# BUILDING ENERGY SYSTEMS AND AUDITING

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**Week - 05**

**Lecture - 22**

## Lecture 22 : Overview of Residential Envelope Transmittance Value

Welcome to the Building Energy System Auditing course on NPTEL. We are in module number 5. We are discussing energy conservation and thermal comfort in the 20-second lectures. We will discuss the overview of residential envelope transmittance value. So, in this particular lecture, we will stepwise demonstrate the residential envelope transmittance value (RETV).

This value, the residential envelope heat transmission, is actually a criterion specified in the Ekonivar Sangita as one of the main essential parts of residential building control to manage heat gain through the envelope in residential buildings and dwelling units. This particular criterion excludes the roof, and for the roof, we have a different criterion that we discussed in the last class. This particular criterion is going to help residential buildings, especially during the design phase before construction, by providing better protection from envelope heat. This will definitely lead to environmental sustainability and also reduce carbon and other impacts. Because residential sector buildings are numerous in our country and the field is growing, we need housing. Based on the new housing that will come in the future, if we provide them with this particular guideline, it will help them achieve a better environment inside and also be cost-effective, ultimately leading to energy conservation. There is a big formula we will see, and this formula has to be calculated or evaluated for each residential building project. This particular formula has three components, and these components account for the heat conduction through the opaque building envelope components, such as walls or opaque envelope components.

$$RETV = \frac{1}{A_{envelope}}\left[\left\{a \times \sum_{i=1}^{n}\left(A_{opaque,i} \times U_{opaque,i} \times \omega_i\right)\right\} + \left\{b \times \sum_{i=1}^{n}\left(A_{non-opeque,i} \times U_{non-opeque,i} \times \omega_i\right)\right\} + \left\{c \times \sum_{i=1}^{n}\left(A_{non-opeque,i} \times SHGC_{eq,i} \times \omega_i\right)\right\}\right]$$

For example, doors, walls, or maybe some kind of curtain walls that are opaque. So, it is a heat conduction. So, it is a U-value criterion. Again, please remember that in the envelope, the roof is not included. The second one is the heat conduction through the non-opaque building envelope material.

Non-opaque building envelope material means the glazing and the window, if the window is a glass window, so through that also the heat will come through conduction and radiation. That will be taken care of in the third part, but the second part takes care of the conduction part of the heat. The third part is the solar radiation through this non-opaque building envelope material like windows and all, so that because of the SHGC control values or also the shading controls. So, after calculating all those values, there are some typical parameters and coefficients we have to take from different tables. This value, the RETV value, should be 15, not more than 15 $W/m^2$.

And this particular value is recommended for all types of climates except the cold climate. For cold climate, we have seen some other type of recommendation which we have discussed in the last slide of the last chapter. So, this is the formula. It looks like a big formula. It looks like a very complicated kind of formula, but it is not so big.

It is not so big in the sense of not so complicated. It is a rhythmic kind of formula. You see these three parts. I have already told you there should be three parts. The first part is dedicated to the

The opaque component, the wall component also. So, the area of the opaque wall, so I can write down those envelope areas which are the opaque areas that have been taken into account. The second one, and this opaque area will multiply by the U value of the opaque area, the U value of the wall. The second part, you see, is the non-opaque area, which means the glass window areas or so, and that is multiplied with the U values of the non-opaque surfaces. So, that is the U value component of the non-opaque.

The third part of the equation is the area of the non-opaque part of the wall. So, that is the glass, and it is the radiation. So, it is the SHGC control thing. So, these three parts of the equation take care of what we have discussed just now, the three parts they have taken. There are some associated parts.

The first one is maybe the A is multiplied with the first, the B is multiplied with the second, and C is multiplied with the third, three coefficients. These are the climatic zone coefficients. We will see how to take that. There are the the coefficients like.

Like ω, see this is the ω 1 or not ω 1, ω the ith ω, that means this depends upon which surface it is. So, it is the orientation factor; there is a separate table for that. From there, we have to take those ω values, which wall is in which orientation, which window is in which orientation—north, south, southeast—those different values are given. So, A, B, C, and the ω values have to be directly taken from the code. There are two tables. The area, opaque area, non-opaque area. And those we have to calculate from my architectural drawing for that particular house or apartment, that yes, this much is the area of the south, this much is the area in the north, this much is the area of the north window, south window, east window.

