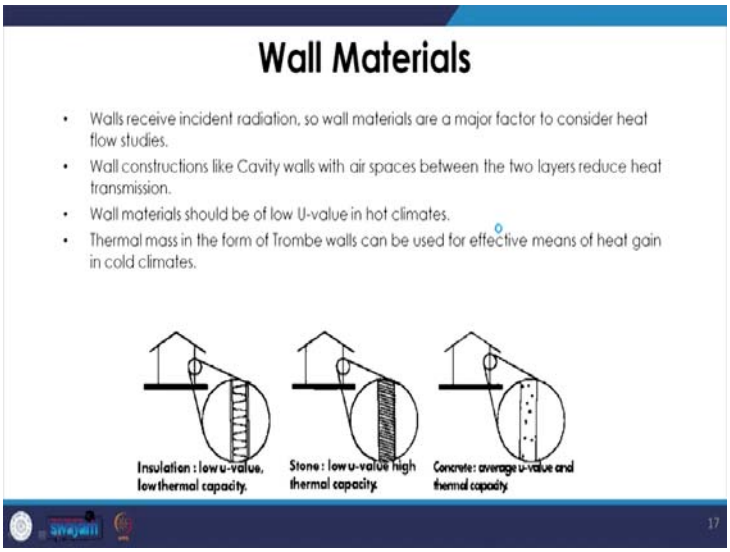
Now, light shelves is an very interesting concept where above the window. So, this is the window and above it we have a shelf which is a permanent feature where the light is and the upper surface of this light shelf is quite reflective very light in color.

So, the light which is falling on to this light shelf is reflected to the ceiling and this ceiling is also maintained at a very light color is also light colored and this further diffuses the light inside. So, this is a light shelf where the direct glare direct onto a work surface is cut off and diffused light and it is it is penetrated deeper into the room.

So, light shelf is very good for distributing the light and in a diffused manner without causing any glare to a bigger area to a larger area of the room. In addition to that we also have windows which are recessed. So, there is shading all around. So, there is a box type of shading and it helps to cut down on direct solar radiation. We can also have minimal shades they also help in controlling the rains and at the same time in shading.

So, depending upon the orientation and the sun path diagram these shading devices can be designed.

(Refer Slide Time: 18:46)



Next, we come on to wall materials. Now depending upon the physiological objective. If you very clearly remember when we were talking about the hot dry and cold climates there we want less and less of heat transfer to take place.

In order to do that we have to have very high thermal mass, so that in extreme summers this thermal mass is able to store the heat which it receives from outside and not transfer it inside while the same heat which is absorbed during the extreme summers is further released during winters that is seasonal variation of this structure. Along with that there will also be a diurnal variation of this structure which results in what we call as time lag.

So, what we normally find in traditional structures in hot dry climate is that there is a heavy thermal mass which absorbs heat during the extremely hot period of the day say extreme noon when the temperature is around 45 43 degree centigrade. And during the night when the outdoor temperature has fallen down to a comfortable range and people can spend their time outdoors that is the time when the structure releases the heat that it has absorbed to the indoors.

And that is the time in them indoors will be flushed out throughout the night and the heat can be released from the structure to the outdoors ambient environment. So, depending upon the physiological objective the materials for the wall will be selected. In hot dry and cold climates, we would want to use materials which have heavy thermal mass which have which can store a lot of heat.

