Principles and Applications of Building Science
Dr. E Rajasekar
Department of Civil Engineering
Indian Institute of Technology, Roorkee

Lecture – 10
Glazing and Shading Systems

In this module, we will look at glazing and shading system. So far, we have talked about the opaque component opaque wall system; here we will look more closely in to the glazing and shading system.

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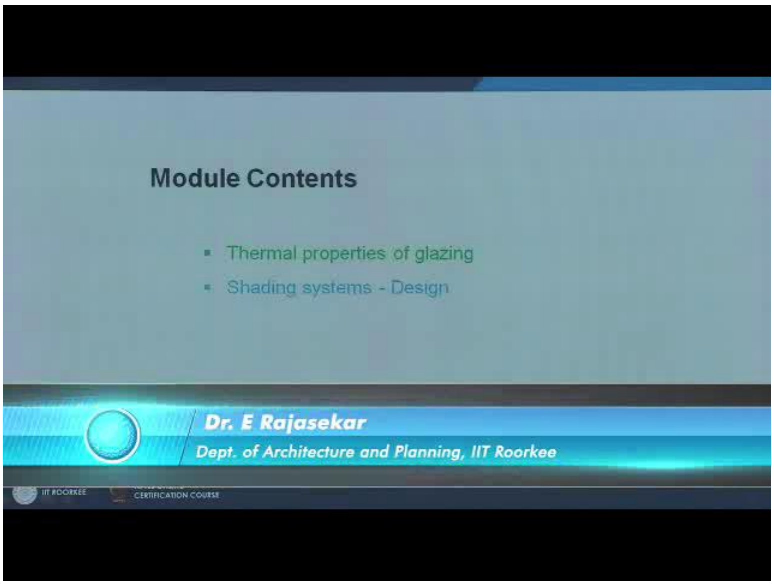

So, we will talk about thermal properties of glazing which is important then the next thing we will talk about is shading system, designing shading system primarily. So, what determines the thermal efficiency of glazing system? This first thing of course is thermal transmittance of glass same as we talk about wall thermal you know transmittance U value of wall but most commonly referred thing is thermal transmittance of glass.

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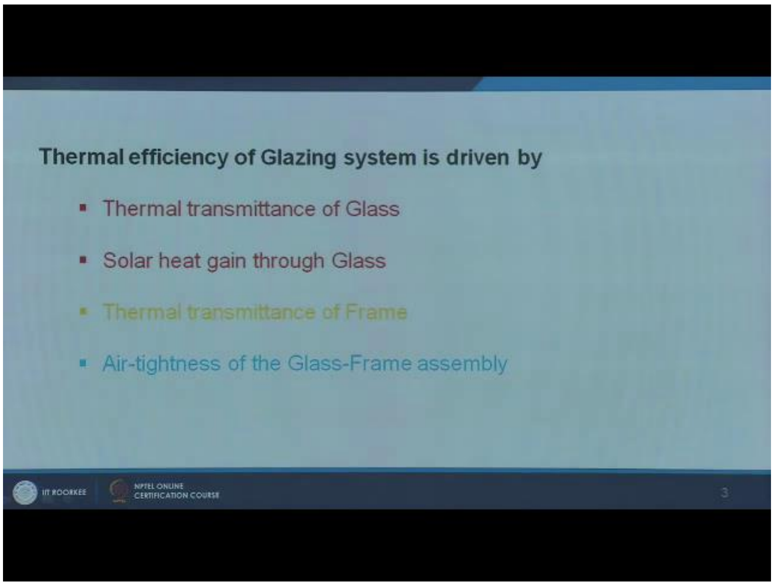

The next important factor is solar heat gain through glass. This is a important factor which ranges from 0 to 1, we will look at this factor more closely; this tells you how much amount of you know radiant heat gets in to the particular system apart from the conductive heat transfer.

Next thing is thermal transmittance of the frame which is you know nothing less than and more or less important than the glass itself; it is also crucial. And the last thing is the air tightness of the glass frame assembly how well your glazing system is sealed. If you have lot of infiltration as we discuss in the previous module we will have heat gains and losses you know hot air coming in as when you heat your building, the hot air will go out there will be you know heat gains and losses which is not intended. So, in that case your cooling load or heating load will considerably go up. So, four parameters are there apart from other things four are very crucial. First is the U value or thermal transmittance of the glass, second is the solar heat gain through the glass, third is thermal transmittance of the frame, and the last is air tightness of the glass frame assembly.

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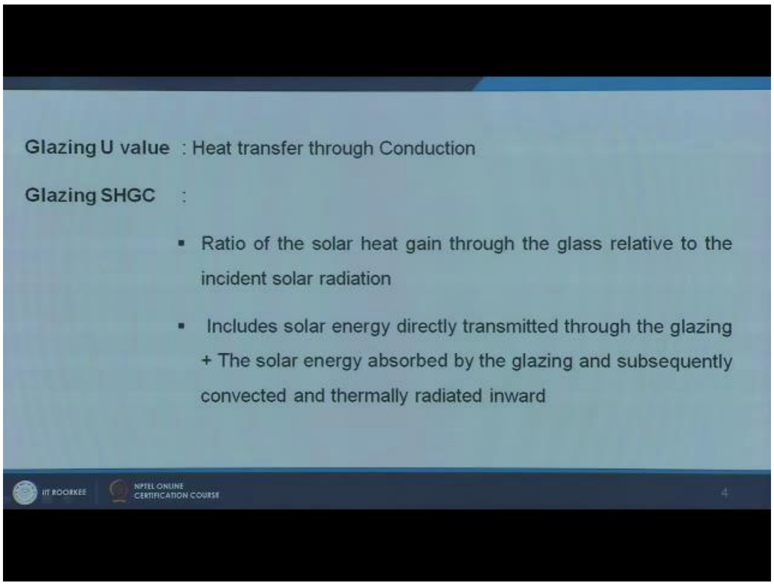

First, the glazing U value which we commonly know the first property usually we refer to; it is a heat transfer through conduction as we saw same as your opaque wall system as well. It tells you how much amount of conductive heat flow happens through the glazing system.

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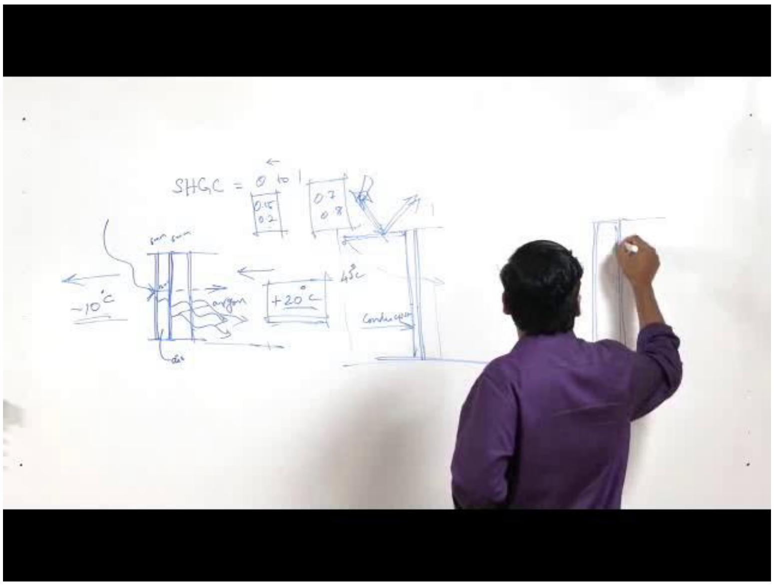

Say, you know imagine you have a single glass system you have a 6 mm glass single glass system versus you have an air gap and you have a double glass system you have a DGU or double glass unit. So, 6 mm, this is 12 mm, another 6 mm. So, as you increase the number of layers or a triple glass system another layer then you will keep you know the U value starts coming down. It essentially tells you how much conductive heat flow happens, so this matters then the next conductive you know property of this air gap are if it is inert gas fill like argon filled then this brings down your U value further the next layer, next layer, next layer apart from in the film coefficient outside and inside. So, the more number of layers are the thickness of glass itself varies are the type of infield whether it is air or a inert gas like argon filled then your U value considerably reduces.

