Sustainable Architecture

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Lecture – 37
Energy Efficiency – II

Good morning. Welcome to this second lecture, where we are discussing about Energy Efficiency in sustainable buildings as part of this ongoing online course on Sustainable Architecture. In the first lecture of this week, we discussed about the various terminologies and definitions related to energy efficiency in buildings.

Now, in today's lecture we will be talking about what are the specific requirements of energy efficient buildings, in terms of the design, in terms of the materials, in terms of the equipment, the practices. So, how fundamentally we can achieve energy efficient buildings? In subsequent lectures, we will look at the compliance criteria for these energy efficiency credits. And we will also see how to attain those credits by performing certain calculations.

So, to start with the first terminology at a building level is energy performance index. Now, energy performance index is a metric to understand the annual energy consumption of a building per unit area. So, it is the energy consumed per unit area per annum in a building and it is an indicator of how much energy is being consumed by the building; lower the EPI of the building more efficient is the building.

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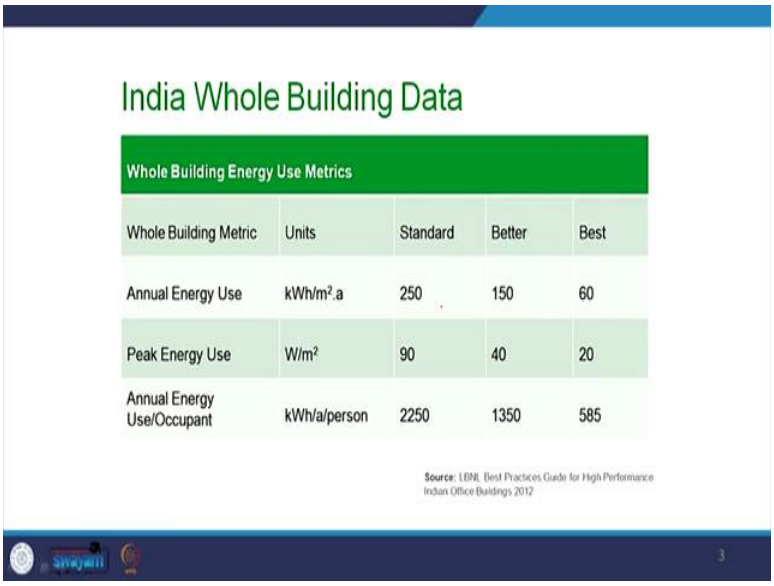

So, we have to try making a building which has a low EPI; if we look at the current data for energy consumption in buildings, which was published by LBNL in 2012. So, as per this data the standard annual energy use the EPI that is the conventional energy use for Indian buildings is around 250 kilo Watt hour per meter square per annum and the best is around 60.

Now, this we are talking about buildings which are using air conditioning. On an average a lot of buildings in India do not use air conditioning and they have the energy consumption annual energy consumption EPI of around 100; this is what the usual number is. And there are buildings just by virtue of not using air conditioning and depending upon a natural ventilation and natural day lighting.

The energy use is reasonably low in our building. But, as we see that the commercial buildings are growing in number and most of these commercial buildings are being centrally air conditioned there are more and more of spaces are being air conditioned. The energy consumption of our buildings in India not just commercial buildings, but also residences the energy consumption is tremendously increasing.

If we have to reduce the energy performance index, if we have to increase the energy performance index which is reduce the number of the energy consumed. We have to change the way in which the buildings are designed, the way equipment is selected and used and the way buildings are operated.

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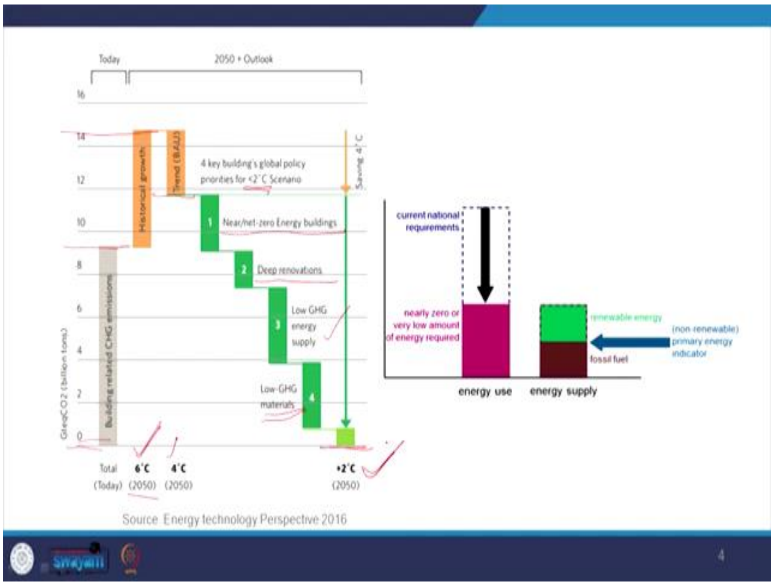

So, this is another report by energy technology perspective which was published in 2016 and this is a global scenario this is not for India. So, currently this is in billion tons of giga ton equivalent of CO 2 released. And if we see the total is somewhere here which is related which is the building related chg emissions. And if it continues to grow like this, it is going to reach somewhere here by 2050 which will cause a global temperature rise of around 6 degree centigrade.

In order to reduce that and limit it at 4 degree centigrade of rise, we have to implement the current global buildings priority for a 2 degree reduce which was still be 4 degree centigrade higher scenario. In order to further reduce it and bring it down to a level which is here, we have to make all the new buildings as near or net zero energy buildings

So, that the buildings produce all the energy that they will consume, in addition to that the existing building will require deep renovations. So, the existing building stock will also have to move closer to the net zero energy requirement. And the energy source on top of this will have to be supplied through low GHG sources such as, photovoltaic or hydro or other low on GHG energy sources.

In addition to that, the building materials will also have to be low GHG building materials. Once we do that we will be able to limit the 2050 scenario to a plus 2 degree rise which will still be higher than the industrial level temperature limits.

Now, this implies that a lot needs to be done in our buildings and buildings are going to be more and more critical if we are talking about the global scenario the global temperature rise. So, what do we do? When we look at these buildings the building design what kind of materials equipments, the first thing which is of utmost importance and concern to us is building envelope.

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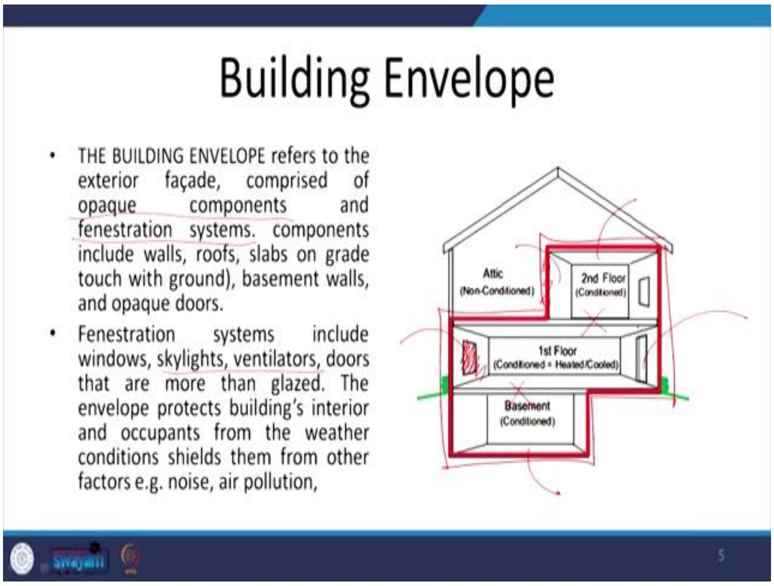

And when we are talking about building envelope, we are referring to the external facade of the building which comprises of the opaque components and the fenestration systems. So, when I say exterior facade we are talking about the building envelope which is coming in contact with the outside environment so, these portions.