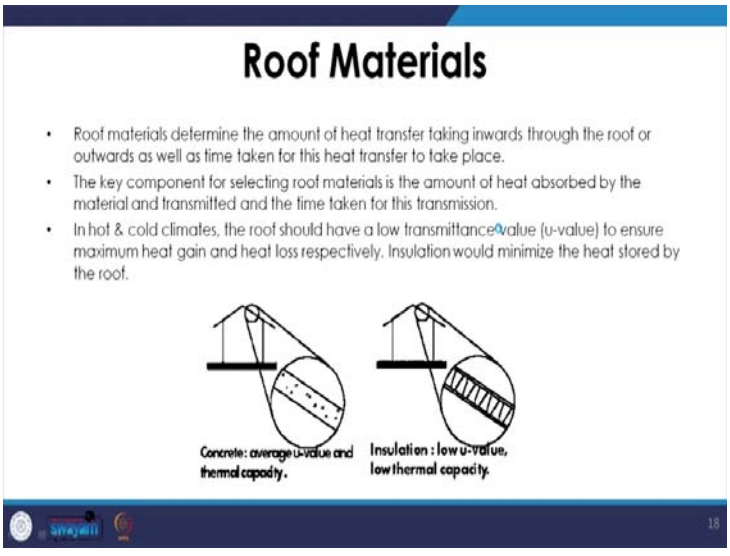
In one humid climates because it is anyways very humid we would want very light materials. We do not want these materials to store heat, but we want these materials to allow the ventilation of air and this is the basis which we use to select wall materials. The quantity the terminology that we use here for understanding the property is U value. It is the amount of heat which is transferred from one surface to the other surface at a unit degree temperature change from a unit area of the wall or surface.

Higher is the u value higher is the rate of heat transfer. Lower is the u value lower is the amount of heat which is transmitted from one side to the other side. So, in hot dry and cold climates we would want walling materials with a very low u value. Now any insulation material for that matter has a low u value. So, in hot and cold climates we want to use insulating materials. That is why you would have seen that in extremely cold countries we have walls which have insulation material packed between the walls.

Now, this retards this reduces the heat flow from one side to the other because the diurnal variation and the variation between indoors and outdoors is extremely high. I am talking about the temperature say outdoors is minus 25 degree centigrade and indoors for comfort you want to maintain around 20 degree centigrade.

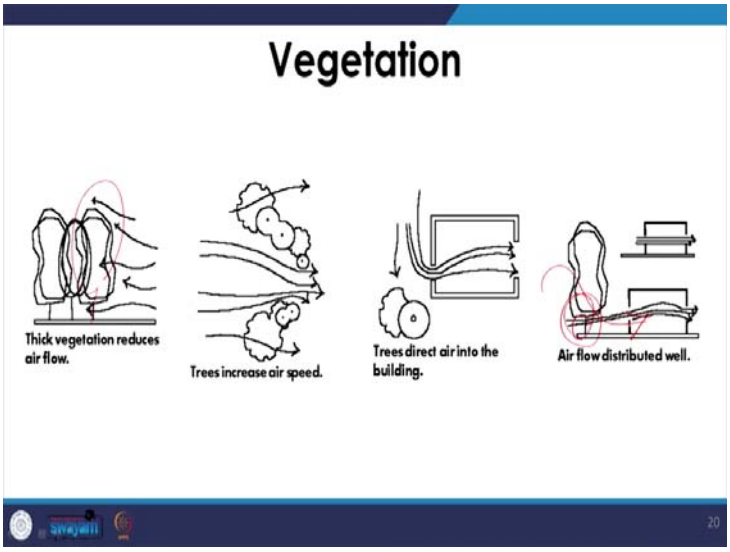
So, we are looking at a temperature difference of around forty degree centigrade from outdoor to indoor. Now if I provide an insulation material in the wall also roof there I will able to cut down on the transfer of heat from indoor to outdoor in this case.

(Refer Slide Time: 22:44)



The same concept holds good for the roof exactly the same where we want thick materials with heavy insulation capacity, low u value for hot and cold climates.

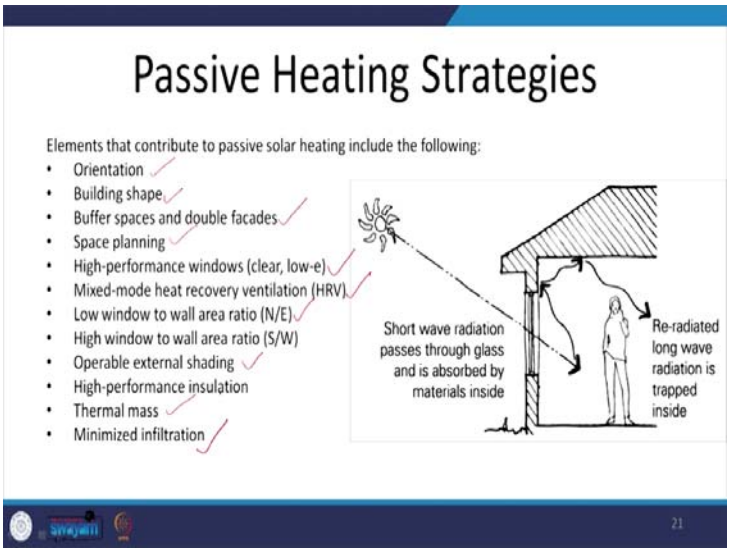
(Refer Slide Time: 23:00)