An air you know air filled versus argon versus a vacuum insulated system, the U value considerably comes down. Apart from this, another important factor is the solar heat gain coefficient that is SHGC commonly referred as SHGC. Some of the older codes are text standard referred it as SC or shading coefficient we will look at the relation. It simply gives you the ratio of solar heat gain through the glass relative to the incident solar radiations. So, what happens when the solar incidence happens on the glass, it is a proportion of the solar energy directly transmitted as well as observed and reemitted. So, moment you have the long wave of solar radiation you know shortwave sorry the shortwave of radiation heating your glass then it absorbs first partly it is transmitted then some of it is observed and then retransmitted each layer retransmits it. Effectively, it is given using a number called SHGC or solar heat gain coefficient; it ranges from 0 to 1 the lesser or more closer to 0. It tells you the efficiency of the glazing system.

So, today we talk about you know highly efficient low e low (Refer Time: 05:04) glazing system, we will talk about them. But they will have SHGC more close to say something like 0.15 or 0.25; this will be efficient system versus you will have something like 0.7 or 0.8 for single clear glazing system, which means more amount of radiant heat is getting transmitted into the space compare to this particular glazing system.

So, how does it matter, imagine you are designing a building in a colder climate, the place like Srinagar where the ambient is getting really close inside your heating the building. The primary mode of heat transfer which is of importance is the heat you know conductive because you are heating the building you do not want the heat to be lost outside; ambient is really cold or imagine the outside is frozen; it is at minus 10 degree. So, you are heating your building say inside is you know plus 20 degrees, ambient is at minus 10 degrees. So, the gradient is inside to outside in this case, you are heating it the ambient it is snow, conductive heat loss takes the primary thing.

On the other hand during summers you really want more direct solar heat gain to come because the temperatures are not going to go very high except for certain extreme cases where you know both summers as well as winter are both harsh. Mostly you know the summer sun is always welcome. So, you want more glazing surface the radiant heat is welcome. So, in that case, you will want the U value as a primary indicator SHGC is also important because you do not want your building to get over heated as we looked at the green house effect where the glass is more transparent to shortwave solar radiation. But when the internal surfaces observe and start reemitting it, it is opaque to it. So, the heat gets trapped inside which is called green house effect which we do not want to happen. So, in that case we try and restrict the radiant property or the radiant transfer through the glass as well.

Imagine, you are designing in a hotter climate or a hot season where the indoor is set 24 degrees, you are conditioning it to 24 degree, and ambient is at 45 degrees. You have a glazing system; similarly, you have a double glass system. So, essentially what happens you have a lot of apart from conductive heat gain you also have a direct solar heat gain which considerably impacts the radiant gain and the cooling efficient in comfort indoor. So, when you design for hotter climate or hotter season's, in fact solar heat gain coefficient becomes a crucial factor. There is a lot of difference if you take a particular Indian location any location most of it is warm or hot locations except for the northern part, which is really cold.

Solar heat gain coefficient has higher impact as compare to U value most of the tests and you know the experiments we conducted we found the higher impact. Say for example, when I am reducing a solar heat gain coefficient from 0.8 to 0.2 there is a drastic reduction in the cooling energy as well as the com improvement in comfort is also much higher compare to reduction in U value. U value is also crucial, but solar heat gain coefficient takes the front seat, if you are designing for a hotter location. It is improved by two different you know things; first is if you are able to minimize or cut off the direct solar radiation. You have sun here; if you have a shading device which is cutting the solar incidence then you can actually improve the performance; actually you are not doing much to the glass here still the conductive heat flow will happen, whereas you are cutting off the direct solar incidence. So, your radiant transfer will be minimized this is the indirect way of controlling the solar heat gain through the window.

So, for this case, we do not look at SHGC or just the glass of the window alone, but we will look at something called the composite SHGC, where the glazing and shading together is accounted for. Other way of looking at is to go for selective or spectrally selective coating where we talked about low e glasses - low emission glasses. So, instead of providing a shading system here I am trying to give you a solution where for example, this is a commercial building for start, where the designer is not interested in providing shading system. This is your building; this is in; this is out. You apply a specific coating on this particular glazing system a low e coating. Essentially, it is a silver coat, which certain you know nano particles associated. What this does is this is spectrally selective. As we know solar radiation has a wider spectrum from ultra violet to visible to infrared; solar radiation is a short way of infrared and then the re radiation is a long wave.

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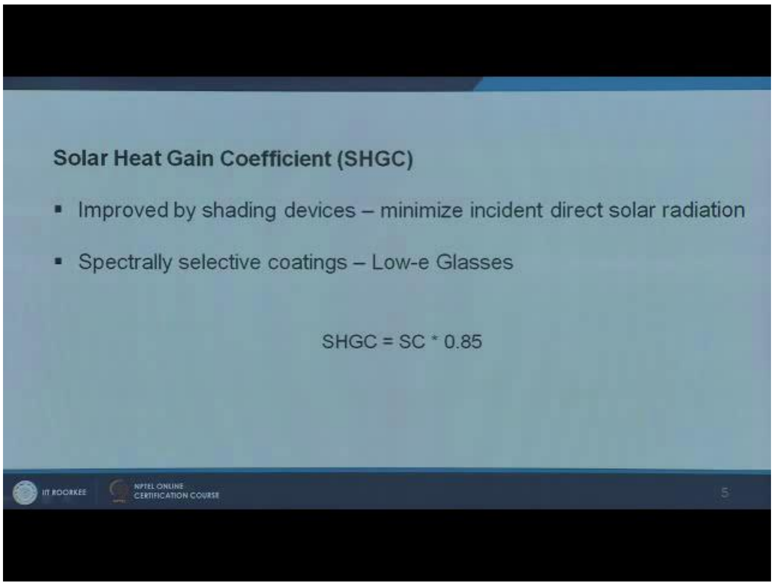

This particular coating will be this can be applied on this surface or this surface.

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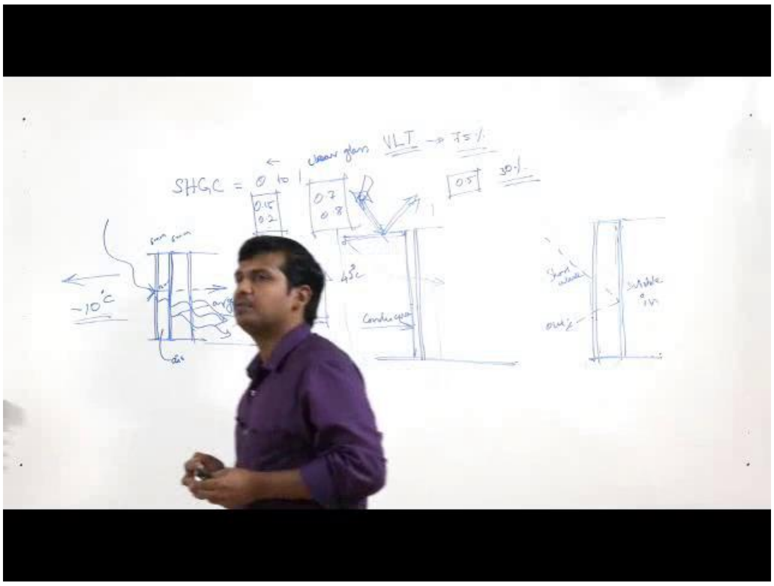

There are variation associated we generally do not do the coating here because of wear and tear, same reason here. It can be done on this face or this face what essentially this does this coating allows visible radiation while it reflects the shortwave. The short wave radiations are reflected back, while the visible spectrum is allowed in that means, it allows light to pass through, but it cuts down in the short way radiation. If you go back you know 25-30 years back in time, moment when people realize that this clear glass or clear glazing system are highly radiative they have a lot of radiant heat gain, they started using a coated glass or a tinted glass. Essentially, it is a mix bronze or some kind of metal, which is mixed in the glass. So, the glass gets darker.