Now, this can be opaque component like wall or it could also be the fenestration system. So, all of this together is the building envelope, the internal floors are not counted as part of the building envelope. When we talk about the opaque components we are talking about the walls, the roofs, the floors. When we talk about fenestration systems, we are talking about the windows, we are also talking about the skylights and ventilators; we are talking about the doors which are glazed and sometimes the doors which are also not glazed. So, all of this together is building envelope.

So, when we say that building envelope is the most important parameter for concern for consideration within building envelope, there are several factors which need to be considered which need to be taken care of when we are designing.

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Part of it we have already seen when we started talking about sustainable buildings we saw that the first thing that we need to do is climatic study. So, understanding the climate as to what the climate brings with it, how can we deal with it through the buildings. So, we have to know about the temperature ranges, humidity, solar radiation, wind speed and direction landform, vegetation, water bodies, open spaces. And all these things as part of the climate and microclimate study. We have dealt with this in detail as part of our site analysis.

Once we have this data with us the next is building orientation and form. Now, when we talk about building orientation and form we are talking about two impacts of it or two properties; one is the surface to volume ratio and also the exposed surface area. Now, surface to volume ratio implies that there will be more surface of the building, which will be available for this heat exchange. We have also seen the three different ways. So, we are looking at conduction, convection and radiation, but if the surface is higher it will be more prone to receive heat through either of the medium conduction, convection or radiation.

Now, if we have we reduce the surface area to volume ratio, we are immediately reducing the amount of surface available for this heat transfer. Even after reducing that we have to design the building because buildings on a site can mutually shade each other or a building itself can shade, through the grooves and niches that are created as part of the building design. So, we have to see how much of the surface area is exposed and this is also dependent upon the orientation of the building.

So, if we are in the northern hemisphere and we know very clearly that the north side of the building will never receive the direct sun, because of us being in the northern hemisphere and the sun path which is there. So, larger part of the building surface should ideally be exposed to the northern side in such a manner that the exposed surface area is reduced.

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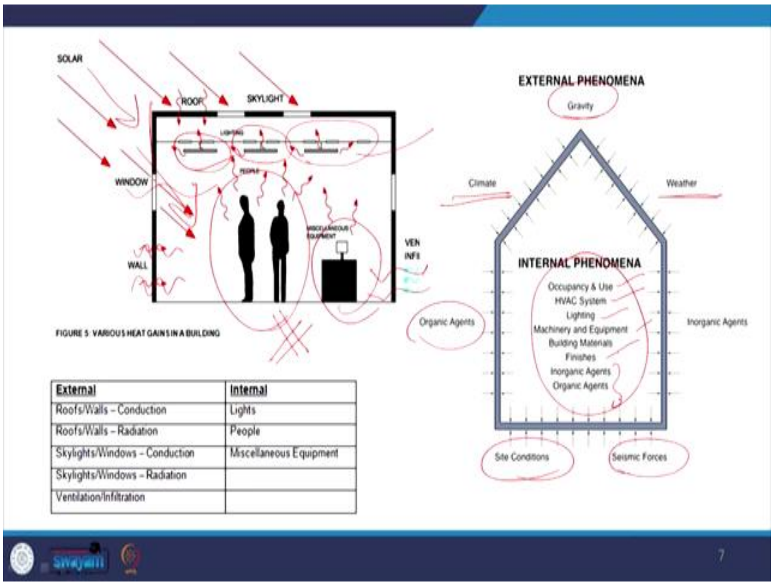

So, if we look at the heat gains in a building through the envelope indoors as well as outdoors. So, indoors the load from indoors is either because of the equipment or because of human beings. So, because of people because we also radiate heat. Now, this is a load which cannot be altered which cannot be compromised, this is the metabolic heat this remains as constant. The other load is through the equipment. So, miscellaneous equipment the lighting equipment there may also be the mechanical systems like fans which may be producing heat as they function.

Now, here we can choose efficient equipment, which produce less amount of heat for the given task for the given output. In addition to this we have a lot of heat gain from the outdoors, now this is through conduction, convection and radiation. So, there is direct solar radiation which is entering into the building and falling onto the surface. There is conduction heat gained through conduction and there is heat gained through convection because of the ventilation and infiltration.

So, all of this is contributing towards a lot of heat gain. And in addition to that if we look at a lot of these factors which will be considered while designing. Here we are concerned mainly about energy, but we have whether to take into account largely we are talking about weather here. And in internal phenomena we have the occupancy and use HVAC system lighting, machinery, equipment, building materials, finishes and the agents which are both organic and inorganic.

In addition to weather and climate which is a prime concern here we also have a lot of other concerns which will be present which cannot be ignored, but here when we are talking about energy let us largely look at these. So, the building has a lot of these internal as well as external loads which need to be balanced to make it an energy efficient building.

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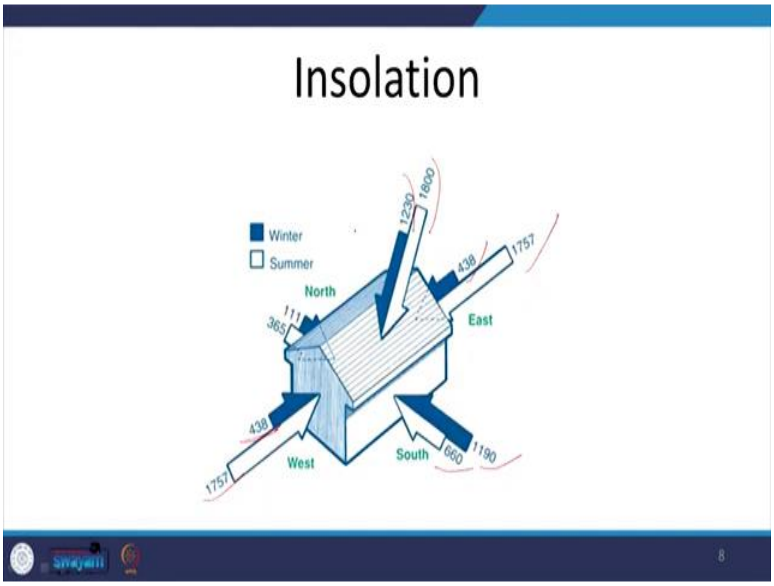

So, we have insolation. Now, insolation is the amount of solar radiation which is received on the building surface that is the insolation. So, when we are designing a buildings. So, first thing which we have seen is orientation of the building to improve the surface to volume ratio and also the exposed surface area; now that is done because all these surfaces are exposed to the solar radiation.

So, we have to reduce the amount of insulation received during summer, but we also have to see, what is the amount of solar radiation which is received during winters. Because the building specially in composite climates the building may require heating in winters. And if we look at the total energy budget sometimes the cost of heating and the energy required for heating the building may surpass the amount of energy required for cooling the building, if the building is not properly designed.

So, we have to see that how much is the amount of insolation which is received on each facade each surface during winters and during summers. An estimate of this will help us in designing the building the geometry of the building.

The next thing which we need to keep in mind is the possible orientation of the building planform. So, different planforms will require or will have different optimized orientations based upon their climate.