Another design feature which we have already discussed, but here we are discussing it with respect to the air movement is vegetation. Now the vegetation diverts the wind, the air into the building or away from the building depending upon how we plant it. If we are planting huge trees or if we are planting small shrubberies, we will depend upon will guide how the air is diverted or diverted into the building or away from the building to summarize what we have discussed so far.

We can put these strategies for passive heating, passive cooling, passive ventilation and day lighting into groups in these groups.

(Refer Slide Time: 23:49)

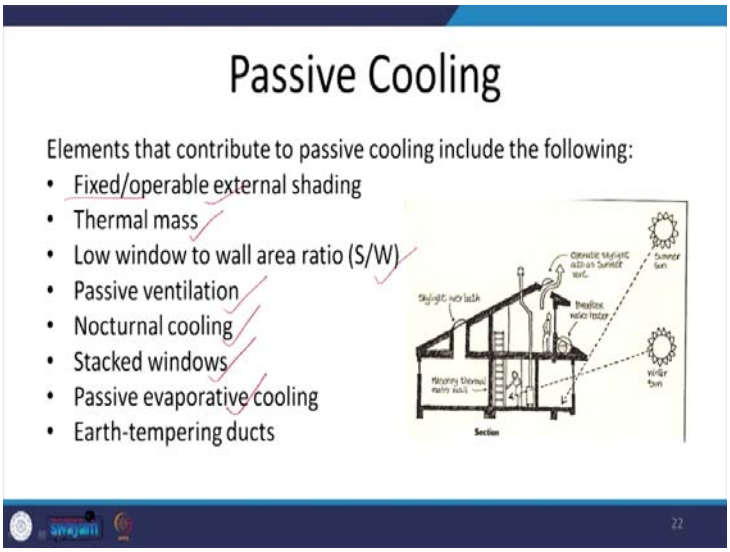


So, if we are looking at the passive heating strategies, we would look at orienting the building in such a manner so as to increase the heat gain. The building shape the plan form such that it has a higher it has a lower perimeter to area ratio. We have to create buffer spaces and double facades such as the greenhouse where the buffer spaces are the ones which interact with the outdoors and store the amount of heat which is received during the day and gradually passes it on to the indoors.

The spatial planning here in current times the material of the fenestration such as high-performance glass, the low e glass is also preferred. If we are talking about the active side of it, we may talk about the heat recovery ventilation were before it is ventilated out the air is ventilated out the heat is recovered from the exhausting air. Low window to wall area ratio where we are talking about the small size of the openings and high surface to volume ratio.

We are talking about the operable external shading as a passive heating strategy because in winters we would want more sun solar radiation to come inside the building, but not during the summer season. High thermal mass and we have to minimize infiltration specially during the cold season cold period.

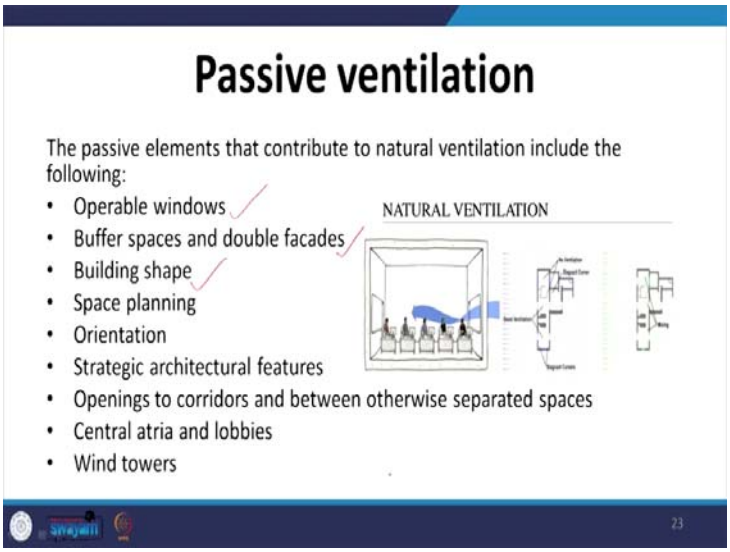
(Refer Slide Time: 25:23)