As a consequence, what happens? The light transmittance through the glass came down drastically. Say, when I said 0.7 or 0.8 for a clear glass, the light transmittance are visible light transmittance that is VLT here will be around seventy5percentage that is 75 percent of light is transmitted in to the building which will actually help you in reducing your lighting energy or lighting loads. So, number of lights can be less or less light can be turned on. Whereas, when you want to reduce this particular thing instead of going for a spectrally selective coating, if you are going for a tinted glass the dark color tinted glass say bronze colored glass then your SHGC might come down; say instead of 0.7, it can go to say 0.5. Whereas, your visible light transmittance becomes 30 percent; so only 30 percent of the available outdoor light can come in to your building; whereas, this has come down marginally. So, there is improvement here, but this is leading to problem.

And the other hand when you use a low e coated or a spectrally selective glazing, this does not happen; even for a glazing with 0.2 SHGC you may be able to get a VLT or visible light transmittance up to 55 percent or with you know the modern day coating it can even be higher. It depends on the type of products or the coating material which is used. The conventional way of referring was shading coefficient some of the data sheets still refer shading coefficient, because some text standards are able to demonstrate shading coefficient SHGC is a factor of shading coefficient you can you know for a quick working you can multiply it by 0.85.

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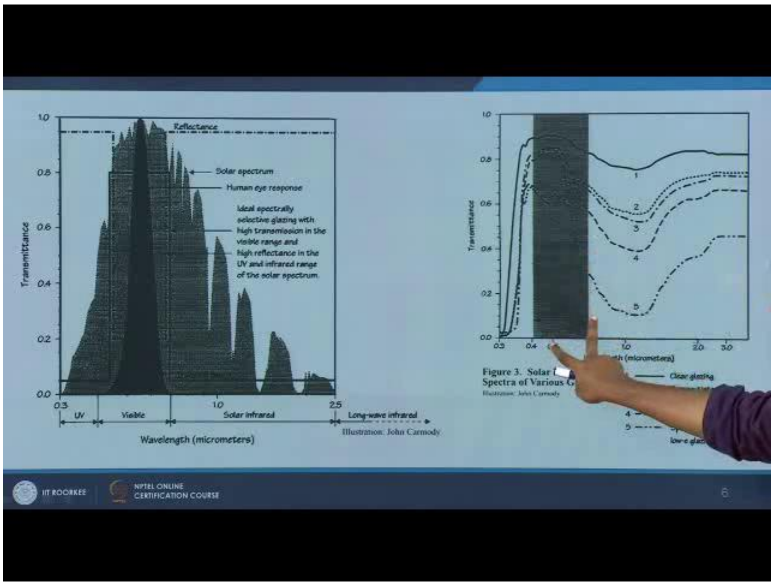

When I said you know spectrally selective coating this is what actually happens this is a demonstration which I illustration which I referred from another book textbook. This is a total solar spectrum, it starts from ultra violet you have a visible spectrum and then this is a solar infrared. This is the transmittance of the system. What happens with the spectrally selective coating, this particular spectrum is reflected back while this particular spectrum is allowed. So, if you take wave length, it allows the wave length in this range, while it considerably blocks. Say this is clear glazy, it allows the lot of day light but it also allows shortwave radiation. Number 2 is a bronze tinted glazing, it cuts down drastically on the light visible light transmittance, but it also cuts little bit on here shortwave radiations. So, here for clear glass, it is around 85 percent visible light transmittance whereas, it is 85 percent solar radiation transmittance shortwave transmittance also.

On the other hand, if you go for also spectrally selective or low e coated, this is number 5; to get a visible light transmittance as highest 80 percentage; you can minimize the shortwave or solar radiation transmittance up to 15 or 20 percentage. It varies as I said depending on the coating and the tint of the glass as well. So, this is more effective in controlling, but one thing we need to note with the effect of coating it is possible, but apart from this by the use of shading system also, but cutting down the source itself that is direct incidence by avoiding using this particular strategy it is also much effective. If you are willing to go for shading system, it is much more you know effective and economic to provide improved efficiency for the glazing system.

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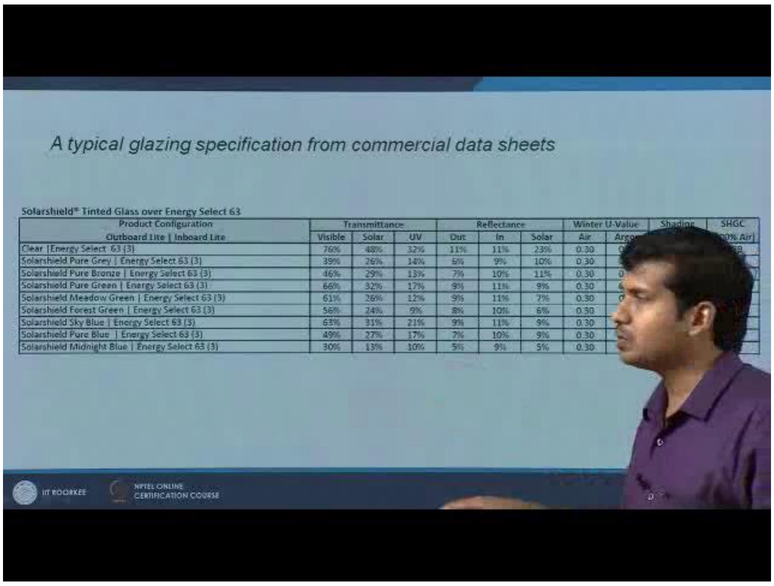

I have referred one of the commercially available catalogues this corresponds to one company. There are lot of glazing companies everybody has an extensive data sheet one of this things. Typically, if you look at the brochures you will have commercial names, which is essentially not important in this section. We will have solar transmittance, visible transmittance, solar transmittance and UV transmittance; some of them give this, but not all. Here we have visible, so this particular glass 76 percent visible transmittance, solar transmittance is 48 percent, reflectance out and in reflection. This actually gives you an idea about whether you know a particular glass say when you see through glass, but still you will be able to see the reflections of your own self, when the other side is not that bright.

Imagine, you are working in an office in a night time, you will be seeing your own images if the inside reflections are higher. Then there is a U value which is for winter again it is you know specific standard some of them give you winter, summer U value, different test conditions. When you say U value, typically, you will get NFRCR - National Fenestration Rating Counselor of US standard tested U value. So, there is the set outdoor temperature and set inside temperature for which the U value is calculated. Some calculation procedures require you to test for different conditions also, but most of these brochures you know data sheets that you get correspond to NFRC standard tested U values then you have shading coefficient and SHGC.

Let us take this first glass. It has a visible transmittance; it is a clear glass 76 percent visible transmittance and about 60 percent or 0.59 solar heat gain coefficient – SHGC. On the other side take another glass where you have an SHGC of 0.22 that is you have brought down SHGC to pretty less than half of what it was here. The U value more or less remains the same with air it is 0.3 U values; here it is 0.3, again U value did not change, but the SHGC has considerably come down. Please remember the U value does not you know significantly get affected when you do a low e coating, it is essential it reflective coating now please recollect the type of thermal insulations we talked about we have resisting insulation which is given by U value. Here, we have talking about reflective insulation which is SHGC effect of coating where you have brought down the efficiency you know brought up the efficiency pretty higher solar heat gain coefficient or the radiant you know cut off radiant has been brought to 0.22.

Visible transmittance also has gone down, but there are also some other glasses, where you have more or less of trade off. You can see for all of them the U value remain the same while the SHGC considerably varies depending on the coating; depending on this the visible light transmittance also considerably varies. So, what are the major challenges, yes, we have an excessive data sheet more or less all the glass manufacturers would give you an excessive data sheet which were you will have series of numbers. Most of them you may not even you know look at or take as a criteria for selecting, yes 2 or 3 crucial parameters you will look at and you will choose a glass, but what are the challenges practically. The first major challenge is what you get from this data sheet is something called center of glass U value.