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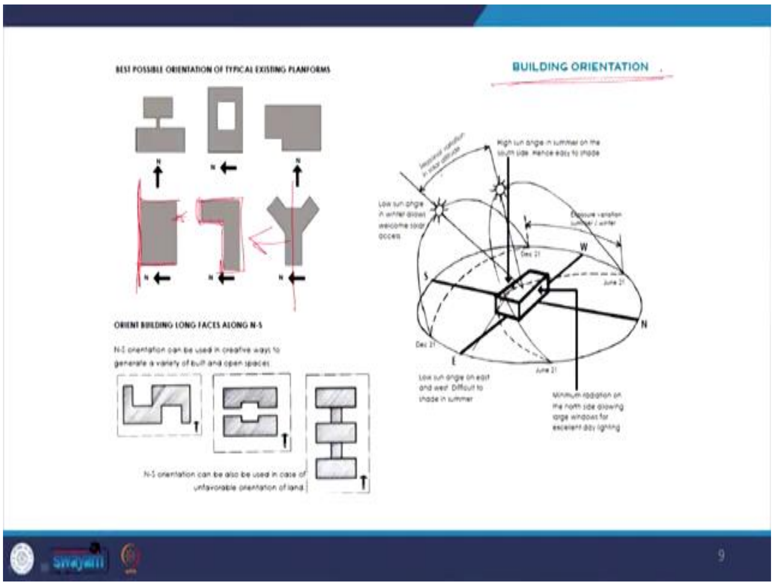

So, suppose we are talking about warm climates, where reducing the amount of heat gain received by the building is a preferred criteria. And if we look at the simple rectangular building the ideal orientation would be to orient your building such that the longer side of the building faces north and south and the shorter side of the building faces east and west.

Suppose we have an l shaped building, the ideal thing would be to expose the again the longer side but, with the projected end towards the north. If we are talking about the there are there is multiple set of building in majority of these cases the longer axis should actually be facing north when we are talking about the hot warm climates, while it will change, when we are talking about the extremely cold climates. In such climates we have to orient the building slightly tilted in order to receive maximum amount of insolation that too in winters. So, first thing is building orientation.

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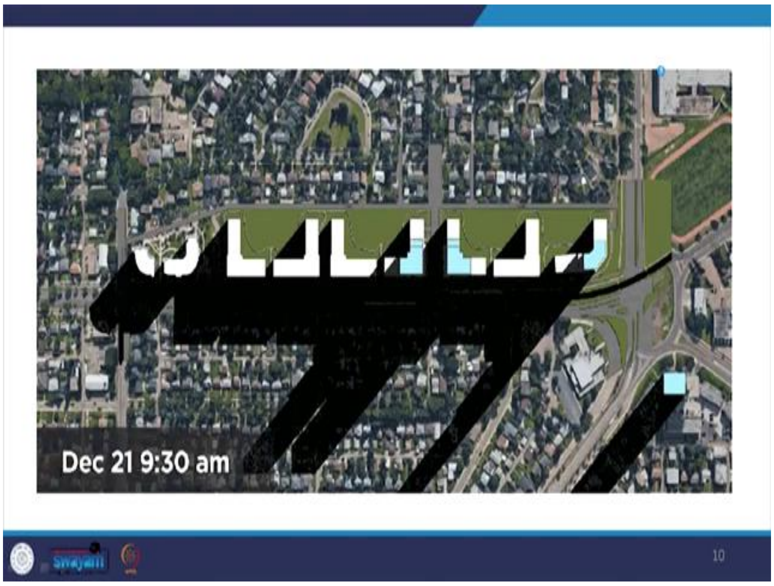

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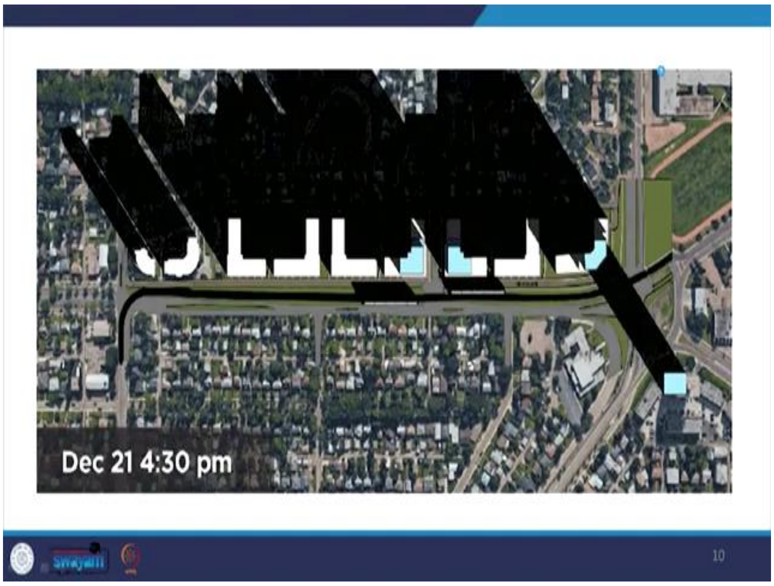

If we look at this particular simulation on the screen, we have to analyze through proper simulation tools what is the shadow pattern and at different times of the day and different times of the year. So, we have to analyze the impact what a particular planning arrangement would have, on the buildings on site the adjacent buildings and also on the buildings around the site.

So, alternatives of building design and placement have to be tried to improve upon the amount of insulation received optimize it. Now, I am not saying reducing it or increasing it that depends upon the specific climate for which the building is being designed. So, here we are not even getting into the specifics of building design, but it is just orienting, it is just placing it on the site together.

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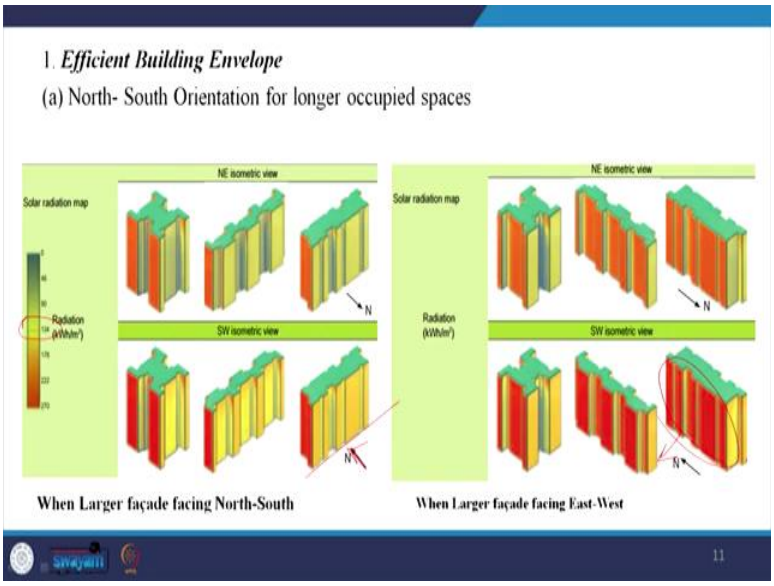

So, as we have already seen that the north south orientation for longer occupied spaces is a better orientation. These are the simulation images and if we see that the same building which is here has been oriented with its longer facade facing north. And we can see that the amount of radiation received on these surfaces is lower as compared to the same building if it is exposed to east and west. And there is a huge amount of sun to which this building is exposed, there is a larger amount of solar radiation which is received.

So, before we actually design the building in detail the first thing that needs to be corrected is the orientation of the building. And very good tools are available nowadays where we can check what is the amount of solar insolation, whether we want to increase it or reduce it, we select the optimum orientation.

