BUILDING ENERGY SYSTEMS AND AUDITING

Dr. Shankar Pratim Bhattacharya

Department of Architecture and Regional Planning

IIT Kharagpur

Week - 04

Lecture - 16

Lecture 16 : Envelope Performance Factor

Welcome to the NPTEL course on Building Energy Systems and Auditing. So, today we will start module number 4, a new module. Module number 4, the 5 lectures will be on the Energy Conservation Building Code (ECBC). And at the very beginning, we will start with the envelope performance factor. So, in this particular lecture, we will give a brief overview of the ECBC code and also discuss how to compute the envelope performance factor for a bit.

This particular code, the Energy Conservation Building Code, was first established in 2007. To provide and establish the minimum standards for building performance from an energy point of view. So, from today's modern needs of society from a sustainability point of view, it is really one of the important steps ahead. This particular code has some areas of focus, and after 2007, the 2017 code was revised. In the 2017 code, a provision of minimum energy efficiency standards for design and construction was mentioned, as it was in the 2007 code.

It also introduced daylight requirements for buildings and shading. We will discuss the daylight part in this particular module itself, maybe in the last two lectures. It also talks about renewable energy systems, which we will discuss in our lecture at the end of our course. It encourages the retrofitting of buildings, which we will also discuss in some of the lectures, maybe in the seventh or eighth week. And it leads to near-zero energy buildings, not completely zero energy, but near-zero energy buildings. One important thing is that this particular code or the method it has suggested in that code.

Was applied to a new commercial building. This particular ECBC 2017 is basically for commercial buildings other than residential buildings. For residential buildings, we have another code, ECO NIVAS SANGHVITA. So, that also we will discuss next. So, for any new commercial building which has a connected load of 100 kilowatts or more or a connected demand of 120 kilovolt-amperes or more.

So, for those larger-scale buildings, this particular code or these particular provisions are applicable. So, what is the purpose of this particular energy conservation code? It is a code of practice. So, it has some rules, some provisions, and some alternatives to consider. In that particular alternative, choose an option from the designer's perspective or so.

Finally, it focuses on energy, sets some standards, and also provides some enhanced levels of energy efficiency. So, it depends on the users' which level of energy efficiency they will try to achieve through their building design, and of course, there are some minimum requirements and benchmarking. This particular code or these provisions are applied to the building envelope because the building envelope, which we have been discussing for the last three weeks, is what actually interacts with the outside environment. So, that envelope's heat gain or heat loss is actually through the envelope. So, it discusses the building envelope.

It discusses the mechanical systems, equipment, and all those kinds of things which are also necessary for running the building. It includes air conditioning systems, hot water supply systems, and all. Interior and exterior lighting, that is artificial lighting, is also included in this particular code. And the power motors, electrical power motors, the renewable energy systems are also included. So, basically, we have discussed all the things, the theories of all the things, we have discussed the envelope theories of the heat gain, we discussed the mechanical systems including the HVAC, air conditioning, and service systems and all.

We also discussed the interior lighting systems, electrical power, motor systems in our second week lecture. Yes, renewable energy systems we have not discussed yet. So, we will discuss it definitely in the latter part. We will today discuss the building performance, the building performance of the ECBC. In this ECBC code, as I told just a little earlier, it has included all types of buildings except, I think, two types of buildings, one is residential and one is industrial buildings, these two are not included.

So, it includes the hospitality that means, this is 5-star, 4-star hotels. It includes the educational buildings, colleges, universities, institutions and all, the healthcare buildings, the hospitals, the shopping complexes, the business houses like the offices and all large and small-scale offices, and it also includes the assembly buildings like theatres and multiplexes and all. In this particular code, they have prescribed two types of methods. And after these two types of methods, you need to simulate or calculate and then you have to see what is the actual performance of your proposed building. So, the first method is called the prospective method where it is an easy method, it is a method that you can compute by your own with the help of an excel sheet or maybe hand computations and all.

This particular method includes the. The building envelope tradeoff method is that particular tradeoff method. So, it is the envelope tradeoff method. So, in that envelope, you know, there are a lot of surfaces: there are roof surfaces, wall surfaces, glazings, windows, and all. So, we can trade off; we can increase some portions, decrease some portions, and change the values of the materials, and that is the kind of tradeoff.

So, by virtue of that building tradeoff method, they are actually proposing a particular factor called EPF or envelope performance factor. So, how your envelope is going to perform in the future. See, the building has not yet been constructed; it has been designed by an architect, and based on that architectural design, how it will perform is indicated by this prospective method if we go through this envelope performance factor. And you have to submit, suppose in some kind of project, you have to submit this EPF report and this building envelope tradeoff report. The second method is the whole building performance method, in which we can use some software and estimate the annual estimated energy.

