BUILDING ENERGY SYSTEMS AND AUDITING

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Week - 03

Lecture - 11

Lecture 11 : Building Heat Gain Calculation

Welcome to the NPTEL course on Building Energy Systems and Auditing. Today we are in module number 3, and the first lecture of module number 3 will be delivered today. Module 3 will be based on building heat load estimation. So, we will discuss 4 to 5 types of modeling strategies. So, in lecture number 11, we will start with very basic computational steps of heat gain.

And we will discuss the heat gain through the conduction method. We have some kind of idea that we have already discussed that in the very first chapter. We will discuss the concept of the overall heat gain coefficient and also the heat gain changes due to solar radiation. So, first of all, we will start with a flowchart. So, in the computation of the heat load, in the very basic or preliminary type of computation, what we will actually require is the area of the surfaces or the envelope.

The area of the surfaces or envelope, if I want to say, means it is the area of the wall, solid wall, or opaque wall. The area of the roof and also the area of the windows, doors, etcetera. So, altogether, this area of the windows or the door, any fenestration that may be glazing or a curtain wall with some kind of transparent material, those come under the fenestration area, and there is definitely a horizontal area of the roof and also the wall. So, from the different envelopes, depending upon the material and depending upon the exposed area, the heat will gain or heat will actually be inducted inside the building. After that, we need to also justify or classify the different thermal properties of those materials, what the U-value of the material is, and also what the U-values of the roof or maybe the windows are.

And finally, we will compute with this equation, which is also known to us, that the corresponding area is multiplied with the corresponding E value and the temperature difference between the outdoor and the indoor, which will finally give us Q, the heat gain in watts. So, we will take a straightforward small problem and let us see how these steps can be taken into account. So, the profile of a particular building is given as 12 m x 10 m for the plan area. And the windows are also mentioned; there are W1 and W2, and the height and width of the windows are also given. W1 is 1.2 m by 1.2 m, W2 is 1.5 m by 1.5 m, the height of the room is 4 m, and the outdoor temperature C. So, there is a temperature gradient that exists, and I need to provide another set of data, which is the U values. So, the U value data for the wall, window, and roof are given as 2.13, 5.23, and 3.59, respectively, as the values of the U value for those three materials. So, then first of all, we have to actually take all the north, east, south, and west directions, and the directions are also mentioned here; the longer sides are in the north and south.

So, the north and south walls are 12 m x 4 m because the height is 4 m, whereas the east and west walls are 10 m by 4 m, and the roof is 12 m by 10 m. So, those length and height are mentioned here in a column. The window 1 and window 2 are also given. So, how many windows are on how many faces? Suppose if you see the north face, there are no W1, but there are 4 W2. See, in this particular figure, there are 4 W2s in the north, and there are 2 W2s in the north and south, and 2 W1s in the south.

So, like that, these things are separated. So, finally, what I came to know from this particular chart is the wall area and the window area. So, I have written it down in another table. So, the north facet, the window areas are 40.8 m^2 and 7.2 m^2, which is this. These two values, like that, the east facet is 34.96 and 5.04, like that, and finally, the roof is 120 m^2, which is the roof area where there is no window in the roof. So, now I know all the areas.

So, I can just add up all those areas. These are the areas. Wall area, wall is opaque. So, from 40.8, then 34.96, 41.5 to 137.12. So, those are the summation of all the wall area multiplied by the U factor, U value of the wall, which is 2.13, I have mentioned in the very first slide, and this is the ΔT. So, this is the ΔT value, this is the U value, and this is the sum of the area. So, if you just multiply this, you will get 4604 watt.

Similarly, the four window areas are also being added up over here. So, this is the area of the window, and this is the U value of the window, this is the ΔT same, and then the value is this 1581. And heat conduction through the roof is 120, which is the area. So, this is only one patch of roof, this is the U value of the roof, ΔT. So, the 6031 is the heat gain through the roof. So, these three now can be added.

Very simply, these 3 can now be added, and then I found out that this is 12261, sorry, 12216.96 watts. So, 12.22 kilowatts, which means almost 3.5 tons of refrigeration. So, how is this conversion done? So, I have divided this 12.22 by 3.5, which is the conversion factor from kilowatts to tons. So, now I have an Excel sheet.

So, the conversion from kilowatts to tons of refrigeration can now be seen. We can go to an Excel sheet and see how it can be calculated. So, in this Excel sheet, If I give the length and the height, suppose the length of the north facade is 12, and the south is also 12, the east is 10, and the west is also 10. The height is 4, which I have already set. So, 12 and 10 are the dimensions of the roof, and the numbers are maybe this is 0, this and let me check with the other numbers.

So, the southern side is 2, 2. So, the southern side face is 2, and this is also 2. The eastern side is 1, 2. So, the eastern side, this one is 1, and this is going to be 2. I think 1, 2, and this is 2, 0 on the western side. This is 2, and this is 0.