So, those are the things we have to calculate from the architectural drawing. Then the U opaque and the U non-opaque and SHGCs, all these things we have to actually, the value has to be put based on the specification of the material, type of the windows, whether it is double-glazed, single-glazed, and we have to take it from some other tables to know or to put that to calculate that. This is the table, table 3, specified for the coefficient A, B, C. Those are the coefficients for the composite, hot, dry, humid, warm and humid, and the temperate. Cold climate is not applicable here. That is a separate kind of calculation criteria mentioned over that, which we discussed in the last lecture.

This is the orientation factor. In the orientation factor, you see here they have given 8 orientations. So, which wall is in, if the wall is in the north, you have some ω value. And this ω value has two lists or two columns. The first column, if the latitude is more than 23.5° north, that is the Tropic of Cancer, above the Tropic of Cancer, that means if your location, if your building is located anywhere in North India, above the Tropic of Cancer location, so you take the first set of values.

For the north, the ω will be 0.55. Suppose for the southwest, the ω value will be 1.202, something like that. And if the orientation factors or the building is located below the Tropic of Cancer, 23.5° north, that is South India and the other part of India. If you see the Tropic of Cancer, it passes through maybe Rajkot in Gujarat,

then Bhopal in Madhya Pradesh, Ranchi in Jharkhand, Krishnanagar in West Bengal, and maybe Agartala in Tripura. So, this is a particular area or the line in the region. In the

Indian map, if you visualize. So above that line or above that area, or below. So if you are below that, maybe you are in Hyderabad, or you are in some part of Tamil Nadu.

So, you have to take the second list. So, the orientation factor changes. So that depends upon the location of the site and also which wall you are considering. And for that wall, you have to separately calculate the area of the window, the area of the opaque, that is the wall, and others, and you have to multiply with the corresponding orientation values of the north and all. We will discuss that one in a numerical problem just now.

We have the shading. So, if you remember, we have a PF factor in the ECBC code here. Also, the same PF, the projection factor, is recommended for this particular case. So, the PF is the horizontal projection by the vertical depth. So, we have to calculate that for any kind of projection, and we have to see what the equivalent shading factor, the ESF, is. So, ESF has to be calculated based on your PF value, which is listed in your

the first column, the left-hand side column, and based on your orientation—which orientation is your window in? Is it in the north, northeast, south, or west? Whatever it is, and also, we have to see there are two different tables. So, this particular table number 10 is mentioned for the latitude more than 23.5° north. So, if you are in some other locations, like South India somewhere there, you have to take table number 11, which is mentioned for the latitude less than 23° north. So, like that, you have to collect or select that particular ESF, the equivalent shading coefficient value. And depending upon the PF and all, then you have to multiply with the SHGC. SHGC multiplication will reduce the SHGC value. The actual SHGC value is the unshaded value—0.3, 0.7, 0.5, whatever it may be, depending upon your type of glass or so.

But if you multiply with ESF because of the Chhajja projections or fins or whatever, that will give you a little bit of reduction. So, see, from 0.1 PF factor onwards, all ESF values are less than 1. So, if you multiply with this, definitely your equivalent SHGC will be less than the unshaded SHGC, except for the first row, which all are 1 when the projection is very, very small—less than 0.1. It is nothing kind of, no kind of projections, maybe a small bit kind of thing for decorative or some purposes. So, for that only, it remains the same.

Otherwise, the ESF will reduce the value of SHGC, and that will give you a benefit in terms of heat gain as well. That is also taken into account for the calculation. So, let us have a small example to discuss that, and you will be much clearer in understanding it. So, I have a building footprint of 50 meters by 25 meters by 8 meters, with the longer sides facing south and north, so the dimension of the south wall, the facade wall, is And the south and north facade walls are 50 by 8, which means $400m^2$ or so.

So, I have calculated that the north and south areas are 400. The 400 because it is something like this. So, this is the envelope plan. So, this is your 50, this is your 25, the height is h, h is 8 meters. So, this is 50, so this area is 50 multiplied by 8.

So this is your $400m^2$, which is, this is north, this is south, this is west, this is east. And the east and west will give you, this will give you 25 multiplied by 8. 8 is the height. So this is $200m^2$. So that I have, this is the facade area.