If you look at the passive cooling strategies we may again go for operable external shading, but in a hot climate fixed external shading would also work fine because for most part of the year the climate of the place is warm it is hot. The thermal mass similar to cold climates low window to wall ratio, passive ventilation an induced ventilation in case of hot dry climate is highly preferred. Nighttime cooling which I was mentioning as a night flushing or night purging, stacked windows window above one another evaporative cooling in case there is availability of water.

So, in case of traditional architecture of the middle east we would find wind towers and badgers which are fitted with what a sprinkling equipment such that when the air comes in through those wind towers it is cooled evaporatively and it is also humidified before it enters the indoors. And in earth tempering ducts we are talking about the earth air tunnels which take the advantage of the ground temperature remaining at a constant.

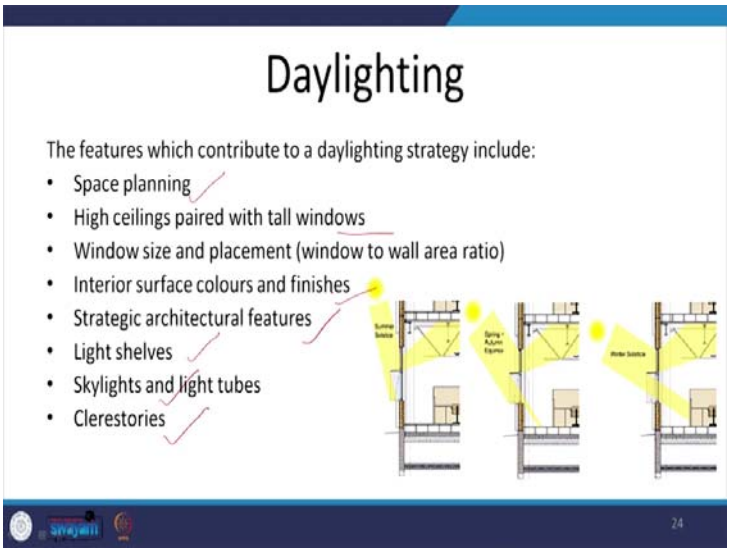
(Refer Slide Time: 26:46)



Then we are talking about the passive ventilation strategies. Here we are talking about the operable windows which is becoming more and more scarce rare in case of air conditioned and commercial buildings we do not have operable windows while we must have operable windows in order to facilitate passive as ventilation. Again, buffer spaces and façades the shape of the building in order to divert wind inside the building, vegetation, spatial planning and orientation all in order to divert wind into the building forced ventilation

Then strategic architectural features such as vegetation, opening to corridors central atrium which is one of it is kind is courtyard which is open to sky and wind towers wind towers are often a very interesting means of inducing passive ventilation.

(Refer Slide Time: 27:46)



For day lighting we have to look at how the space is planned. We have to look at high ceilings when they are paired with tall windows. In such case looking at light shelves skylights and light tube skylights are often very good means of bringing in daylight to deeper areas.

Clear stories in factories and a lot of industrial buildings we find a lot of clear storeys being used. And here when we are talking about day lighting, we look at the interior surface colors and finishes and some of the strategic architectural features such as planting deciduous ventilation or vegetation. I will stop here for this lecture and in the next lecture we would talk about the software which is called climate consultant.

So, when you look at the next lecture where I work upon climate consultant you should have the climate consultant software. It is a free to download and use software available online you can download it install it on your systems when you look at the lecture when you listen to my lecture so that you can work hands on the climate consultant software.

Thank you see you in the next lecture.