BUILDING ENERGY SYSTEMS AND AUDITING

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Lecture 35

Lecture 35 : Energy Retrofitting of buildings Types System and key phases

Welcome to the NPTEL course on Building Energy Systems and Auditing. We are in the module number 7 and this is the last lecture on the module number 7. Module number 7 is basically we are dealing with the building operational energy and the energy retrofit. In the last lecture of the module number 7 that is lecture number 35, we will be going to see the energy retrofit of building and we will analyze that one from the point of view of the cost energy and the carbon payback. Also, we will discuss some the concept of the cool roof systems.

So, first of all let us discuss the cool roof system because as you know the most of the heat gain in a particular building is actually through the roof because the most of the time the roof is under solar radiation and extensive solar radiation particularly in the climatic zone in the hot and dry climate. climate, composite climate and also the warm and humid climate. An extension of the daytime and also that daytime extension is in the summer time in the that depends upon the latitude, but this extension of the daytime and the amount of the incident solar radiation creates a have a problem in the top floors. So, there are some guidelines which actually first has been derived by Government of India, the disaster management or National Disaster Management Authority NDMA as a handbook. The name of the handbook is Heat Wave Action House Owners Guide to Alternate Roof Cooling Solutions.

It was published in 2021 April. See, as I said that this roof is one of the potential areas where there is enormous amount of heat gain is there and the it actually increases the average temperature almost around plus 45° in the some of the areas of the composite and the hot dry climatic area mostly in the Uttar Pradesh. Delhi, Rajasthan and all. And this particular create lot of the issues and then the excessive amount of the air conditioning

load and if not air conditioning load if you cannot actually in the hot dry climate, we cannot open the windows because the outside air is extremely from the offensive in the nature from the temperature point of view. So, the one of the solutions is the cooling the roof systems. So, there are a manual.

So, I will actually forward this manual in our forum and also, I will go through this manual little bit. So, this particular the handbook by NDMA has given so many types of solution and these solutions Basically, can be employed in the residential building or any type of building to safeguard the top most floor. It can be gone with a bamboo thatch screening type of solution, green net shading, mist cooling solutions, cool roof paint. I think there is a small there should be a T over here it is not paint it is a paint.

the then the the gravel roof, the modified bitumen membrane, then the the the thermoplastic member members, the the paints and finishes on the rooftop, hollow concrete tiles, heat insulation tiles, the inverted iron pot method, mass that kind of a thing is also there. The extruded poly-illustrate method we have already discussed that one in the earlier discussion. Lime concrete is a very age old kind of solutions which is available with us. Broken china mosaic or the cellulose fibers are also applicable. So, in that particular guideline or that particular handbook.

if we go, we will actually this particular handbook is based on the different locations as per our zonal map climate zone map India is divided into five climatic zones. So, it is the all the solutions which was mentioned over here may not be applicable for all the type of climatic zone. We can select that it was mentioned that which climatic zone is has to be and there are two type of expertise that may required. The first one is do it yourself kind of a thing that we can do by ourselves only with a little help of somebody others. In second case maybe some of the cases we require some kind of a technical expert.

So, that is also mentioned in that handbook. And the building typology—there are four types of typologies: if this is a sloping roof structure, what kind of scenario we can go with; if it is a flat roof; if it is a new building; or if it is an existing building. So, based on that, the different types of building typology are also suggested in that book. And in this book, each and every method that we have just now discussed is given this kind of visual—the symbols. The climatic zones: HW, which means hot and dry; WH, warm and humid; and composite, CM, I think.

This CM is composite, right? CM. So, these three climatic zones I can go with this bamboo thatch or palm leaf roof screening. So, it has mentioned in a diagrammatic view

also what the different layers are and what the different types of supporting structures are required. Building typology is also mentioned—it is given as a do-it-yourself kind of scenario. You do not need any kind of experts; see this is that symbol. So, like that, it has mentioned over here, and also in that particular each page consists of one such kind of treatment. The material is readily available because thatch and those palm leaves are available everywhere.

