BUILDING ENERGY SYSTEMS AND AUDITING

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Lecture – 18

Lecture 18 : EPF - Analysis

Welcome to the NPTEL lecture on Building Energy Systems and Auditing. We are in module number 4, and this is the third lecture on module number 4, lecture number 18. Today, we will discuss the EPF analysis. So, in the previous two lectures, we have discussed the envelope performance factor, the basic strategies, and the calculation or estimation method of the EPF. We have just started a brief discussion about the Shading Equivalent Factor.

We will see the Shading Equivalent Factor in more detail in this lecture, and we will do a typical analysis of the EPF. So, we have discussed that shading is another very important passive solar component which can protect the building from heat gain. So, as per the ECBC, we have to actually find out the projection factor, which is the ratio between the horizontal projection versus the vertical depth of the projection to the window sill. So, there are some students in my class who sometimes ask me that if this projection is not exactly at 90°, if it is at some other angle or so, then what could be the projection factor calculation. So, my answer is that the ECBC does not say anything about that, and we have to go with the definition provided by them.

So, it is the vertical depth versus the horizontal projection. In cases of fins, there are the depth of the fins and the depth of the window portion of the window. Because fins are at a regular interval. In cases of fins, there are depth of the fins and the depth of the window portion of the window. because fins are in a regular interval.

So, that is how much the depth of the fins is and how much the associated window width is, which will give this H by V ratio or the projection factor ratio. And based on this projection factor ratio and this ratio, we have to find out the shading equivalent factor SEF. SEF can be used with this equation, which we discussed in the last lecture. Where

we require PF values, and with the PF, it is multiplied with some factors: PF to the power of 3 is multiplied with the C3 factor, PF squared is multiplied with the C2 factor, and PF is multiplied with the C1 factor. It has to be added up, and then another C0 factor has to be added to that to get the SEF. These C1, C2, C3, and C0 are based on two parameters: one is the latitude, and there are two such tables—one for locations where the latitude is 15° or more, and another for 15° or less—and also depending on the orientation of the facet. So, there are eight such cardinal orientations.

$$SEF = (C_3 \times PF^3) + (C_2 \times PF^2) + (C_1 \times PF) + C_0$$

So, let us just find out the PV of this particular chhajja and the corresponding ACF values. So, here the depth is 450, and the depth of the chhajja from the horizontal depth—I am talking about 450—and the vertical depth from the bottom of the overhang to the sill is 1200. So, that gives me 0.375 as the PF. So, I have to use this, but I need to know the location, and also this particular table number 4.12 has been given in the ECBC code. Let us suppose I want to do it for New Delhi. The latitude is more than 15° north.

So, I have to use this table. This is for equal to or greater than 15° north, and this is what I want to find out for the east facade. So, this is my row. So, I have marked it with the red arrow, and this is the overhang. This is called the overhang because it is just like a projection over the window.

So, these four values I have to take. So, C3 values are 0.05, C2 values are 0.42, C1 is this one 0.66, and C0 is 1.02. So, I know all the 3 values, all the 4 values, C values, and also the PF values. So, I can use this equation and directly multiply and make the addition. Finally, I got the ACF value as 1.329 or something like that.

So, similarly, I can do it for some latitude which is less than 15°, maybe Chennai, maybe Devandram, maybe some down south areas locations. So, I have to now go to the other table 4.13, which is for the less than 15°, and I am here, let us suppose I am calculating for the south. So, I have to take the same, I mean not the same, the south row, the red color arrow provided that one, and all the four values are taken from the table, and then similarly, I can multiply and add. So, now it is 1.067.

So, let us see the nature of this PF and the nature of the ACF, how it changes. So, I have calculated for both, for the more than 15° and the less than 15°, and all the four orientations: north, east, west, and south also. These are the table, these are the values, and if I plot it in a graph, in the x-axis there are four directions: north, east, south, and

west, and in the y-axis it is The values of ACF, the shading equivalent factor, so I see it is a good association in the north, good association in the east, also in the west, but there is a huge gap in the south. South, you see, in case of the blue line, which is the latitude more than 15°, it has a value like 1.43, something like this.