It has a WWR of 20% for all the sides. So, 20% of all is the window area. So, 40 in the case of the east and west, 80 in the case of the north and south, and the rest of the area. So, I have deducted 20, 200 minus 40 is 160, which is the wall area for the west and the east, and 320 is the wall area for the north and the south. Even though I have mentioned the roof area as 1250, it will not come into any calculation because the roof area is not going to be there in the calculation of the RATV.

Whereas the total wall area is also 960, this is also not going to come into the picture. We have to take it separately here. It is not like the ECBC or EPA formula. It is separate; you have to take it because there are separate $\omega$ values or orientation values. So, I have written down all the things. Also, the window U-value is 0.75, and the wall is 1.5, which is mentioned. The shade, that is SHGC, is 0.3, which is also mentioned. It is in the hot, dry climate, so I have to take those particular ABC values, and the location is above 23.5° north, so those data are given.

The details of the overhang will be given in some other picture. So, let us see first here. So, we have to see that the building roof is excluded. So, that is what we know. So, this is the thing.

So, for the hot dry climate. So, I have to take A as 6.06, B as 1.85, and C as 68.99 in the second line. So, that is first of all. We have to take the $\omega$ factor, which is the orientation factor. So, I have four orientations: north, east, south, and west. It is for latitudes more than 23° north, maybe in Delhi, maybe in Lucknow, somewhere there. So, this is my first row. I have to consider this row. And these are my values for the north. I think I have a separate table for north, which is 0.55; for south, it is 1.089; for east, it is 1.155; and for west, it is 1.143.

So, I just have to take the right values based on my orientation and based on my latitude. I have given some criteria. So, suppose for the east and north windows, there are some WW for all the facets. So, for the east and north windows, suppose the projection is 1 foot, the sunset projection is only 1 foot, and the depth of the window is vertical, this V is 4 feet. So, PF is 0.25.

Whereas, for the west and south, you have a little bit more projection. Suppose it is 2 feet, not 1 foot, and the depth remains the same, 4 feet. In that case, the PF value is 2 by 4, which is 0.5. So, it is a bit more PF value, the projection factor. So, based on those two types of PF values. And there are four orientations: east and north are a little less, 0.25; west and south are a little more, 0.5. I have to find out the SEF, the equivalent shading factor.

So, I have to take the table number 10 because this is specifically mentioned for my location more than 23.5° north. So, I have to take two. First will be definitely from here. So, this will be for east and north, sorry, east and uh north. And point five was there, right? So, point five is this. So, this is for the west and south. So, and these are my so west and south means I have to go like this, and this is the west. So, this will be my one of the uh the SEF for the west and the south. South is here. So, same line south is here.

So, this one is the south value. For east, it is this one. This one 0.855 will be the east, and north is 0.922 will be my north. So, let us see. I have

Table number 10, I have the latitude because it is more than 23.5°, and these are the values. Yes, I have rightly selected those values, and the west and south are those values. So, those 5, sorry, 4 values for the 4 orientations for 2 sets of P f value we have. I have marked them, and I have to use that for my equation. I have SHGC unshaded SHGC 0.3 in my problem statement. So, I have to multiply that 0.3 with different ESF values for the different orientations, which is 0.922 for the north. So, I multiplied 0.922 with 0.3, and I got the equivalent SAGCC.

This equivalent SHGC is a little less than the actual SHGC of 0.3. There is a little bit of benefit I am getting because of the chhajja. But in the case of the south, as the chhajja projection is more, the ESF is much less. So, I have to multiply this with that. So, 0.3 has now become 0.18.

So, much more benefit I am getting in the case of the south because my chhajja projections are more, 2 feet. In the east, I am getting 0.3, which converts to the equivalent of 0.25. You see, for the west, it is 0.3, and I am getting 0.21. So, it is again a little bit more of a drop because the PF factor is 0.5. So, next, I have to calculate based on the equation provided to me in the earlier cases.

So, the first part is based on the first part of the equation. So, it is the wall part; it is the opaque part. So, if you remember, I have 340m² of the north. The same for the south, 160m² of the east, and the same for the west wall area. I have a U-value of the wall; all the walls are 1.5. I have an orientation factor that came from the earlier slide, 0.55. And all, I think this one, I have to take to all the slides now because all these calculations and formulas are based on ω in all three parts. See, this ω is best placed in all three parts.