It is lightweight, has high insulation capacity, and is comparatively less costly compared to many other treatments. The ridge is the weakest point of the thatch roof. So, that is also mentioned over here. It is prone to fire or fire risks, and those are also mentioned. So, it is giving you almost medium to high.

kind of the sensibility from the thermal gain. 6 to 8 month is one of the issues probably for this particular thing that after 6 to 8 month you may need to change the scenario because thatch will definitely be going to have a problem after a monsoon season or so. So, that period 6 to 8 month or whatever may be that is giving you the what is the time period of this particular installation and then thereafter you have to change it. The cost is mentioned as less than 100 rupees per square feet.

So, that is also you must when you choose from the basket you must know. Then, there are steps that first you have to clean the roof surface and then there are the you have to fix the bamboos and then there are thatch and all. So, it this is something like that and then we may I may go to that particular handbook itself. And, then we can so, this is that handbook that you can actually download or we can provide in our forum. This is national disaster management authority handbook.

So, in issues these are all the type of the the system that has have been mentioned I just taken from this particular handbook all the references. So, these are the typical the way that we can follow we can go for the cool roof systems, cool wall systems. So, these are the typologies and then it is that that what we have just now discussed that bamboo thatch and palm leaves. So, in a page, you need you I mean visually and the graphically they have mentioned everything. Then next one is the green net system you see this is also mentioned over here with a figure and the steps of the the first second and third step this is a medium type of scenario.

And, it is highly durable. It has been noted that this is going to last 2 to 3 years, and you have to change it periodically. Then, you can go for the mist kind of cooling system. You can spray water on the roof, and then the roof will be cooler. This is the way. So, this is a

roof paint system which has a lifespan of 3 to 5 years. So, you see, in this particular thing, there are 5 steps. So, it is very informative—this thing, a very informative handbook. One must visit this particular handbook and take that one in the application that may reduce the roof heat gain.

It will not only reduce the heat gain if you have air conditioning in the upper floors, Then, definitely, it will give you a lot of relief. If not, then it will reduce the temperature, and you can go with the ceiling fan or other types of forced or natural ventilation. This inverted earthen pot, if you see, is one of the very old methods and a very proven method. There are three layers: the first layer is this earthen pot, then you have to put the cement mortar, and lastly, go for the IPS kind of floor finish—the Indian patent stone kind of cemented floor finish. So, this has given you a lifespan of 20 to 30 years.

So, this is one of the manuals; the other manual It was published by—this is also a cool roof manual—published by the Delhi government way back, maybe 10 years ago, because Delhi is in one of the areas of the composite climatic zone of our country, and there are a lot of problems regarding the scorching heat in summer months. So, they have also provided pictures and all. They have given the stages of construction and what to do and how to go with this roof treatment, or this is the ceramic tiles roofing. Then, this is some other type of adhesive, and then providing the roof with a light color which has a high albedo. So, like that. And if you see, they have done some case studies on page number 26 or so—yeah, this is page number 26—where they have given the study which is shown like this, the dotted line which is here.

So, this is the pre and this is the post. The pre-application time was highly diurnal variation of the temperature of the roof. And then after the application, you see the amplitude of the variation is quite low, and this is damping. Actually, this particular amount of the heat gain is damping. So, this is very interesting. They have also conducted some kind of study. And the heat flow, also in watts per meter square, they have studied. This is the first one, the temperature study. Then the energy-wise study also they have calculated, and it shows that there is an enormous amount of reduction in the temperature heat gain and also in the energy.

So, let us go back to the PowerPoint presentation, and so we understand that the roof is one of the issues, and this can be sorted with this particular type of cool roof treatment. Handbooks are available. Next, we will see the LCS stages. The LCA stages, if you see, it has various stages. In some of the literature, it has been used like 7 stages, 5 stages, or

so. But if you just go with those in detail and if you just comprehend that one. So, we can actually see it is a 4-stage, which we have been regularly talking about since module number 6 onwards or maybe 6 onwards.

So, the first stage is the product stage where any material—because you know this rehabilitation or this particular retrofitting is based on the material life. And material has two types of life: one is called the technical life, where the technical property will be degraded down to a certain point that you have to remove and you have to put the new material. And there is a second way we can see another type of life: the aesthetic life because it gets discolored sometimes or it may fade out. So, we may have to change it. So, this depends upon the material and the material property.