But in the case of the south, in the case of less than 15° north, its value is almost close to 1, which is 1.07 or so. So, there is a huge change in the south value because it is the sun path. Actually, below 15°, the sun will not be so much in the early if you see it is not so much in the southern zone. Mostly, it will be in the northern zone, and in more than 15° or whatever the latitude, it will be mostly in the southern zone. So, that is why the shading, if you give in more than 15° in the southern zone, it will be helpful. The more is the ACF value.

And in less than 15° zone, that much of the benefit you may not get because the sun is not quite a long time in the southern areas or so. This is due to the sun path. The ACF, also I mean ACF, I have calculated just now we have seen, and then suppose the SHGC is 0.3. So, the modified SHGC value will be the actual SHGC value, that is, suppose it is 0.3, and divided by the ACF values are different values in the different orientation and different values for the different places or locations. So, as we all can see here, the SHGC is always more than 1 mostly. So, definitely, the modified SHGC values will always be less than this. Like, may say that SHGC modified will always be less than mostly always less than the SHGC actual.

As SEF is more than 1, ok, and I am dividing every time. So, definitely, that will be less than the actual SGC value. That is one thing we have to note down. Next, what I have done is that this is for less than 15° latitude, which is below south or I mean in the southern zone of India, and for different PF values. 0.25, 0.37 already you have calculated, and also 0.5. So, I am increasing the projection. The projection factor increases means that the H value increases with respect to the V value.

So, I am increasing maybe from 1 foot to 2 feet to 3 feet, something like that, and if I increase the horizontal projection more and more, the sun cut or the sun rays will be cut. And the PF value is increasing, and based on that, you see in the case of the north everywhere, and in the case of the east, it is increasing and maybe so it is increasing. I mean, if these three lines are basically for the three PF values, and this gray color is the 0.5, this is the, sorry, 0.5. So, I will write like PF equal to 0.5, this is for the the PF equal to 0.5, this is for the PF equal to 0.25 or some.

So, it is increasing everywhere, it is increasing, but in the north, it is not so much predominant, but at least in the east, west, and the south, it is predominant. So, we may conclude. So, from that, huge projections may not be very effective in the north, but a higher number of projections will be very much effective in the east, south, and west directions. Similarly, in the latitude which is So, this is less than 15°, I am sorry, initially what I have told is that it is more than 15°, that is in the northern plain, northern India, and this is southern India, which is less than 15°.

So, you see there is a dip, there is a dip in the case of the south. Because the sun path is mostly in the northern area. And it is increasing, it is also increasing for all the three other directions, the north, east, and west. East and west give very good incremental, very much increase in the SEF value, but the south is predominantly very flat. We can see the south values are very flat, 1.28, 1.43, and 1.59, something like that.

ACF, the range of ACF which is applicable for the ECBC, states that it is applicable for anything between 0.25 and 1. Less than 0.25, we should not give any kind of modifications or so. Next, we will be going to do a little bit of analysis. Suppose this is a building; it is a one-floor, ground-floor building of a U kind. The boundary dimensions are given over here; the flow rate is 5 meters, WWR is 30%, the climate is hot and dry, and the building type is an office building of 12 hours. So, let us find out what the EPF value is.

So, I have calculated the facade area and also calculated the window area. So, this is the north. Area, so if I go back, it is the north on this side, the upper side. So, this is the north; this is the north. Ah, this is the south; this is the south. This is north, north. So, these three are the north, and this is the east, and this is also east. This is the west. And this is the west. So, you can calculate and multiply with 30% of that; it gives you the window area. Multiply the rest of the 70%, which is your wall area. The roof is also calculated as 800 meters square. So, I have found out some of the other parameters. I found out the total wall area is 630 mm square. The surface area, the whole surface area of the building, is 1700 meters square. The volume also I found out; the roof area multiplied by the height, which is 5 meters.

So, 4000 meters cube, meter cube, is the volume of the building. The S-V ratio, S stands for the surface area, and V stands for the volume. S/V ratio, surface area versus volume ratio, is 0.425. So, based on that, I have calculated based on this material chart with the U

value of the wall, roof, and the glass window, and the SHGC. So, I got, I take the table; you know how to take that table. I have that.