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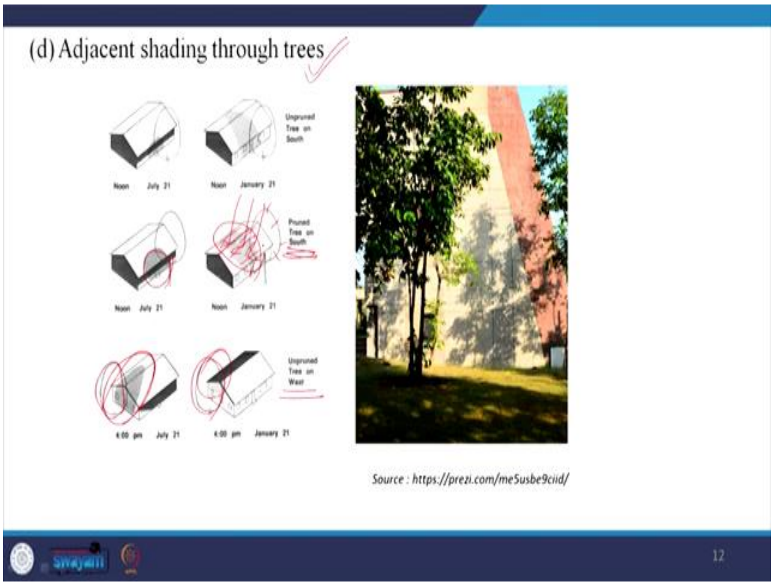

The next is we have to plan, we have to design the elements which may provide shading trees are one such element. So, we have to optimize and we have to design accordingly the placement of these trees. So, if we see what happens if we plant trees on the south? So, if we plant trees on the south, which are like evergreen trees we see that there is lesser amount of shade which is received in summers.

And there is more amount of shade which is received in winters which is something we do not want in a composite climate, which is what prevails during for the most geographical part of the country. However, if we see if there are trees which are planted on the west, in July there is a larger shadow which is cast on the building as compared to January when a smaller shadow is being cast on the building. So, with such kind of exercises we can also see, which is the optimum direction.

Now, this one was for an evergreen tree where we have assumed that the foliage remains the same. This could also be altered if we select deciduous trees, which will shed their leaves during winters. So, we may have plantation of trees in such a manner that they are able to shade the building in summers while when they shed their leaves in winters they allow for all the solar insolation to receive the building.

So, not just the planning of like the design of the landscape scheme, where the trees should be planted but also a discussion on what kind of trees should be planted adjacent to the buildings. So, that the desired impact on shading is achieved.

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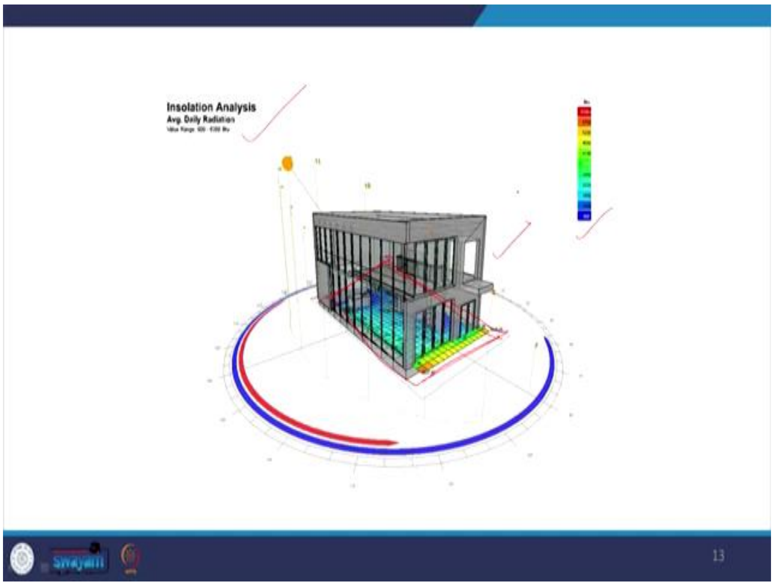

So, what we are essentially doing is, we are doing the insolation analysis through a lot of simulation tools this one is through ecotect where we load the weather data file. We know already how the sun is moving for a given place and then we calculate the amount of solar insolation which is received indoors.

So, you can see this grid here, we know the amount of solar insolation which is received by a particular building for a given place. With the help of this right in the initial stages of design we can orient it in a proper direction. So, that the daylight is maximized while the solar insolation is optimized to. After the building has been properly oriented, we talk about the building envelope composition, we talk about the materials. So, since more and more buildings are becoming air conditioned and we are less dependent upon natural ventilation, we are talking about building insolation as an important part of the building envelope.

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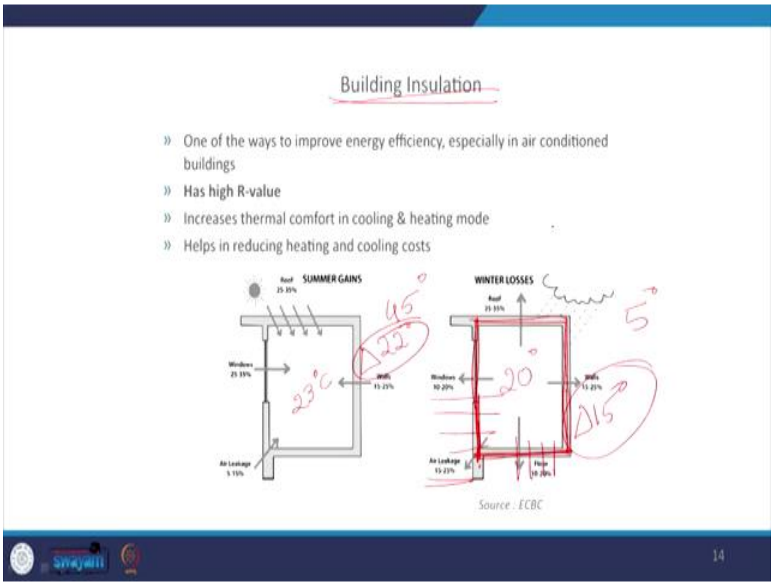

If it was a naturally ventilated building, there is not much difference between the indoor air temperature and the outdoor air temperature. There is some difference because of the absorption because of the heat retained absorbed by the building mass. But when it is an air conditioned building the indoor environment is absolutely different from the outdoor environment for most part of the earth. And there is a lot of difference between the indoor and the outdoor.

So, in extreme summers assume that there is around 23 degree centigrade which is to be maintained inside or say 24 while outside it is like 45 or 46 degree centigrade. So, it is a temperature difference or delta of around 22 degree centigrade which is a huge temperature difference. And the same thing might happen in winters, when indoors we are again maintaining an indoor temperature of around 20 degree centigrade while outside it is around 5 degree centigrade.

So, again a 15 degree delta is a huge temperature difference again. To reduce this, to reduce the amount of energy which is required to bridge this gap or to maintain the indoor conditions as such, we need to insolate the building. So, that there is less amount of heat gained through the building envelope. So, we are talking about the walls, the floors, the roofs and the windows all of them and also air leakage.

So, what we have to do is, we have to insolate it we have to break the heat traveling, we have to break the path which through which the heat travels from outdoor to indoor or indoor to outdoor. We have already seen what our values are what are the properties for insolations, but the aim for insolation is to select a material which has a high R value and place it in such a manner that it breaks any thermal bridge.

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So, there is no connection from outdoor to indoor because of this insulation which is pattern between. If we do that in case of summers, the heat will be absorbed by the outer layer and then it will be reradiated back when the outside temperature falls during night but, it will not be transmitted inside. The same will be during the winters when the heat will be absorbed and then reradiated back into the system and it will not be lost.

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So, the insolation is increasingly become important not just involves. But in fact, more important in roofs the inverted earthen pots has been a very common technique which we have used in our buildings since old ages, it is a traditional technique.

So, what actually happens is that, these inverted pots they trap a lot of air inside them and this air actually acts as an insolation material. So, just like what we just saw as a insulation material in the wall which was installed, this air cavity acts air is the best insulator for that matter. So, this air cavity which has been created it acts as an insulation material.