So, these ωs are those which I have first calculated from this table number 9 or somewhere, and every three values are multiplied with each other. See this multiplication of every value and summation, and this is the summation. So, this is the multiplication equal to these four values. And the summation is this. So, this is the first value except the a. I have not multiplied it with the a. So, this dotted box, the dotted rectangular box, is 1338.24.

So, similarly, I can find out the other two parts also. The second part, the dotted box for the second part of the equation, the A non-opaque, which is 80m² for the south and north, 40m² for the east and west, those are the window areas based on your 20% of the WWR. And the U value of the non-opaque is 0.75, given in the problem. So, I have to multiply it with this width. The U values and the ω, ω remains the same, the same value which is corresponding for the north, south, east, and west, so that gives me these four values, which is this.

Of these three numbers, and then this is the summation. So, this dotted rectangular part I have calculated, and that value is equivalent to 166.94, and I have to multiply this 166.94 into the b value, which is there already with me. I will do it in the last stage or step. The third one, I have to calculate for the third part of the equation where the same area has been taken into account for my calculation, 80 and 40 for the north, south, east, and west. This is the SHGC equivalent after multiplying with the ESF, which is what we have calculated. You see, it is 0.27, 0.18, 0.25, and 0.21.

So, the same value I have written over here is 0.27 to 0.21. And the orientation factor remains the same because this ω will remain the same. So, this is the one, this is the one, and this is the one that remains the same for all, right? So, again, I am multiplying with all these three numbers. And these three numbers give me this 12, this 16, 11, and 9.6, and then the summation of those 49.98 is the summation value of those four multiplication values of four orientations, and that is nothing but the dotted rectangular box.

I am still multiplying; I have to multiply with the C value. So, what I am left with is this value, I also got this value, and this value has also been evaluated. So, I know the A, B, and C values, and I already know what the total envelope value is. I have to multiply it, add it, and divide by that. So, I will do it in my last slide. So, this is the final equation.

So, the envelope area is 1 to 0, 0m², it includes all the area, window and the and your wall area. So, 400 and 200, all the dimensions, orientations, these are the A values. I have already noted down that one earlier. And now, what am I doing?

I am doing the multiplication. So, this is 13.38. I am sorry, not 13.38; it is 1338.24, which is this value. This is 1338.24. We will check that with the earlier slide.

This is 166.94. So, this one, the dotted rectangular part, was 166.94. So, this is 49.98. So, this is 49.98, and these values are your A, this is your B, this is your C, which is this B, this is your A, and this is your C. So, I will just let me check once with the previous one. This one is your 1338.24, the first one.

The second one is 166.94, and the third one is 49.98. So, these three values are here. All the rectangle values that we have calculated in the earlier stage. So, all are multiplied by A, B, and C, and all the values are added together, and the whole addition is divided by 1200, which is your envelope area. This is your A envelope.

So, this is the multiplication value, and this is your envelope value. So, I got 9.9 W/m², which gives me an indication that the envelope, other than the roof, will transmit heat. Maybe gain or maybe protection, as a quantification of that particular heat gain, is 9.9 W/m². So, 9.9 W/m² will be fundamentally the performance of your envelope of that residence. That is the residential RE envelope, then T transmission transmittance value 9.9 for this particular building, based on the areas, based on the U values, whatever shading the 1 foot and 2 feet in those orientations, and all based on the location of more than 23.5° north. So, for all such locations, as per this particular code, Econimus Sambhita 2018 says that it should be a maximum of 15 W/m².

So, I am much less, so I am happy that this particular building with this particular envelope. Or whatever you may say, it will be good. It will ask for the code, and far below it is below 10, it is good. So, these are the steps, these are the steps for doing it. So, in the next discussion, we will see another problem of this kind, this nature. And we will see that for a practical case, for a particular apartment, there are two types of apartments we will see, and see how we will calculate these RETV values and a little bit of analysis of that.

So, in this particular lecture, we discussed the RETV values from the Econodio-Sambhita part 1, 2018. And we came to know that it depends upon the facet surfaces' characteristics. Corresponding materials for WWR, and these auditory takes care of the climatic zone and the building orientation also. Thank you.