So, that is a straightforward thing; you just do some kind of software simulation and find out what the total annual load is. But, when you start any kind of design, sometimes that design may change, or there may be some uncertainty about whether your design will be selected or not. So, in that particular stage, a whole building performance is not very much required because it requires time. Once the design is finalized, once you get the particular job, then probably the whole building simulation and performance method is fine. But if you have two or three alternative choices, if you are just in the bidding process, you are just bidding for a particular design, so in that particular scenario

The prospective method holds good; it is easy, less time-consuming, and it can be done in-house because, with the simulation and standard software simulation, you have to actually employ somebody or you have to go to your consultant. So, they will charge you and all. This particular efficiency or this performance level in the ACVC code. In the 2017 code, they called there are three such standard levels or performance levels. The first one is called the ECBC building. I have highlighted it in blue color, the ECBC building.

So, if our building can achieve that particular typical EPF point. So, I may say that this building is an ECBC building. Which is actually going to reduce, I mean, the energy consumption of that particular building may be reduced by 25% with respect to the typical building where you have not taken any kind of ECBC consideration. You can go further; you can lift your design strategies or the ECBC standard a little more, a little stricter way, and then you may achieve an ECBC plus standard. So, this first one is just ECBC, the second one is the ECBC+.

And if you can achieve that ECBC+, you may say that it will go on to save almost about 35% of the energy compared to the typical building. And the third level is super-ECBC, which is further more very well guided and very strict ways of doing things; there are no such options available maybe, but if you can achieve that particular ECBC super ECBC point or whatever. Then, you may say that this building is wonderful from the energy consumption and conservation point of view, and it will be almost like 50% less compared to a normal or typical building. So, we will see this ECBC, ECBC plus, and super ECBC classification criteria in the next lecture. So, let us first discuss the building envelope tradeoff method.

Based on this method, we have to find out this EPF, which is the envelope performance factor. So, first of all, it is the performance of the envelope. And in the envelope, mostly it has three things, as you know: it has some kind of wall system, an opaque wall system, it has transparent glazing's, and the fenestrations, which have a ratio called WWR, the window-to-wall ratio. So, this particular envelope tradeoff method or this EPF factor computation is not suitable or should not be used where the WWR is more than 40%.

That means, if a building is fully glazed or mostly glazed, so the amount of glazing is much higher, around 50, 60%, or maybe 80% in some cases of these buildings. This particular method is not suitable for that or shall not be used for that. And there are no other alternative methods prescribed as of now for buildings which have WWR more than 40% by ECBC. Probably in the future, they may come up with some kind of guidelines. So, as we all know, this envelope is the prime boundary where through which the heat gain and all these things are happening. So, ECBC provides a particular calculation way to find out a factor, and we can compare your 2-3 alternatives or 2-3 architects who were bidding. So, whose performance was better based on this particular number or this particular factor, which is called the EPF. So, if you see an envelope performance factor, if you want to elaborate, we will see the mathematical formulas, but if you actually see, there is a design development. In the design development, what happened is we actually do some kind of compact design compactness; we see how much compact your design is.

So, you see the envelope surface area. How much is the envelope surface area? So, those are all numbers. Envelope surface area is a number. How much is the volume of your building? That is also a number. What is the building orientation? That may not be a number, but at least you may say that the longer side is in the east-west or the south-north directions. So, there may be some kind of three to four choices over there.

The amount of fenestration, that means WWR and whatever, and also the amount of area of the fenestration. The types of shading devices are the long hanging devices, the overhangs, or whatever fins, and all those kinds of things. So, those are all design developments. The architectural design we do, we design the building, compact building, much more surface areas, volumetric expansion, building orientations, and all those kinds of amounts of illustration. Everything is design development. The second step, what we can do after the design development is done, is we can actually put our choice of material, envelope material.

So, what should be the wall material should be normal brick, fly ash, SCC blocks, or maybe normal bricks with the cavity walls. So, there are a lot of choices, like normal brickwork or fly ash brickwork with some kind of insulation also. So, there are a lot of choices. What could be my roof material?

What could be my window material? Is it a double-glazed or single-glazed window, or it may be a very reflective kind of window, or maybe it is a normal kind of one-leaf 6 mm glass or whatever. So, finally, the U-value and SHGC will come into the picture, and then that will devise some kind of heat gain formulas or heat gain phenomena also. Of the design development and the envelope material choice, and the third one is the definite to the climate because of where this particular building is located. Is it in these 5 climatic zones that India probably has? These 5 climatic zones, probably not, probably when there are the 5 prominent climatic zones.

So, where is your building located, and also some of the other things which are required for the climatic data? Of the particular area. So, latitude data or the orientation also comes in some way or other. So, in this particular case, out of these three baskets, the first two baskets are the architectural design plus properties of envelope material selected for the building, and the second one is your location, latitude, and climatic zone. So, that fulfills our entire design process.