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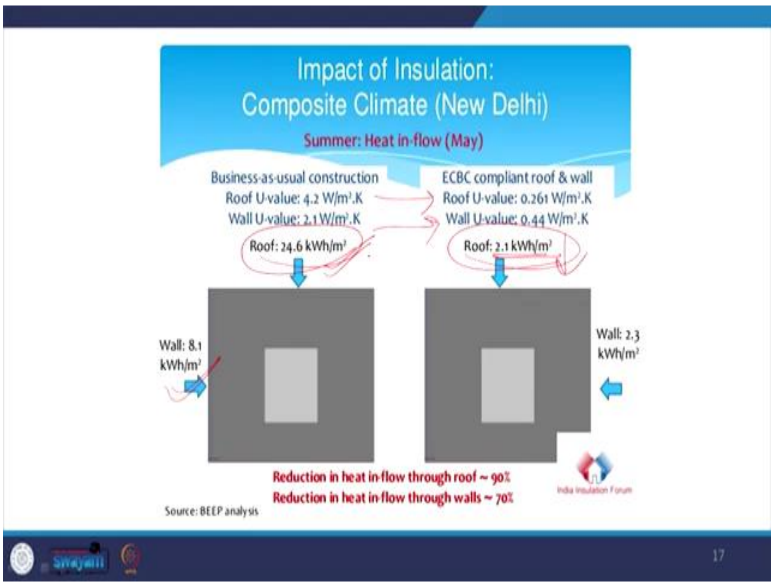

So, if you look at the impact of insulation, without the insulation being installed used in a building, this is the amount of heat gain which was received through the roof and through the wall. And if an insulation was added so, we reduce the roof U value from 4.2 to 0.261 and the wall new value from 2.1 to 0.44.

The amount of heat received through the roof has substantially gone down, it is tremendously low from 24.6 kilo Watt hour per meter square it has been reduced to 2.1 kilo Watt hour per meter square. Now, this implies that this much less amount of cooling will be required for this building.

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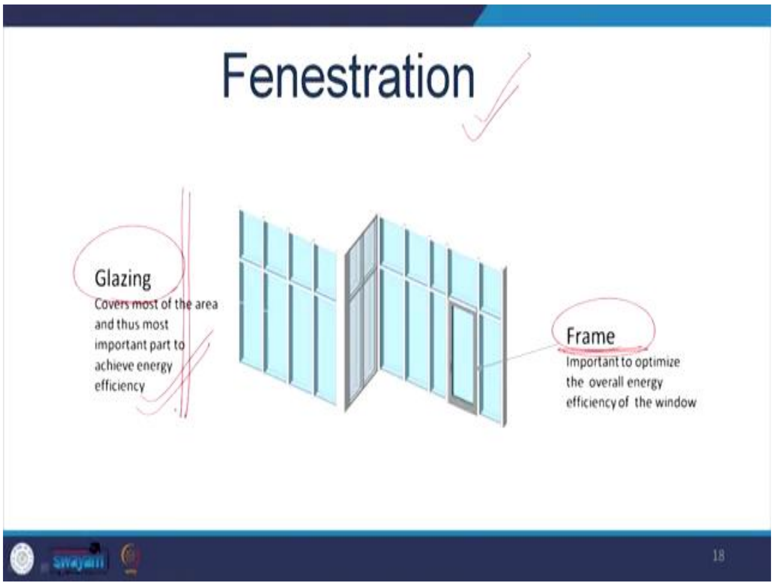

The next important parameter or the component of the envelope is fenestration. Now, in fenestration we are talking about two components; one is glazing and the other one is frame. Largely the fenestration is comprised of glazing as far as the area is concerned but frame, is also important because sometimes even after using high efficiency glass; if the frame is leaky or if the frame is allowing for a lot of heat transfer then the performance of the high efficiency glass will also be reduced.

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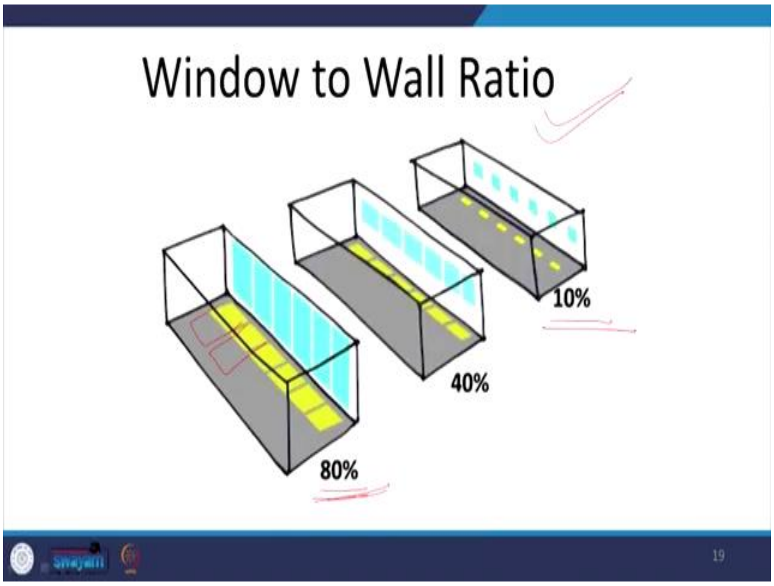

So, when we are talking about fenestration, we are talking about two to three things. One which is the most important from a design point of view is window to wall ratio. Window to wall ratio is the percentage of the wall area which is occupied by windows, higher is the window to wall ratio, higher is the amount of light which penetrates inside and also the amount of heat which comes in it is directly proportional in whichever climate it is.

So, there is more heat transfer which takes place through the windows. Higher WWR implies there is an increased rate of heat transfer and also increased amount of daylight which is available as we go on reducing the WWR both of these reduce.

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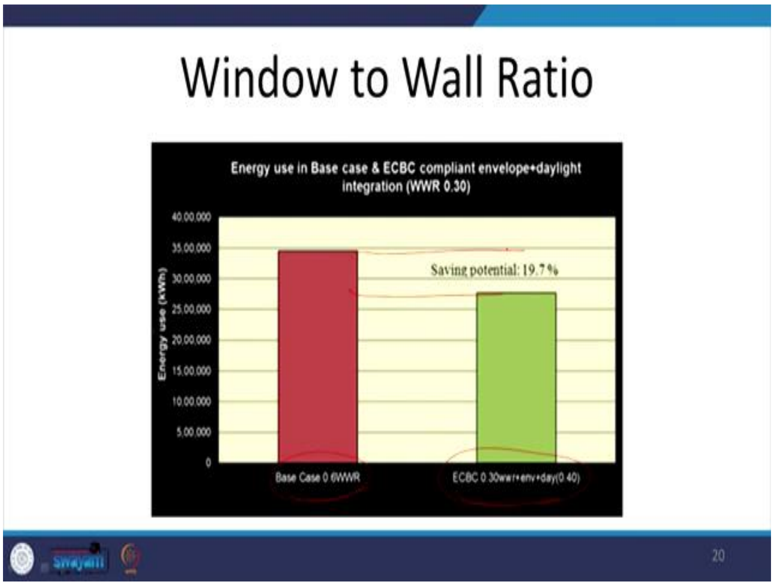

So, this is in one of the cases, where in the base case if a WWR of 60 percent was used versus if without doing anything just the WWR was reduced to 30 percent there was a direct saving of around 20 percent which was achieved. So, that high is the impact of window to wall ratio without doing anything without selecting the material. So, the first and foremost is designing it correct for designing it with optimum amount of windows. Once we have selected the optimum amount of WWR, then we go on to select the right type of glazing.