So, ultimately, you will get the total chart ready, and then the values of your total. From the north facade, it is 1.744 kilowatts of your heat gain. So, this graph, this particular graph, will show you this bar chart, which will show you the heat gain through different envelopes from north, east, south, west, and roof, and this pie chart will give you the percentage. So, the roof is the maximum, 51 percent of the heat gain is through the roof. And this is the other side, but here I have taken only the outdoor temperature and the indoor temperature difference over here, you see.

And this is the place where you can put your values of the U-value of the wall, U-value of the roof, U-value of all the window values, SHGC values, we will take in the next and we will see. So, in the presentation now. So, we have this chart ready. So, whatever we got, the final value is 12.1

to 12.2, almost the value of your heat gain through the conduction or so, and the 3.5 is your tier. So, that on this particular chart, we have shown just now. Next is the concept of the overall heat gain factor. So, if you see, as we have just now calculated, The first terms, 154.4, 21.6, those are the 120, those are the surface areas.

If you add them, you will get 296, which is equal to the total envelope area. This envelope area is the perim multiplied by 4, and this will be the area of the roof. So, the total 296 is the envelope area. I think we have to multiply this by 4 because the height is 4 m, or so we will correct it when we distribute it to you. Now, the next layer: if you see this, these are the respective U values of different portions of your envelope. That is, 2.31 is for the wall, 5.23 is for windows, the roof is 3.59, and finally, the last part is the ΔT part, okay. So, if you see this, it is the product of the area and the U value.

And if you take the temperature difference, this product of the area and the U value is called the overall heat gain coefficient. So, that is the kind of criteria for the heat gain of the envelope. If these overall heat gain coefficients are higher, it will definitely admit a lot more heat. So, that will give you a kind of health of the building. If it is low, then it will not admit that much. So, this overall heat gain coefficient, which is the multiplication of the corresponding area and the U value of the different materials of the envelope, is a kind of scenario that comes from our architectural design of the building because surface areas and all are decided upon, as well as the material U value. Multiplied by the temperature difference, if I multiply with different temperature differences, I will get different heat gain coefficient values.

So, whenever the architecture of the building is fixed, this OHGC is fixed. Now, on different days, the temperature is not always going to be 38°. In the evening, it will be less. In the morning, it will be less, and in some other months, it may be more. So, like that, the 38 may change to some other°. So, ΔT will change, but each time I multiply it by the OHGC of the building, I will get the total amount of heat.

So, this OHGC in my case is 872.64 and With the temperature difference, if I multiply with the 14°, in my case, it is for the 38 minus 24, which is the 14° difference in this case. So, directly if I multiply, I will again get this 12.22 kilowatt. Which I got by breaking down all the things. So, the summation of all these things, as you all know, is going to be 12.22 kilowatt, otherwise, I can actually go through the OHGC factor.

So, now suppose the temperature I just told you, I mean that this temperature has changed instead of the 38°, it is 40° outdoor temperature, and indoor temperature I kept as 22°. So, the temperature difference is 18°. So, what I will do is I will just multiply the OHGC with the ΔT, which OHGC is 872.64, and now the ΔT is this, which is now a little higher, from 14° to 18°. So, your total admitted heat load is more than 15.71 kilowatts.

So, if I will try to model a particular building based on the outdoor temperature only, no radiation, no other kind of scenarios, only the outdoor temperature and indoor temperature. It is best to go with the OHGC, first compute the OHGC, and see the scenario changes in the hotter month, the summer month, the winter month, or the average temperature, or whatever it may be. So, now, next let us see the heat load computation with the solar radiation. If the solar radiation comes into the panel or the building, different panels of the different surfaces of the building, also the roof, then what will be the change.

So, I have given the 3 solar radiation phases. Suppose in the morning at 10 o'clock, the sun angle is such that the azimuth and the altitude angle are such that Only the east facade is receiving 150 W/m^2 radiation because, you know, the radiation unit is W/m^2 The south is getting 75 W/m^2, and the roof is getting 30 W/m^2. The north is 0, no radiation over here, and the west is also 0. Now, at this particular point, suppose the north and west are 0; they are not getting any So, I have to give some additional data to model this one. I have to give SHGC because I need to give SHGC due to the solar radiation. There will be some heat admitted through the window by radiation.

There will be some kind of absorbance and surface conductance. From there, I have to find out the solar air temperature, which is actually the body temperature of the outside wall. The heat transfer will take place, or the heat conduction will take place, not because of the outdoor temperature but because of the outdoor surface temperature. So, I have to go to a new flowchart where I have to first compute the solid temperature by virtue of this equation. This equation has also been discussed in the very first module. The outdoor temperature plus something plus I into A by F naught, A and F naught are the surface conductance and the surface absorbance and the surface conductance.

And instead of the To I have to take the solar air temperature over here. So, this has to be taken, and also additionally A into SHGC into I has to be taken. I here is the solar radiation. So, I know this particular the adjustment, the solar radiation adjustment, has to be taken into account for the east, south, and the roof because these three surfaces are having some kind of solar radiation as per the data given in the last slide.

But north and west will remain as it is because the I value is equal to 0. So, the solar air temperature will be equal to the outdoor temperature of 38°. So, I have done the calculation. So, I have given three sample calculations for the north wall. So, for the north wall, as the solar radiation is 0, you see the solar air—I am sorry—as the radiation is 0, the solar radiation is 0.