At least the envelope portions may not be the working or functional portion of the building, but the envelope portion of the building. I am not interested probably, as of now, in what your functional requirements are and how your building will function and all, and the fire exits, all those things, no. It is all about the envelope of the building, the location-specific, and the material-specific. So, in the design development stage, we can find out the roof area, we can find out the wall area, we can find out the The window area, and the window area also you have to find out separately: how much is the north window area fenestration, how much is the south fenestration, east and west.

We can also think about how much the U value of the roof material will be, what the U value of the wall material will be, what the SHGC and the value of the fenestration materials should be in all four directions, and also from the climate data, this code will help me. The first two, if I say that the first one, calculate as per your architectural drawing. Your architectural drawing is ready. So, you can calculate the roof, wall, and window area. This you can obtain from the material specification mentioned in the BOQ and all these drawings, and all, what is the material, brick.

So, you know its U value, take that one. This climatic data are the C factors, C, C factors, capital C. For the roof, you have to collect or select some kind of C factor from the CVC code. As per the building type and the climatic zone. You have to, for the wall, collect the C factor for the wall for different climatic zones and the building type, and also for the C factor for fenestration. There are two C factors for the fenestration, one is directly linked with the U value, and one is directly linked with the SHGC.

So, these are the code C factors mentioned. See, there are five such tables there. So, this table, the first table, is probably for some climatic zone that was probably cropped. The second one, you see, it is written as the hot and dry climatic zone also.

So, this is for the temperate climatic zone, this is for the cold climatic zone, and this is for the hot and humid zone. So, this is definitely for the composite climatic zone. So, those are the C factors we will see how they will be taken into account. So, finally, what are the steps involved in this EPF? So, what you have to do is find out the EPF of the roof, the EPF of the wall, and the EPF of the fenestration, and we will arithmetically add those three to finally find out the total EPF of my building.

Now, the EPF of the roof will be calculated by multiplying three things: the U of the roof, the A of the roof, the area, and the U value of the roof, and the C of the roof, the C factor that has to be taken from the code. The U value is your choice, A is your area, so you have to calculate that from your design and put in the material, whatever it is. And if you have the summation sign, it is there for nothing; if your roof has 3 or 4 portions with different materials, you can add those.

Similarly, you can find out the EPF of the wall by multiplying the Q of the wall, the A of the wall, and the C of the wall mass and other walls. So, mostly we go with the mass wall because we usually go for the mass wall; this is for the other type of wall, the curtain wall. So, mostly we will not take that one. So, the C of the mass wall will again be taken from the code.

Now, this is a big equation for the EPF of the fenestration. So, if I go back, these two take care of the EPF of the roof. This will take care of the EPF of the wall. Now, the fenestration is taken care of by this equation. The big equation looks very big, but it is a very rhythmic equation.

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\begin{aligned}
EPF_{Fenest} = {} & C_{1Fenest,North} \sum_{w=1}^{n} U_w A_w + C_{2Fenest,North} \sum_{w=1}^{n} \frac{SHGC_w}{SEF_w} A_w \\
& + C_{1Fenest,South} \sum_{w=1}^{n} U_w A_w + C_{2Fenest,South} \sum_{w=1}^{n} \frac{SHGC_w}{SEF_w} A_w \\
& + C_{1Fenest,East} \sum_{w=1}^{n} U_w A_w + C_{2Fenest,East} \sum_{w=1}^{n} \frac{SHGC_w}{SEF_w} A_w \\
& + C_{1Fenest,West} \sum_{w=1}^{n} U_w A_w + C_{2Fenest,West} \sum_{w=1}^{n} \frac{SHGC_w}{SEF_w} A_w
\end{aligned}
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It has four lines. The first line is for the north fenestration. The second is for the south, east, and west. So, I told you earlier that you have to calculate the area of the north windows, south windows, east, and west separately, not like the wall. The wall area and roof area you have to calculate as a whole.

There is no need to calculate the east wall area or the west wall area, but here you have to calculate the different directions. And the first part, which is the C1 part, the first part of all, is actually with U into A, that is the U value of the window, because you know the window takes care of both the conduction heat gain and also the radiation heat gain through the SHGC. So, U of the wall multiplied by the A of the wall and the corresponding C factor of the wall and A of the area of the window. And the SHGC of the window and the corresponding C2 factor. The C1 factor is for the U values, and the C2 factor is for the SHGC, right?

And there is an SCF, SCF is a multiplier which is because of the shading and all that is called the equivalent shading factor. Equivalent factor. So, we will discuss how to calculate the shading equivalent factor in the next lecture or maybe the next two lectures. So, for each calculation, let me see how I can calculate. So, suppose there is a building, its dimensions are 50m x 25m x 8m, north-south oriented, 20%.