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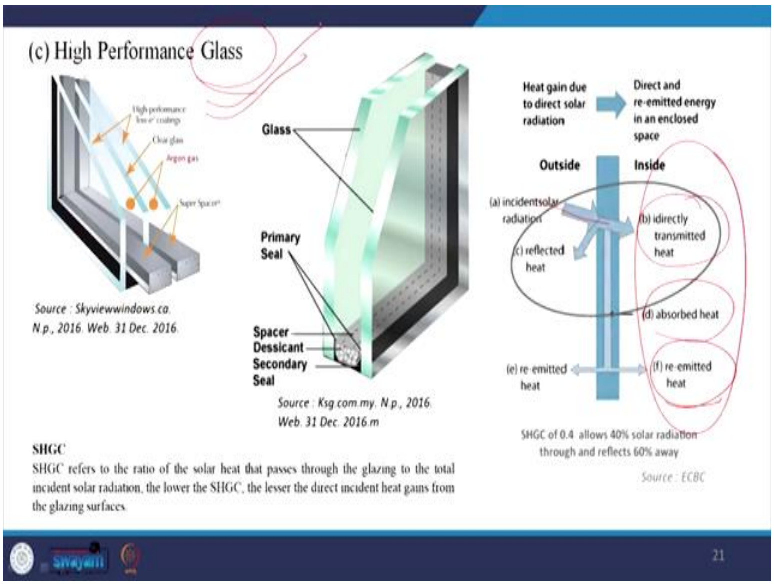

Now, we are talking about selecting the glass as the first parameter. And we have already discussed how the glass transmits heat inside, it may be directly transmitted, it may be absorbed and then reemitted heat. So, the total amount of heat which is transmitted to through the glass has to be seen. We have already reduced the WWR and then we select the right type of glass which in warm climates or in cold climates, reduces this heat transfer through the glass.

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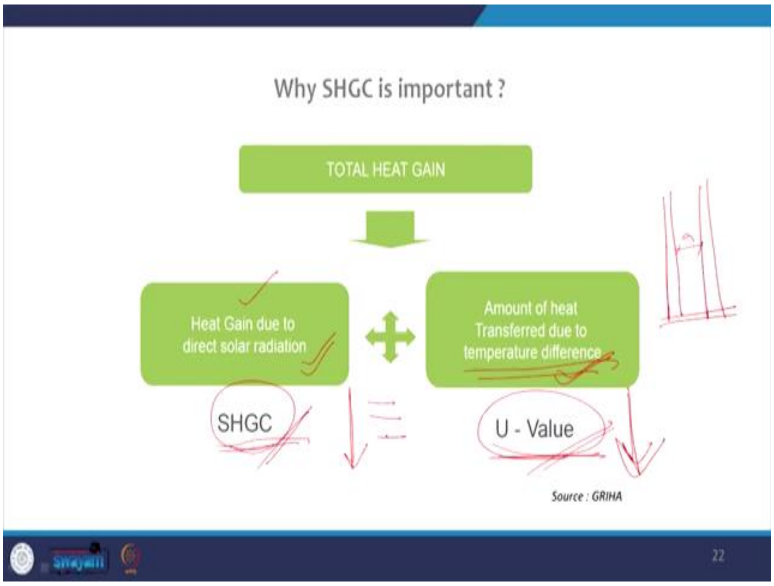

Now, when we are talking about selecting the high efficiency glass there are two values of utmost important when we are talking about the heat gain. We are talking about SHGC and we are talking about U value. Now, U value impacts the amount of heat which is transferred due to the temperature difference which is what we have also seen in the previous lecture.

While SHGC is the property of glass, which impacts the heat gain due to direct solar radiation lesser is the SHGC, lesser is the heat gain due to direct solar radiation, lesser is the U value, lesser is the amount of heat transfer due to temperature difference.

Now, often if you look at the specifications of the glass, reducing the U value automatically reduces the SHGC; this is often. If we have a doubly glazed unit for example a glass unit which has two layers of clear glass, with an air cavity in between in such a case the U value is reduced, but the SHGC is not reduced as much. Now out of these two, which one is more important?

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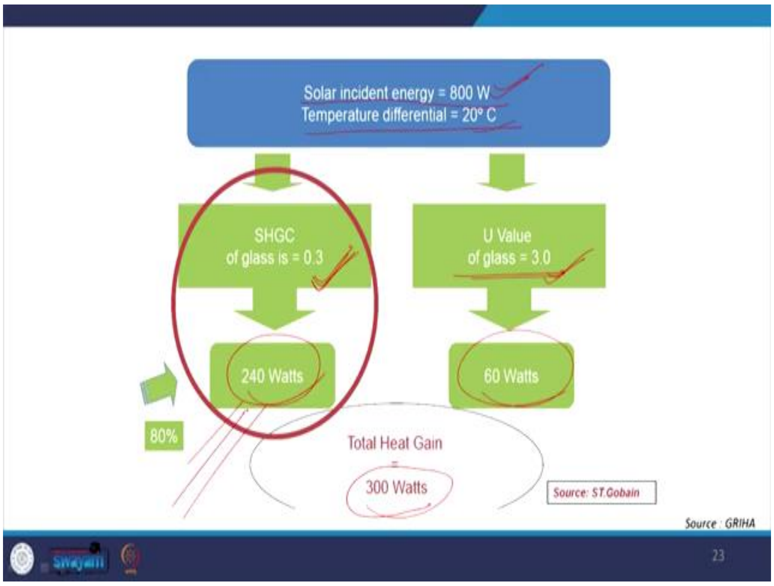

So, if we look at this particular example, if an if the SHGC of a glass is 0.3; which implies that 30 percent of the total direct solar heat which is incident on the glass is transferred inside. While U value of the glasses 3.0 and if we assume that this total incident solar energy is 800 Watts and the temperature differential is 20 degree centigrade which is in an extreme summer season.

Because of SHGC out of 800, 240 Watts will be transmitted inside or transferred inside out of the incident solar energy. While by virtue of the U value of this glass it will be transmitting around 60 Watts of energy inside because of the temperature difference. So, the total is around 300 Watts of which 80 percent is contributed because of SHGC.

So, we know what is the importance of SHGC while selecting the glass, which is more important. Now, the reduction in SHGC as the property of the glass happens because of certain coatings layers on the glass. They may be reflective coatings they are often, able to reflect the amount of heat which is incident and these coatings they come with specific type of glasses which are also the high efficiency glasses, but the costly ones. The saving grace is that if we reduce the amount of radiation falling onto the glass, there is direct reduction in the amount of heat which is transmitted.

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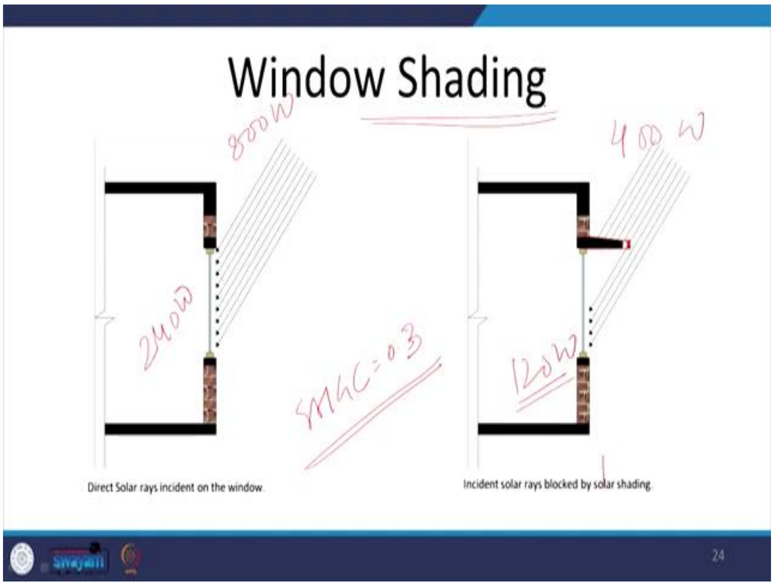

So, earlier in the previous slide, if we saw that there was an 800 Watts of solar radiation which is incident of which 240 Watts is transmitted with an SHGC of 0.3. If I do not change the glass property here, if I just introduce a shade almost 50 percent of this solar incident radiation is cut off with the help of this shading. So, it is only 400 Watts of which around 120 Watts will be transmitted inside, if we do not even change the property of the glass. So, here we see that when we are talking about the window design the fenestration design, window shading is an important parameter.