So, the solar air temperature becomes the same as the outdoor temperature of 38°. Whereas, in the south facet, the the solar air temperature—the solar radiation is 75, that is the I value is 75. This is the TOA, and this is the absorbent for the windows, and this is the F naught for the windows. So, there is a little hike in the temperature. Instead of 38, you have to take 40.5, you see. So, similarly, for the east facade, it will be 43.

And for the roof, it will be 43.6. So, for the roof, the I value is this much—300 or something—and then your absorbent A and F naught are some different values. So, there is almost a 5.6° hike in the solar air temperature. So, that has to be taken, and the T in—what is T in? T in is your indoor set point temperature of 24°.

And your ΔT will now change for the wall, the windows, the roof, and all those elements. Everything has to be taken into account in your equation number, where everything has to be multiplied by the corresponding surface area and the U value. So, with Excel, we can do it very easily. So, that particular value, if you read here, suppose I just see the heat conduction to the east wall. Now, the east wall area is, you know, this is the east wall area. There is an equal sign over here. 4.39 is the east wall area, 2.31 is the area, this is the U value that will remain the same, but here you see this is your T indoor, and these 41° is T solar air temperature.

So, now you are getting a different value of Q. Similarly, heat radiation through the south window will be A SHGC into I. So, the SHGC factor has to be taken into account. So, this is 397, 397 is the south facet, and this is through radiation. So, this is your A into SHGC into I. And this is your heat conduction, which is A x U x ΔT, and this ΔT is the difference between them. This is your ΔT, right. So, I am getting heat conduction through all the surfaces, heat conduction to the wall, window, and also the roof for all the facets. This one, heat conduction to the east wall, is 1265. This is what I have actually calculated or just as a token of explanation.

And now, if you add up, you will get the total heat conduction. Through those five surfaces, starting from the north, east, south, west, and the roof, plus these two values will be your total heat conduction for the radiation through the window because only the east facade and the southern facade have the solar radiation. So, the solar radiation. So, the total solar radiation due to conduction and radiation will be something like this, and again, if you add up the sum, it is going to be 16.81 kilowatts. So, almost like 16.18 kilowatts or something.

So, we can see in the Excel we can see in the Excel. So, I have given the facet data. So, for that, it can now be 16.51. So, if I do not give any of these values, if I put all these values as 0. So, 0 0 I will get 12.48 for 4 6 or so.

So, only for the conduction I am going to get the values, but if I just give some, suppose if I give some north facet value, suppose the north is maybe 100, the east is maybe 200 or something, and the roof is maybe 250, I will get some different value, ok. Suppose at some other time, suppose in the afternoon, this north is going to be 0, the east is also going to be 0. The south facade may have 300, the west facade may have 250, and this roof may be 400, then you will get some different value. So, you can change the param, you can change the values, you can also change, suppose in this particular case, if you want to see, if I just go for

Suppose, let us read this one as 19 point something, 19.26 is the total heat gain, and 5.5 TR tonnage of refrigeration is the total amount of heat the air conditioner required for this room. So, now if I just provide a better material, suppose 1.5 is the material value of the wall. So, see, it changes, it goes down by 17 from 19 to 17. Suppose you further improve the window value from 5 to 3, 3.5 maybe 5 to 3.5. Further, it will give you a reduction in the total heat gain from 17 to 16.8 or something.

You can also improve the SHGC value, which may be 0.3 or something over here. So, again, there will be a further decrease in the heat gain. So, this is a very interactive chart, and you can actually use this chart. I will send this chart through our discussion forum. And, you can actually go with this particular chart, and suppose in these particular cases, you just decrease the internal temperature.

Suppose the set point temperature, the internal set point temperature, is 20°, not 24°. So, what is going to happen? The total heat load will increase or decrease. The total heat load will increase. So, from 15.57, it is definitely going to increase to 18.57 or so. Right, because I am decreasing the internal temperature set point from 24 to 20°.

So, suppose the outdoor temperature is very hot, instead of 38°, it is 42° or something very hot on some odd days. So, definitely, it is going to improve or increase. So, it is now 18.57°. So, it is a very interactive chart. You can change the peak value the peak value of your solar radiation and just find out what will be your total tonnage of refrigeration required for this particular room. You can have the set and absorption values, you can have the surface conductance values that you can keep, and this chart you can see the different conduction values and the radiation values and the total conduction plus radiation values for your heat load.

And the pie chart and the bar chart are going to help you. So, again, let us go back to the PowerPoint presentation. So, here we have that particular discussion about what we got if we take care of the radiation also on the surfaces. So, the nutshell of this particular discussion is that the total building envelope through the conductive and the solar radiation has been taken into account, and the cooling load is estimated and explained.

And we have explained one very important criterion, which is the overall heat gain coefficient, which is a very easy way to understand, but definitely it is kind of, you know, an approximate way to find out the heat gain coefficient. We will take this particular overall heat gain coefficient in the next lecture to see how that will help us to estimate the heat load. Of course, this is approximate, but still, we can do that and estimate some kind of heat transfer load. Thank you very much.