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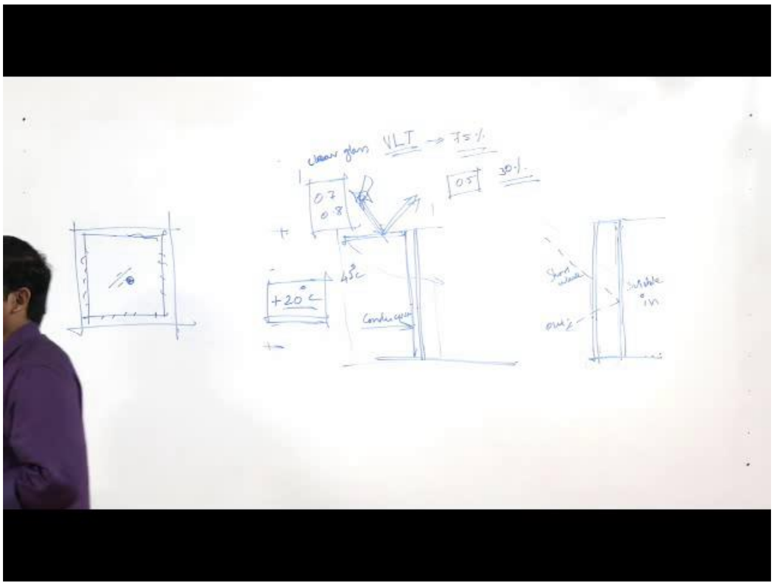

So, if you have a glass like this, you have frame all around, this is your glass. In this case, what actually happens? The value that they give you they would have tested this glass panel through typically hard plate apparatus what I was talking about. So, essentially, the value - the U value that they give you is something called center of glass U value somewhere taken corresponding to what happens in this the edge effects are the effect of the interaction with the typical frame system is not considered. There is the minor difference though it is not huge impact, but still there is an impact between the centers of glass U value to edge of the glass U value.

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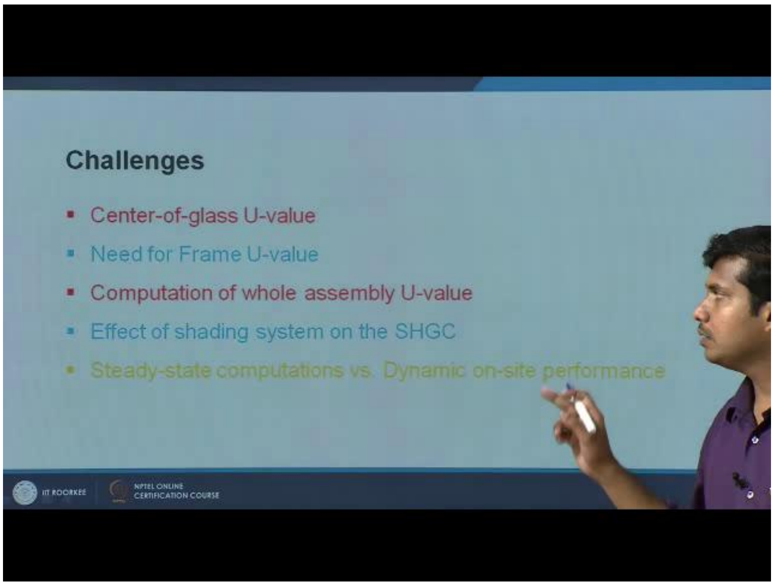

Number 2, the need for U value of the frame itself, imagine you have a U PVC frame versus an aluminum frame versus a highly insulated thermal barrier aluminum frame or different type of structural facade system versus nonstructural facade system with thermal insulation without thermal insulation. So, see you have a highly insulated glass here if the frame itself is not thermal insulated then you will have a lot of gains and losses happening at this particular juncture. So, this particular thing becomes a weaker link, this will create problems for you.

Number 3 is computation of whole assembly U value. So, imagine, the next step hurdle you have crushed, you have the glass U value you also have the frame U value. Now, how do you compute the whole assembly U value? Do you think for each of these combinations, so you have chosen a frame out of 1000 option available and you have chosen a glass out of 1000 glasses available in the market? Do you think somebody is going to test the whole system and give you, no, for specific projects for larger projects you might be required to test you know in the laboratory a glass frame assembly also. Some sophisticated projects depending and the requirement might demand you to test this as well, but some of the projects you can compute them. If a standard you know good tested value reliable value is available for glass and frame then it is possible to compute the whole assembly U value. Again you know please remember here we talked about the material level property; here we are talking about the assembly level property.

The next important thing is the effect of shading system on SHGC. Naturally, you know you buy this from a separate company this is sold by a separate company, and essentially when you have a shading system that is sold by a separate company. So, whose you know either it is a hand you know cast (Refer Time: 21:22) shading device concrete or you know machinery shading device or it may be a aluminum or steel section which is available like louvers or blinds that we are going to install. So, the effect of this particular shading system on the glass is another crucial thing, which needs to be accounted. Apart from all this whether we are doing steady state computation, a particular instance in which U value and SHGC are determined versus the dynamic site performance. What happens to the solar movements, what happens to the insulation versus how much is getting transmitted is highly dynamic. These are challenges, but with all this the industry has proceeded much faster so we have more or less standard values available.

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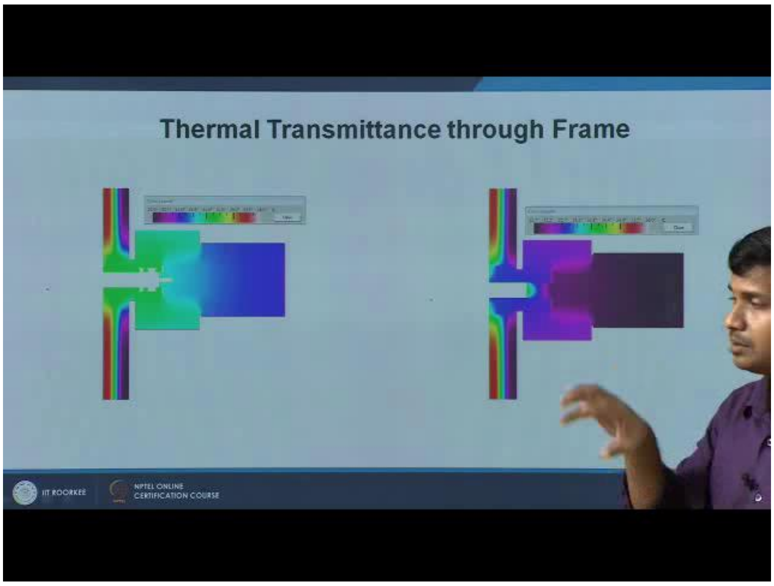

Now, just to give you better picture what I have been talking about. Two different frame systems this particular frame versus the other one I am not getting in to details of what frame it is and what they actually mean, but typically the heat transfer through this frame is relatively higher compare to this.

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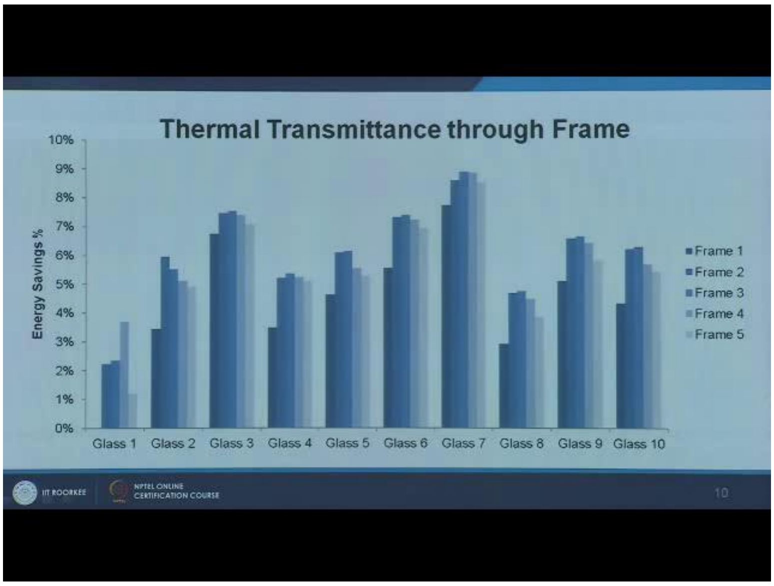

And the effective different frames actually we took ten different glasses five different frames and how much amount of energy saving happened, yes glass has a lot of impact compare to this versus this. The savings has gone up say here you get about 8 to you know 9 percent saving, whereas you get around 2 1 to 2 percent saving in this particular glass. But what we need to note even with this glass, if you go for an efficient frame, you can go as highest as 4 percent as saving. Even if the glass is really good, even the frame is not good, you will lose 1.5 to 2 percent of your estimated energy saving. So, frame has a crucial role in the effect of the energy efficiency you know impact of the overall system.