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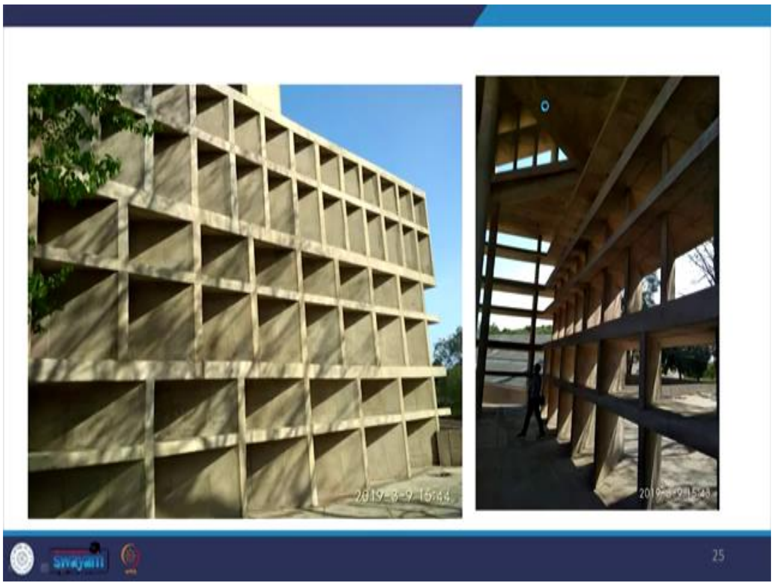

So, window shading should be provided, but it should be optimally designed.

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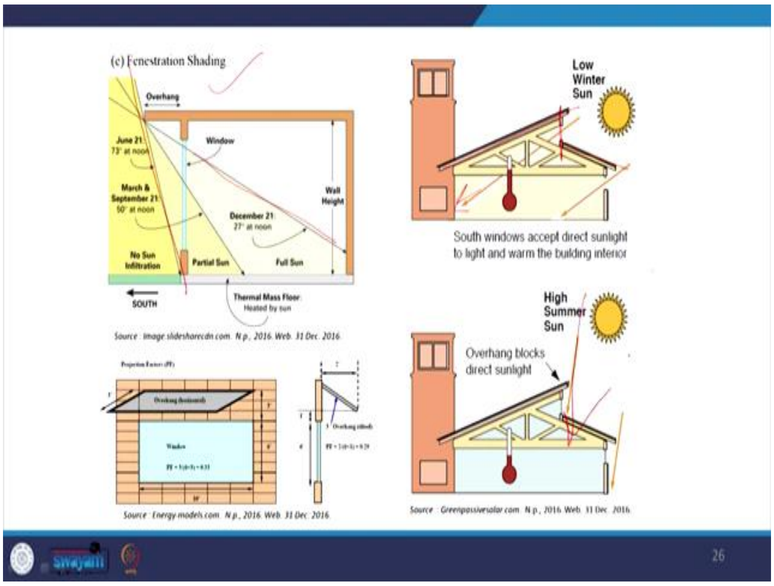

Because the moment we provide for window shading, we are also cutting down on the amount of direct daylight which is penetrated inside. So, if you reduce the amount of daylight, we are increasing the amount of artificial light which is required in the building.

So, we design the fenestration shading appropriately we orient the fenestration in such a manner that it allows for the winter sun to penetrate in while it blocks the summer sun. If we are planning for some skylights, we should plan them in the similar manner where the low winter sun is penetrated while the high summer sun is cut off. So, the fenestration shading should be optimally designed.

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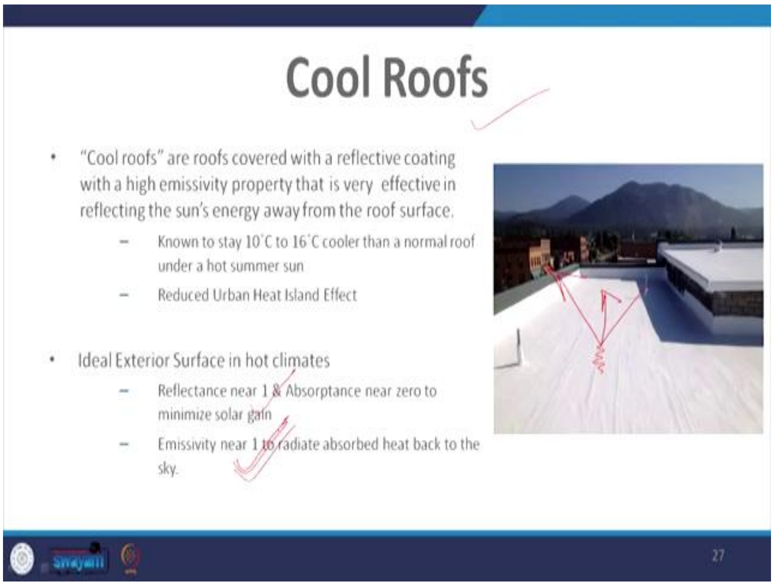

Next very important strategy is cool roof we have already discussed about cool roof. Now, cool roof is a roof which has a high SRI value which implies that its reflectance is also very high and its emissivity is also very high. So, when it has a high reflectance it reflects almost all the heat that is incident on it, whatever little is absorbed it is all reradiated back because it has a high emissivity.

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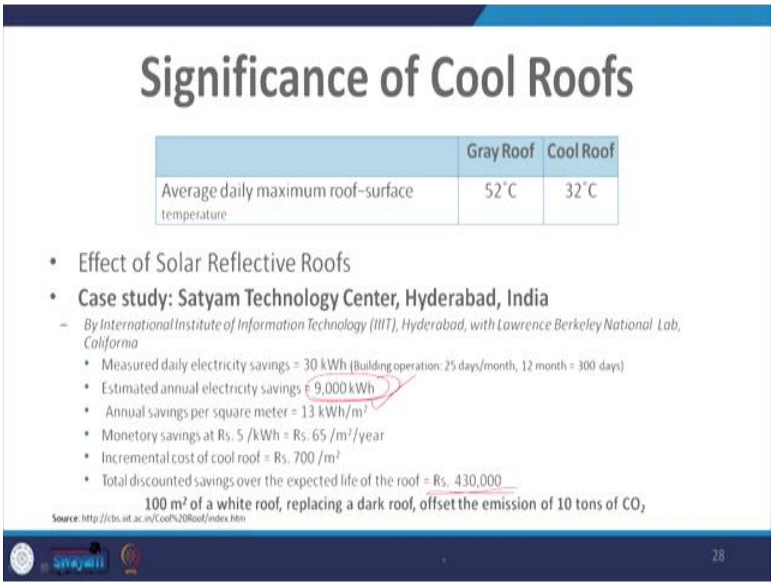

So, cool roofs are also very impactful when it comes to reducing the heat gained through the roof and this was a study which was conducted by triple IT, Hyderabad in association with Lawrence Berkeley national laboratory. And they found out that it is quite cost effective when we look at the advantages.

So, the overall estimated annual electricity savings by painting the roof with a cool roof material was of this order. And the total savings over the expected life of the cool roof which was much higher than the investment which has gone in towards the installation of the cool roof.