The Excel chart, and then from there, I can calculate so I can calculate all the values, the EPA values of the roof have 21, 1340, the wall is 9, 112, something like that. I have used the U value for the roof as 1.8. If I go back, I can find out this is 1.8. Similarly, the wall value is 2.26, this is 2.26, and the wall area is 630. So, this is 630, and this is the roof area is 800, and you know these values are the C values that come from here. And this is for the hot and dry climate C factors, and 6.4 comes from here. So, I got these two values.

Similarly, I also found out the C values and the EPF of the fenestration as 40,414. So, based on those purple color values for the C factor in SHGC and the red color, the C values that is C1 values for the U value and multiply with the 5.3, what is this 5.3? 5.3 is nothing but the U value of the glass window. And what is this 0.76? This 0.76 is nothing but the SHGC of the proposed glass window.

So, now these three numbers should be added, and this number has been added, and finally, I got 70,868. So, in my Excel chart. So, in this Excel chart, what I have done is I have provided those values in the north, south, east, and west, and 800 is the roof, and this is 30% is WWR, and the U values is 2.26, and 1.8 is the roof U value. 5.3 is the window, and the 0.76 is the window SHGC, ACF I have taken one. And this is I have cropped this particular one, the hot and the daytime building, 24 hours building, and the hot and dry climate values over here.

And I got this 70,864, which was actually calculated in the PowerPoint presentation. So, let us go back to the PowerPoint presentation. So, these are the 70,864. So, in the second trial, what I did is that I have that particular flow diagram. So, I have already discussed that there is a design development.

So, I had an open plan of 30% WWR. So, that gives me 70,868. Just now, we have calculated the open plan. I am talking about this U-shaped plan, one floor. Now, what I did is that I went to a second type of plan, which is a compact plan, the same the same WWR of 30%, same location, same material, no change in that.

So, a changed building layout, what is the change? I have two floors now, each floor having 5 meters of height, but two floors. So, what I did is this particular wing, this wing number 1, you see this wing number or left wing and the right wing. The dimension of

that is 20 meters x 10 meters, 20 x 10, this is also 20 x 10. This I have kept over that, over this, this is 20 x 10 because this total is 40, this is again 20 x 10.

So, I have just over that. So, those two wings are now over that. So, that becomes this particular floor, two floors with a height of 20 meters by 10. 20 meters by, I think this is a small mistake, this has to be 40 meters. So, 40 meters by 10 meters of the total overall area.

So, I got the EPF value based on that. So, this one, the second one, I calculated a compact plan with 30% WWR. So, a compact plan of 30% of the WWR. So, see the area changes, the north area is 400 by 400, that is a 40-meter length. North and the south, and the height is now 10 meters because 5 meters and 5 meters, two floors.

So, the east is now only 10 meters in length and 10 meters in height. So, it is 100 square meters east and west, south and north are 400, and the roof is also 400 because it is 40 meters of length and 10 meters in width. So, again, I put those values in the Excel, and I found that 61955 is the value. So, it is reducing.

So, if it is a compact plan, how can I know that it is a compact plan? Because again, I have found out the total area of the surface area. So, if you remember, the earlier surface area was 1700. And that was divided by the volume of this thing, which was 4000. So, that gives me something like 0.425. And now here, the surface area becomes 1400.

14000 less, but the volume remains the same because the two floors, the ground floor from the two wings, is now added to a second floor, so the volume remains the same. The roof area decreases from 800 to 400, which is a big benefit, and your S/V ratio also decreases from 0.425 to 0.35, and your total value of the EPF. Definitely going to decrease because your S/V ratio decreases, meaning and keeping the same volume. So, that means, definitely, the surface area decreases from 1700 to 1400. So, there is a 300-meter square decrease, and this 300-meter square decrease is a good amount of area decrease from the roof. And based on that, the wall area was 630, and now it increases to 700, but the roof area decreased from 800 to 400, almost half.

So, these calculations, if you go through them, then you see the roof EPF was 10,000 something, which was earlier. Almost like 21,000 something, almost half, because it has to be, because if the roof area is just half, no material change or so. So, what we understand from here, if you go for the design development, is a compact plan. We will

go to reduce the EPF value. So, total heat gain also definitely is going to reduce. It is reduced and deducted. Based on the heat gain from the envelope.