It has U-values of the roof, walls, and windows given, SHGCF of the window is also given, and thirdly, we need the data of the climate. So, it is a daytime building, a daytime office building, which runs for 12 hours only in the morning and is located in the hot dry climatic zone of India above 15° north latitude. So, the first line gives me the design development sense that it is a building with areas and all these things, window areas and all. The second line gives me the envelope material choices, and the third line gives me the climatic data. So, based on that, I have to calculate the EPF of this building.

So, first, what I did was I found out all the facade areas, and based on the WWR, I have a WWR constant of 20%. So, based on that, I found out the window area, all the facade window areas, and the wall areas. So, these bold digits are required for my final calculation. I require the whole roof area for my calculation. I require the whole wall area; I do not require individual wall areas, I require only the whole wall area, but I require individual window areas for my calculation.

So, this is that particular part from the code if I just go back a little bit. This is where you have to take the proper climatic zone data. So, my climatic zone is hot and dry. So, I have to take this particular table number 4.17. So, in that table, I have that one crop, and this is the particular table.

So, you see, I have first found out the EPF of the roof. So, there are three things: one is the area of the roof, which is 1250. multiplied by the U of the roof, 2.5, which is given in my problem, and the C of the roof is 14.82, which I have taken from this. Now, why have I taken from this? Why not 21.12?

Because this is a daytime business building. It is not a 24-hour building, hospitality, healthcare, or whatever. No, it is a daytime building, an office building. So, I have to take that particular part, this particular part of the table, right? This second part is for the 24-hour building table also.

So, this one is next. So, then this is the EPF of the roof, 46,000 something. The EPF of the wall, I know 960 is the wall area, 1.5 is the U value, and 6.4 is the mass wall. I have taken the mass wall because this mass wall is mostly used for the cases, and I have only one type of wall. So, I do not have a summation.

So, that is invalid for me. So, finally, 9216 is the EPF of the wall. Now, I have to go to the fenestration. In the fenestration, you see this is that big formula we are discussing. Now, this is the C factor of U corresponding to U. So, that means the C1 is associated with U on all four sides.

So, minus 3 - 0.37 is the U factor C value of the north window. So, the C1 for the north window should be -0.37, and -1.35 is for the south window. So, -0.85 is for the east, and -0.8 is for the west. And these are the purple color, big values are the C factor for SHGC, which is absolutely absent in the case of walls because SHGC is 0, or there is no concept of SHGC in opaque walls.

So, for the north, C2 are for the SAGC because C2 belongs to the SAGC part of the equation. So, 101 is for the north, 252 is for the south, 219 is for the east, and 226 is for the west. So, you just have to carry this number from the appropriate hot and dry climate zone, appropriate daytime or 24-hour building, and now I have calculated. So, those numbers have been taken. I know the U value of the windows is 0.75, SHGC is 0.3, and these are the minus values, minus 0.37, whatever we have just discussed. And this 101 is for the U, and this is for the SHGC.

So, this is the U value, you know, 0.75, and 80 is the area of the north window, 80 is the area of the south window, 40 is the area of the east, and 40 is the west, and all are multiplied by 0.75, which is the common U value. And those negative numbers are the C1 factor for all four sides. Multiply that, and you will get the number plus. The second part. The second part is this: 0.3 is the SHGC. You see, this 0.3 is the SHGC, and this 80 and 40 are the areas, and this 101, 252, 219 are those corresponding C2 factors associated with the SHGC for all. Multiply them and add them. So, -22.2 + 2439.84. So, it becomes 2417. So, this is all four, and add it up. So, the total EPF of the fenestration is 13714.5.

So, I got the EPF of the fenestration. The equation may look very clumsy, but it is a very rhythmic equation.

If you understand this equation once, then probably you can just do it by calculation by virtue of the Excel sheet or so. So, these are the—sorry, I should have shown it before. These are the areas of the windows or so, which is cropped, and then this is the total EPF I have. 4, 3—the EPF has calculated for the roof, wall, and fenestration.

So, 69,243 is by EPF proposed—the proposed EPF of my building. And these are the three out of that; you see the EPF of the roof is very, very high—46 thousand something, which is almost 67% of the total EPF value. The wall is less—13%, which is 9,6216, and the EPF of the fenestration is 20% or so. For at least by this calculation, based on my architectural design surface areas and all, based on my WWR of 20%, based on my chosen materials or so, my proposed EPF of this building is 69,243. It may be good, it may be bad, or maybe worst or very good—I do not know, but that we have to see with the ECBC or ECBC plus or super ECBC criteria in the next lecture.

So, what we understand or what we do here at this particular time is we have just understood the energy building conservation code practices recommendation—some of the recommendations, of course, a brief outline—and also, we have just completed seeing how a simple calculation for just like a small building, of course, but how this particular equation actually takes care of the envelope performance factor (EPF). Thank you very much.