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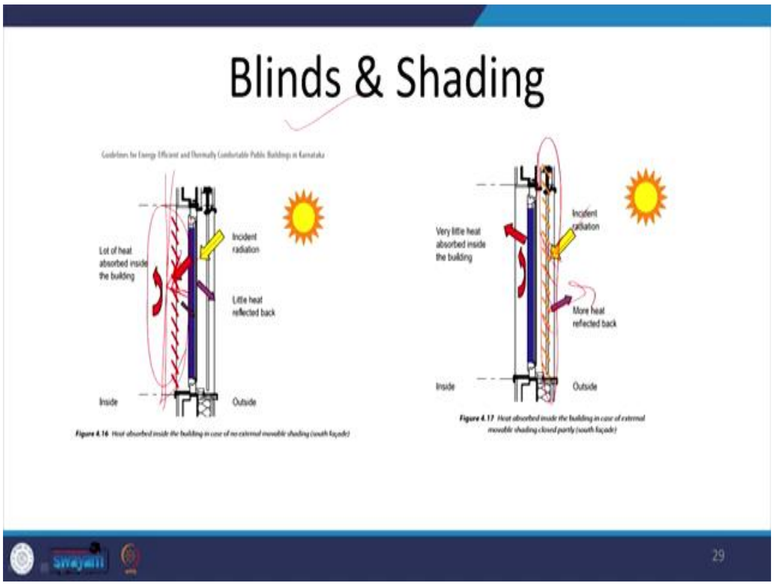

The next is blinds. So, blinds cut off the amount of direct solar radiation which is penetrated which is passed from the fenestration to the indoors, but the location of the blind where should the blind be installed that plays a critical crucial role. If we install the blinds in sides which is what the common practice is. The heat has anyways penetrated inside and most of the heat which has penetrated inside will remain inside despite the blinds.

So, we may have a feeling that there is less amount of heat which is coming in if blinds are installed inside. Actually most of the heat has anyways come in while if we install it outside most of the heat which is incident is blocked by the blinds and it is reflected back and very little amount of heat is transmitted inside.

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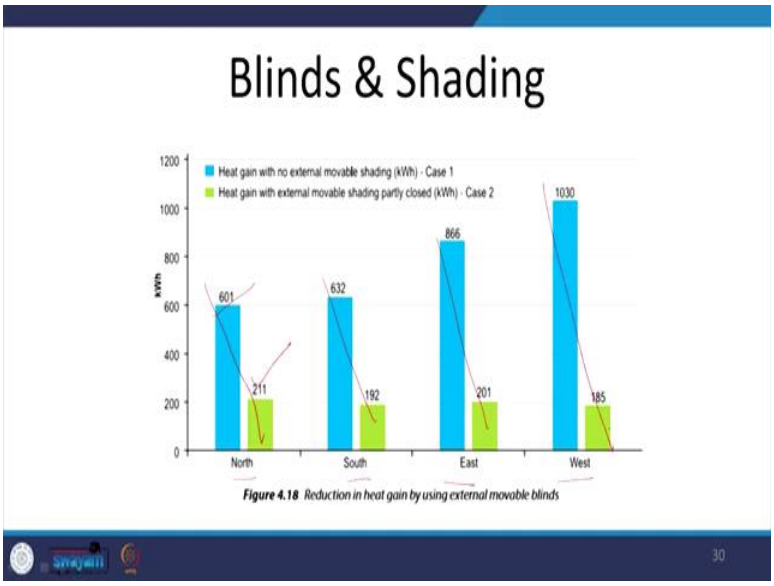

So, this is a quick comparison for each of the facade side if the blinds are installed outside, when it there is a moveable shading which is externally installed. And in this case when it is not installed there is a significant reduction in the amount of heat gained on all the sides specially the west. So, the blinds are very interesting and impactful components, which can be incorporated as part of the fenestration.

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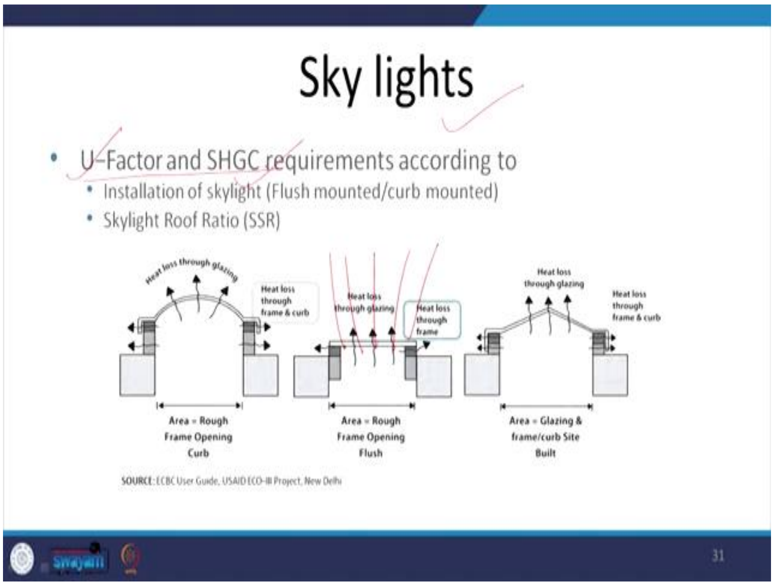

The next is skylights. The skylights they permit a lot of natural light or the daylight, but at the same time they also allow for a lot of heat to come inside the building. Again we have to look at the U value and SHGC requirement for these skylights specially because they receive direct sun and their part of the roof. So, a lot of sun is received and hence low U value and low SHGC should be preferred for the skylights.

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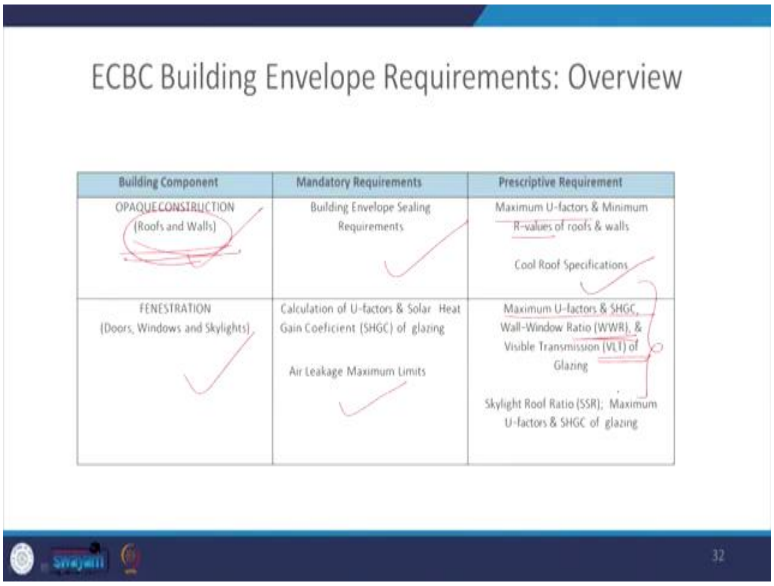

So, if we look at the overall ECBC envelope requirement we see there are two types of requirements for the building envelope. Here one part is the opaque construction which includes roofs and walls and when we are to are talking about roofs and walls. We are talking about the mandatory sealing requirements and we are talking about the U values and R values and also the cool roof specifications.

When we are talking about fenestration, we are talking about as a mandatory requirement reducing the air leakage. And as a prescriptive requirement we talk about U values and SHGC. We talk about WWR limiting the window wall ratio and we also talked about the VLT the Visible Light Transmittance; because it is a compromise. So, we have both these heat gain and the light going simultaneously.

So, we have to look at all these properties of the fenestration. I will stop here for today's lecture. And we will discuss more about the building envelope requirements and how to design these buildings and the compliance criteria in the subsequent lectures in this week.

Thank you for being with us, see you again.