So, in the in terms of the energy retrofit also we should see those the progress of the material or this equipment or maybe any kind of the the object which I going to provide in the building which can reduce down my energy bills or so from the production stage to end of life stage. So, in the production or the product stage the raw materials supply transportation to manufacturer and the manufacturing will be done that we all know in the construction stage B 1 and B 2 are the transport to the construction to the site and the construction installation process. The use stage as C2, C1 to C4 are the use we can do some kind of maintenance, we can repair and replace and then finally, we can retrofit the retrofit the material and at the end we can go for some kind of a demolition, we can give for some dismantling, sometimes we can recover that one and reuse that one or recycle you can send it to the recycle plant. So, this same will follow for the for the any retrofitted material or retrofitted scenarios.

So, this particular side which is the the productions side is called the upstream the process process area. This construction is stage is the core the process area and the use and the end-of-life stage is called the downstream process area. Now, based on that we understand some of the analysis or the part of the analysis that we have to do for based on this the LCA is two more type of analysis we have to actually execute if we have to. So, if you have to give some report or any kind of choice basket if I give. I told you in the last lecture is that we give mostly two three options what type of retrofit a particular client may go for, but just two three options will not be going to serve our purpose we have to give some kind of a thorough analysis of that.

So, one of the analyses we did discuss in the last lecture is the economic analysis. We have to find out the how much is the payback period. We have seen in the last lecture that

the LED lamp gives me a quite handy payback period of almost about 340 days or something like that if you remember. So, that is less than a year. So, I may go for that, but if suppose the payback period is quite high and quite high is like 5 years or 7 years or something like that and in between that due to this LCS stage you have to replace the material.

So, then it will be a difficult because we in I mean the before the payback period I have to replace the material. So, then they then definitely that particular that particular choice basket I may not prefer. So, that is one of the ways to see or analyze a particular the application of the retrofitted retrofitting the options are economic. a payback period, but there is other two type of payback period also one is called the energy payback period EPBT. So, it is a ratio between the difference of the initial embodied energy and before and the after retrofit and the annual saving of the energy.

It is very simple. So, it is giving me a ratio that will also give me how much time I require to get back, get back that one. What get back? Because there is a difference between two energies of course, those two energies are the initial embodied energy of you see the first one the initial embodied energy of after retrofit and sorry and after retrofit and the before retrofit the some Δ energy.

So, after retrofit is definitely going to be the high. So, I may say that this E I stand for embodied, A R stand for the after retrofit is always going to be high with the energy or this embodied energy of the before retrofit. retrofit then only we do something some material some more new systems items or maybe the equipment and then it is going to be the retrofitted. So, definitely the after retrofit embodied energy is high with respect to the before. So, this Δ this is the Δ this the difference is the Δ divided by OEAS.

OE stands for the operational energy, AS stands for the annual saving. So, how much annual saving I am going to do? How much energy saving? because why I am doing this particular retrofitting because saving the energy.

So, per annum how much operational energy I am going to save definitely I am going to save it because suppose I have some kind of graph I mean some this is a time. So, after maybe 5 years 5 years I am I am actually I am actually using per year something like this energy. So, then I do some kind of a retrofitting. So, then I will this energy will be decreased this is the energy So, energy will be definitely decrease otherwise why should I go for this retrofitting techniques or so after 5 years or after 3 years whatever.

So, this is my saving. So, this is this particular thing my is my operational energy saving sorry the annual saving AS, AS stands for the annual saving of the operational energy. So, then I can if I see this ratio then I can say that after some years after such years after T years after EPBT years I will pay back this energy whatever extra I am actually I am inserting in my building is going to be payback through the energy saving point of view. So, this is one of the analyses we can do and another one is the CPBT, CPBT is the carbon payback period method. It is also very similar expression.