So, I am going to decrease the envelope area overall. Almost 300 square meters of the envelope area is decreased, and based on that, there is a reduction in the EPF total. I am having a compact plan, the same compact plan, but now I am reducing the WWR. The WWR earlier was 30%; now I am going to do it with 20%. So, I have recalculated the area; the facet area is still the same, 400. 100 for those, and the roof will be 400. The north and south are 400, 400 square meters; east and west are 100 square meters. The WWR is 20%. I have recalculated the wall areas and all.

So, in that case, the EPF total further reduces. It was earlier 61 in the first case when it was an open plan; it was 70, then 61, almost 62 maybe, and this is almost like 50,000 something like that. So, the EPF roof has not yet changed; I mean, from the second alternative to the third, it was not changed. It is 10,670. But there is a little change in the EPF wall. The EPF wall will be increased because there is an increment in the wall area, which is governed by this 30% and that change of 20% of the 30 to 20% change of the WWR. But there will be a considerable amount of change in the EPS of the window. Earlier, it was 41,000; now it is 27,000. So, finally, again, there is a small

change, a shift towards reduction. So, now what we understand is that the design development itself is improving my performance. Improved performance means that it is going to decrease my EPF value. So, I have taken two stages of the design development. A very cozy kind of plan instead of a very open kind of plan where I can reduce the

The total surface area of the building, particularly the roof area of the building, and I go a little bit to two floors, and I can reduce the surface area without compromising the volume of the floor area. The floor area remains the same, the volume remains the same, but instead of the ground floor, I am going to the two floors. And, the second strategy that I have taken is reducing the WWR, I am going from 30% to 20%, 20% is quite a healthy WWR. We need the windows for the daylight, we will see in the next lecture how the daylight will be affected by the WWR at all, but 20% is quite a good%age of the WWR for daylight or so, and that also gives some kind of reduction. Now, next what we want to do is that we have to touch the second strategy, which is the envelope material choice. So, in that now I am going to propose some kind of changes in the material, that means changes in the sense that the same 250 brick wall will be there, but I am going to insulate

it by 50 mm EPS, and it will actually change my U value drastically. Drastically change means it was something like 2.6, sorry 2.26 or something, now it is 0.51.

And the double clear glazing, two layers of glazing, and one is reflective outside, that brings the U value of the window from 5.3 to 2.8. SHGC also will be reduced from 0.76 to 0.28, and also, I am going to give some kind of a waterproofing layer. Of course, waterproofing layers are there also in the first choice, but additionally, 50 mm EPS insulation I am going to provide with 150 mm, 6-inch thick RCC slab. So, that will again reduce the U value of the roof. Earlier it was something 1 point something, and now it is 0.5. So, I have calculated that one in the Excel.

So, I think this is going to be This is going to be a change. So, the north area is, I think, 400. The south is also 400. This is going to be your 100.

This is going to be your 100, the east and west. The roof is again 400. And WWR is 20%. So, let us give it 20 straight away to all, and this U-value of the roof, I remember, is 0.5, and these values are 2.8. The U-value of the window, SHGC of the window, is 0.28.

So, let us see, there are changes in this particular column, you see, and I just have to put the value of the U-value of the wall, which is 0.51, the wall is 0.51, so let us give it for all the walls in all directions. So finally, it is fifteen thousand five hundred and forty, and in my calculations also, it is fifteen thousand, and in my calculations also, fifteen thousand five hundred and forty. So, what changes I found? See, I have the first option, open plan, 30% of my 30% was my window-to-wall ratio. My EPF total was 70,000 something, this big value. Compact plan next, the double floors, but the WWR remains the same, 30%. I got 61 or 62,000. Then, compact plan, some 10 reductions of the WWR from 30 to 20, almost 50,000 is the reduction. 50,000 is the EPF, and finally, it is 15,000 only, from 50 to 15,000 only, when I have a compact plan. With 20% of the WWR and with some change of material, some good insulative material both in the wall and the roof by EPS insulation and double-glazed windows, that gives me a very good reduction and a very comfortable position from the EPF point of view, 15,000 or so, but we have to check with the

this EPF value with the EPF to EPF plus ECBC plus or the super ECBC or ECBC compliance. So, what we understood is that this WWR and S/V ratio, that is surface area to volume ratio, plays a role in the envelope heat gain, and that actually changes the EPF value based on that. Also, we discussed the shading devices today. So, thank you very much.