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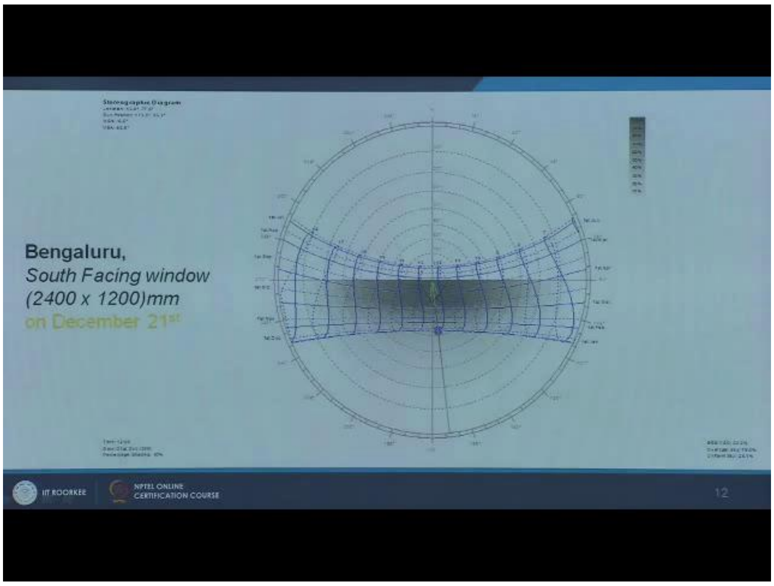

How do you design shading device a quick overview of the process involving in designing shading system. We have you know looked at the solar charts what I have super imposed here, you know in a following session I will also demonstrate how to compute this using certain tools, but to take a quick look at it. You have a solar chart sun path diagram, this is for Bangalore, the window size is 2400 by 1200, and this is facing south. So, you see a thin you know set of gray lines it gets darker as it goes here. This is on December 21 that is winter solstice. So, this particular window which is you know imagine the window is located here. There is a shading system a simple horizontal shading device 450 mm thick, it is going to cast a set of shadow; after a while you will not get much shade, when the sun is here you will get shade. So, this typically gives you a estimate. I will show you a more details about this.

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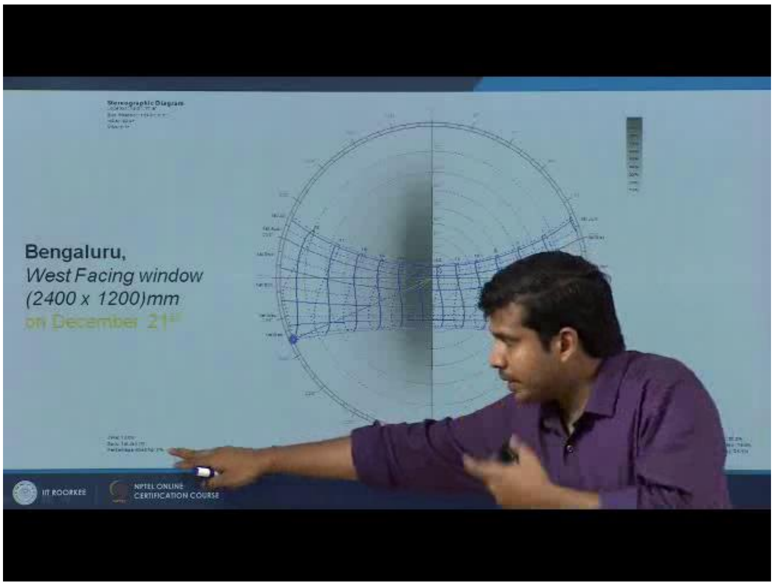

This is for a west-facing. The same window located on a west-facing wall. Take a closer look at this. This is a uniform over cast sky the amount of shading the percentage efficiency of the shading percentage shading is 40 percent for a south-facing wall with a 450 mm shading device. Whereas, almost you get no shading if is a west-facing wall yes horizontal shading devices are not effective.

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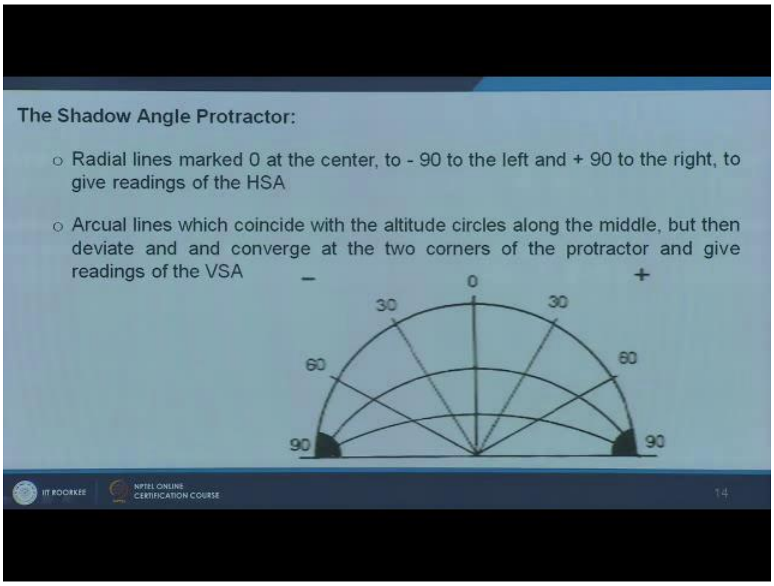

We will look at more in detail. The conventional method of calculating shading was using a shadow angle protractor on sun path diagram. Typically, this is like you know you have radial lines marked 0 at the center and goes up to plus 90 and minus 90. Then you have this arch line; they coincide with the altitude angle and here it coincides with the 90 plus 90 and minus 90. You typically mark the duration and time in which season and duration in which shading is required. You put this over super impose it and then I will show you some examples of how to do this, but before that few angles are important.

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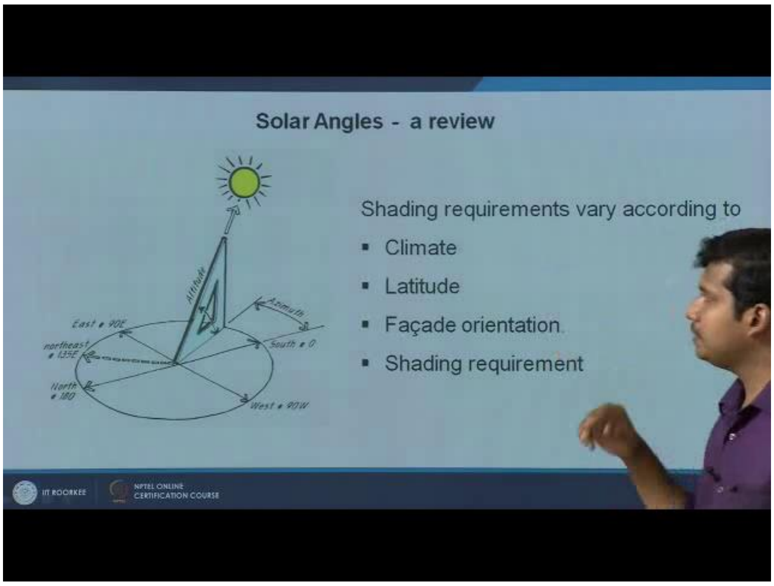

We need to you know recollect assume at this you know this is like a trigonometric projection of the 3D sun movement on 2 dimension. It gives you the azimuth angle on which orientation relative to north or south where the sun is located. And altitude tells you relative to the horizon at what angle the sun is located. Shading system requirement vary with respect to climate, latitude, longitude of a place facade orientation and typical shading requirements.

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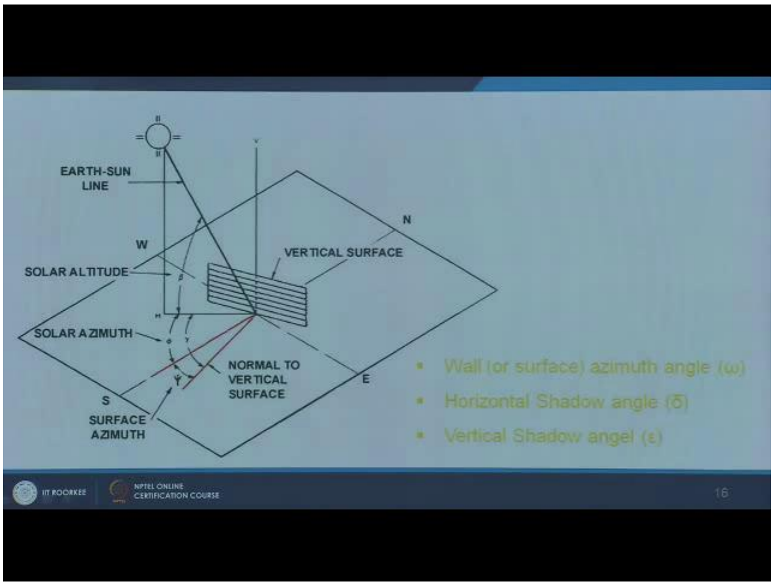

Apart from this altitude and azimuth angle, we have three other important parameters; one is the wall or surface azimuth angle that is to which particular orientation the wall is tilted to can be referred to from north or south. Then you have something called horizontal shadow angle and you have something called vertical shadow angle. We will look at these two things more in details.

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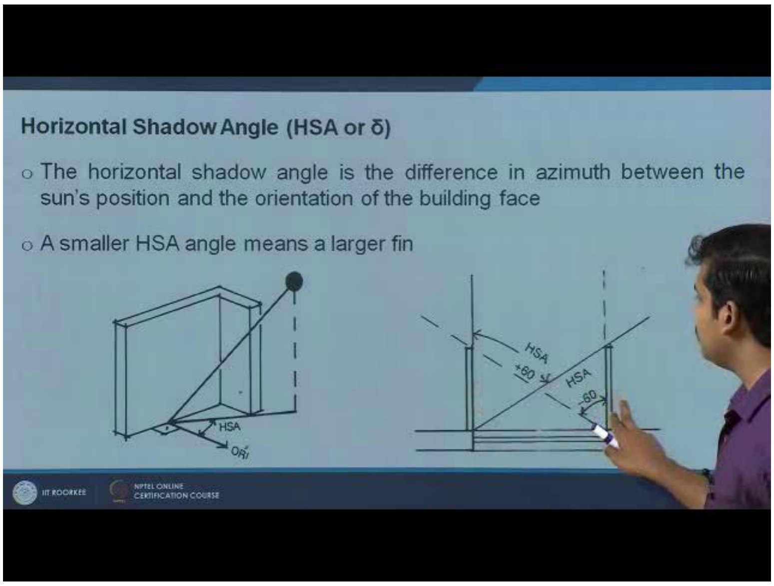

Now horizontal shadow angle is a difference between the azimuth of the suns position and the wall orientation that is wall azimuth and the solar azimuth, it gives you the difference that is effectively it takes in to consideration the orientation of the wall surface. So, this gives you the horizontal shadow angle; the difference actually gives you the horizontal shadow angle. So, how to understand this, if horizontal shadow angle see if this is the line drawn this actually gives you how much projection you will need. So, the lesser the horizontal shadow angle, this line converges and this projection is going in to come further ahead. So, this is a vertical shading system the effectiveness of the vertical shading system is given by horizontal shadow angle.

So, if you have two see you know this is us for example, south-facing surface you have sun moving from this side to this side as this gets further the cut off duration increases. So, you want for example, 8 am in the morning to 6 pm in the evening you want cut off; the depth of this over hand the vertical shading device this is plan-view, this will further depend. So, the cut off will be more, similarly, for the afternoon hours. Alternately if you want the cut off only from 10 o'clock in the morning to the 3 o'clock in the evening this can be shorter or if the latitude of the place you do not get deep southern sun, this can be lower. If the sun is just passing on like this then you may not need a deep vertical over hang, this is as per horizontal shadow angle considered. It is nothing, but solar azimuth minus wall azimuth.

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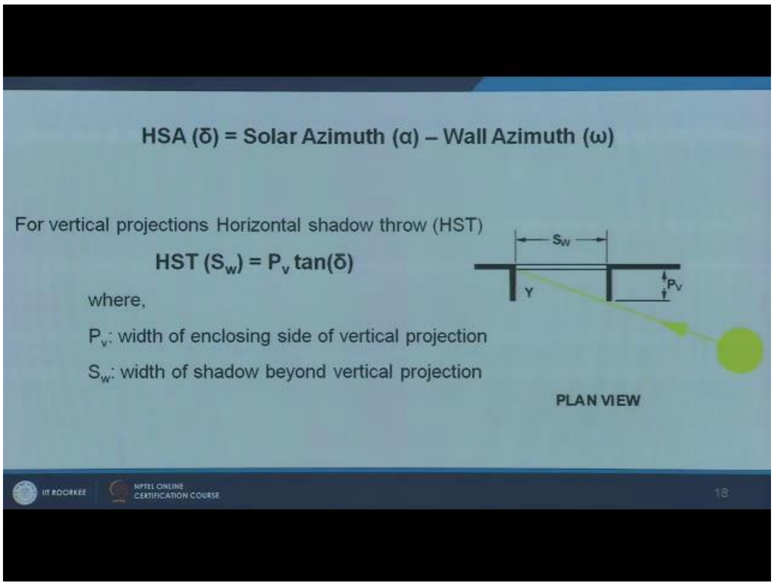

Once you have this number, horizontal shadow angle, you can actually find out what is a P V that is that is the projection depth the depth of the projection required for which you will need the window dimension. Mostly you will have the window dimension. In this formula, then you will know the left hand side. So, I know what is the width of the window say imagine I have a 2 meter long window then I only do not know what should be the projection required. So, to know this, you will take this in this side, it will be the width of the window by tan horizontal shadow angle. So, the horizontal shadow angle gets to the denominator, the lesser it is the deeper the shading you are going to get.

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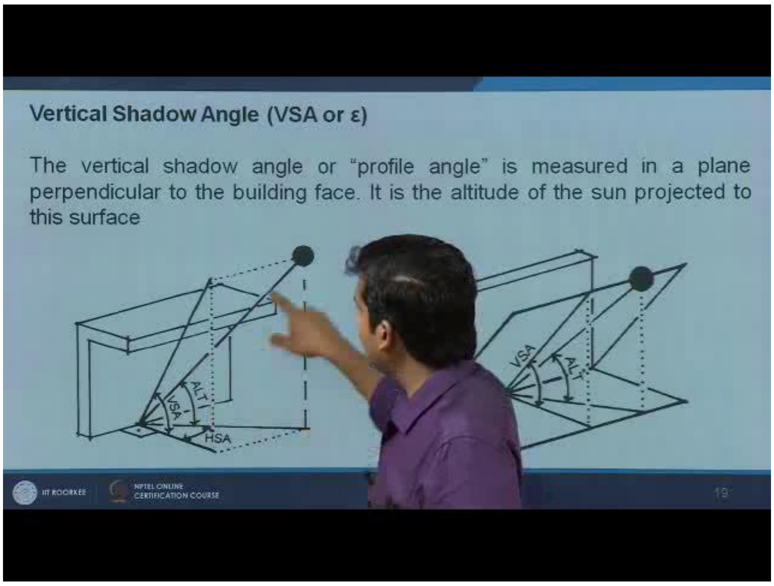

The next is the vertical shadow angle this is the reverse of it is more or less the altitude versus the cut off. So, the lower the altitude of the sun, you are going to get more solar incidence on your window surface. So, the vertical shadow angle will vary accordingly similarly here lesser vertical shadow this is taken between the horizontal plan and the range where you need the cut off. It can be same as altitude angle provided you want to cut off the whole of the sun. If you do not want the sun on this particular day then your shading device will be this deep, for example, you have a window this is a south oriented window sun is here during October, you have sun coming here.

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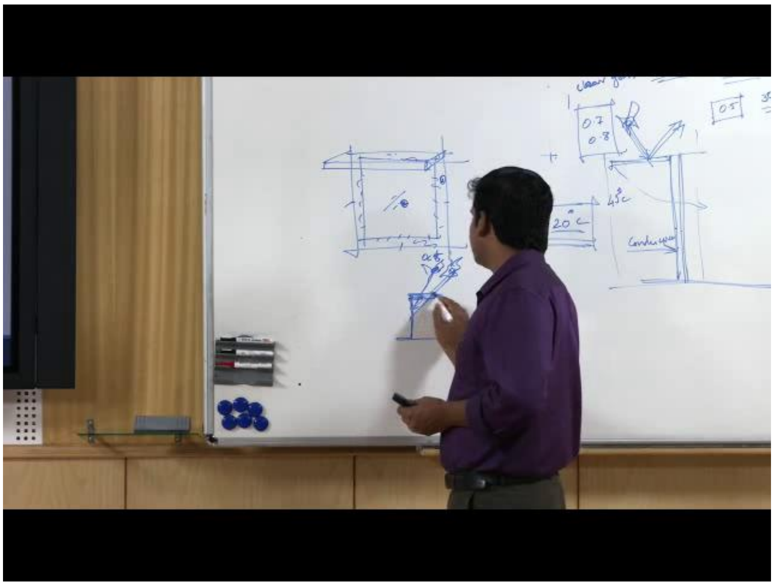

So, you want a cut off you have provided a shading system like this. Then this is October; in December you are going to get sun at this point you may not want to cut off the December sun. So, you can just cartel your shading system at this point. So, you will be getting sunlight during December. But if you further want this to be cut off even during December then you need a deeper shading system. As the vertical shadow angle comes down the shading depth increases similar to what we saw in the previous example.

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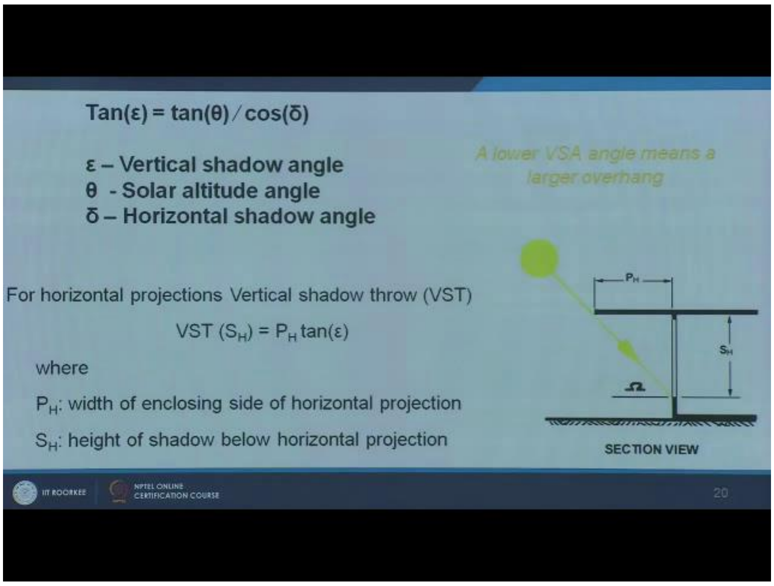

Same as that if you will know the height of the window, what you need to know is a depth of the projection, you will know what is the vertical shadow angle. Once you know the vertical shadow angle you can determine the cut off and how much width is required or alternatively if you know the width you can find out what is a shadow throw how much shadow it is going to throw on a particular fenestration.

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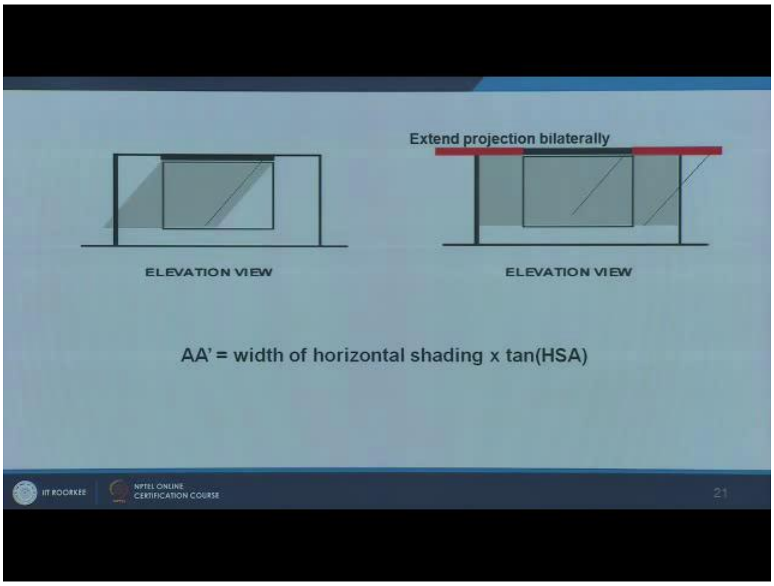

Apart from this another small step which is needed in shading calculation even if you provide a proper horizontal shading system, the sun is moving from this end to this end then you will have sun crating from this sides. So, to cut this off you need a slight projection there is a formula here the depth are AA dash I have mentioned here this particular depth shown in the red line can be given by width of the horizontal shading in to tan horizontal shadow angle. This will give you how much projection extra is required.

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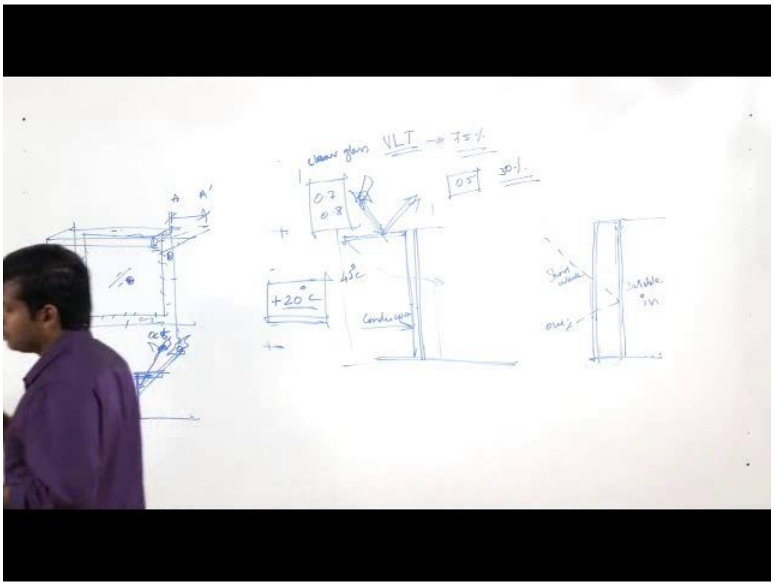

So, if you have a window this long whether I should cartel it here or should I extend it further and if so how much extension is required this particular depth that is AA dash which I have mentioned in the formula is given by this simple equation. How do we go step by step, first is to determine the cutoff date, to take a solar chart, determine the cutoff date to which you need you know you want to exclude sun and start and end time whether you want it for all through the sunshine hours or specific duration. Say you want from 9 to 130 or say 4 o'clock in the evening for our ease of working let us say 9 to 4 o'clock in the evening, we want cutoff on a particular day up to a particular day.

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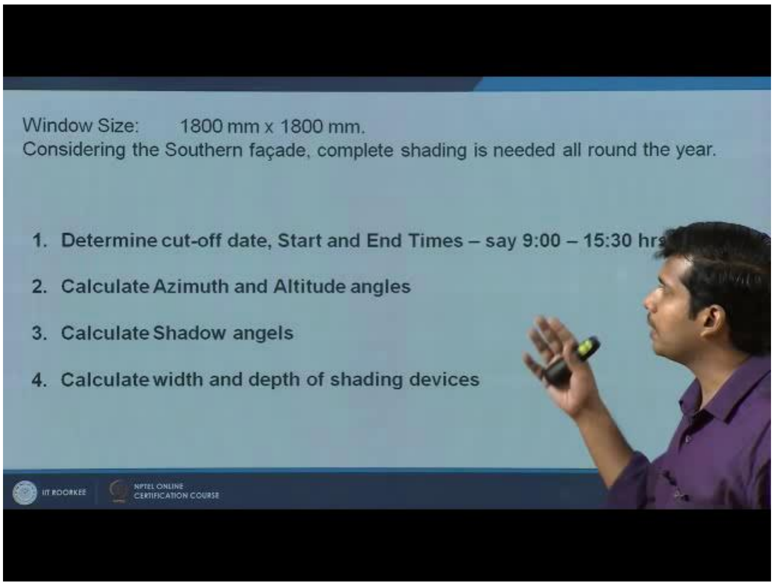

Then calculate azimuth and altitude angle calculate the shadow angle and further estimate the width and depth of shading system.

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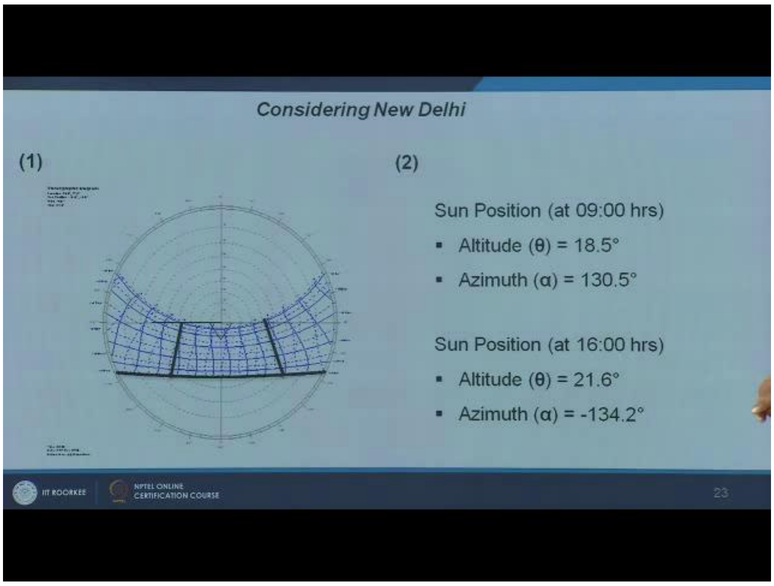

To show you graphically, the first step is 9 o'clock in the morning to 4 O'clock in the evening I am saying this is a south-facing wall. So, I want to exclude sun all through the year up to December 21st up to winter solstice I will prefer excluding the sun. The altitude, I have taken Delhi as a location the altitude on that particular extreme. So, I have to find out the extreme case December 21st at these 0.123 I have to find out. Altitude angle and azimuth angle are known; suns position, this is at 9 O'clock, this is at 4 O'clock in the evening, same altitude and azimuth angle is determined.

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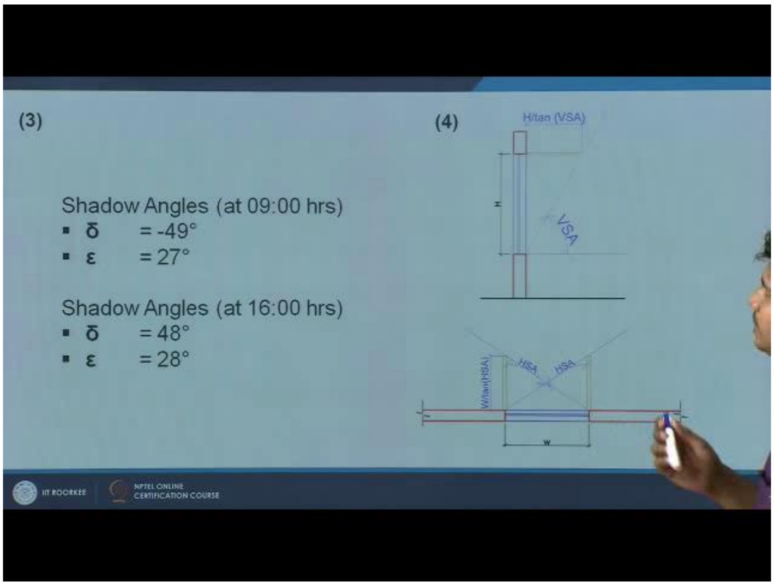

Next, determine the shadow angle horizontal and vertical shadow angle. Once side determine what is a horizontal and what is a vertical shadow angle, as I said I know the window height and width with that I can calculate the projection which is required horizontally as well as vertically. So, this is a traditional way of calculating. Another approach using computational tools I will be demonstrating in one of the following sessions if you take a code like energy consideration building code which is most commonly used for building applications today. It gives you very simple approach or simplified approach rather you may not be able to precisely find out the shading projection and depth for any specific location, but overall it gives you two conditions.

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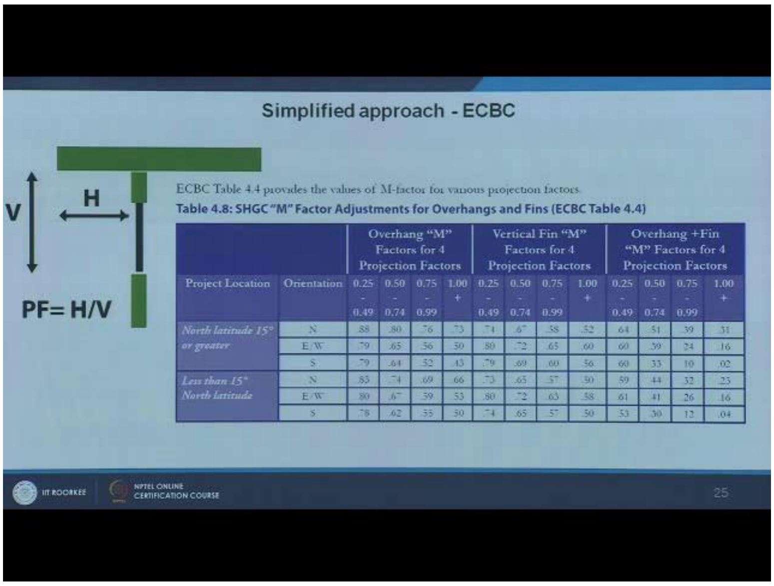

One is north latitude 15 degrees or greater, and less than 15 degree north latitude that is below 15 degrees and above 15 degree to specific instances are given and 4 orientations are addressed - north, east or west and south. First thing is it asks you to calculate something called projection factor which is nothing but this versus the vertical you know how tall is your window plus the small you know gap that you provide here the missionary provide here. And what is a depth this particular thing usually you will want to determine this so the formula turns the other way. Then if you know the projection factor, you can substitute it here; for different projection factors, you have something called m factor or you know which is needed for the shading calculation. So, once you know the projection factor, they give you how much factor of amount of m factor is given is taken from this table. If you substitute then you will get a desired amount of shading depth.

What I will do in the subsequence section I will demonstrate software with which you can determine the shading and one or two worked examples using this projection factors as well. So, we looked at the thermal properties of glazing, what is important glass frame and assemblies, then we looked at shading systems typically what angles are involved and how do we design a quick estimate of the shading depths vertical and horizontal shading devices.

Thank you.