So, this is also a ratio. This ratio is between the embodied carbon after and before. So, again, this is the embodied carbon, the embodied carbon. This is the embodied carbon, the initial embodied carbon after retrofit, which must be higher than the embodied carbon before retrofit. So, this is the Δ carbon, the difference between them, the Δ carbon. So, that much extra amount of carbon—carbon means, you know, it is the GHG gases, which are equivalent to energies also.

Because anything we do, the expenditure is the energy expenditure, and due to the energy expenditure, you have to burn coal or you have to burn petrol or so. So, that is why it actually creates some kind of carbon emission. So, equivalent CO2, equivalent carbon dioxide, you have to calculate. It is there; it is there in the charts, and everything is there. And because of this particular renovation or this retrofit, annually, I will save some carbon.

So, the ACR is the annual carbon reduction. So, definitely, why am I going to do it? I am going to do it because this energy will decrease annually, and if the annual energy is decreased, definitely the annual carbon for which my building is responsible is going to decrease. So, again, this ratio will give me some tentative timeline or the payback time for the carbon. So, this is the payback carbon time.

So, now we will see one small problem and we will end this lecture. This problem states that a room has a plan dimension of 12 meters by 8 meters and originally had an RCC roof with a U-value of 2. So, initially, when it was constructed, this 12-meter by 8-meter roof was made of RCC with a U-value of 2. Now, the roof is proposed to be renovated with EPS, which is a 75 mm thick polystyrene material. To reduce solar heat gain, the U-value of the EPS is 0.3 W/m²°C, which is very low.

That is why it is a very good thermal insulation material. The average solar air temperature of the roof can be taken as 45°, and the indoor air temperature can be set at 20°. So, 45 and 20° are the two different temperatures—one surface temperature and one

inside temperature—that create the temperature difference we must consider. There is heat gain, and that heat must be removed by air conditioning between these two temperature phases of 45 and 20°. The air conditioning in the room will be used for 10 hours—10 hours, I must underline—daily. I will use that room for 25 days in a month.

That is for 8 months in a year. I will not use it for all 12 months because, for 4 months—possibly winter—I will not use any air conditioning. So, daily 10 hours, 25 days in a month (the remaining 5 or 6 days are holidays), and 8 months in a year. This is my strategy, or this is the total scope of the calculation. To calculate the annual energy.

Estimate the annual savings and all those kind of a thing for due to the renovation. So, first of all I need to see if it is a RCC roof what was the scenario and if it is I put the U EPS of U value low U value the what is the combined effect of the U value and what is the scenario. So, first of all I found out the the combined U value based on the based on the U value of the roof which is RCC this is the RCC ofcourse, this is 2 is for the the original this is original RCC and this will be then renovated or retrofitted. this is RCC plus your EPS. This gives me 0.26 this gives me 0.26.

Now, the surface area of the roof is 96 m² 12 by 8 and the temperature difference is 25°C. So, we will calculate the roof heat gain which is a this the formula which we carry through the very first lecture or very second lecture or so.

The heat gain = Q x U x ΔT.

So, the heat gain through the original RCC roof will be the this is my Q 48000 watt this is my area this is my U value and this is my ΔT. Similarly, the no change in the area no change in the ΔT, but there is a change in the in the in the U value see this is 0.26 is the U. So, for that now the heat gain is 626 W So, now under this circumstances that is with the EPS with the RCC route.

I am getting a heat gain of 626 W and definitely it is much less and I have to responsible to wash out that particular heat only. I do not want to do now 4800 it is retrofitted. So, my job is less. So, the load on the air conditioning system will be much less with respect to the if it is not retrofitted also. So, the reduction in gain of the heat is this much 4174 watt and it is going to use for the daily 10 hours.

So, this is the hours, this is the days in a month and this is the number of months. So, almost about almost about 8348 kWh So, this has to be divided by this has to be actually

divided by this will become in has to be divided by 1000 and then you will get this value. So, 8348 kWh will be now hour is there.

So, this much hour. So, kWh will be the energy requirement for the the annual energy requirement or not annual energy requirement it is the annual energy saving you may say because of the retrofitting. we can go through lot of analysis. First one is again the analysis for the economy point of view the EPS installation cost is 1200 rupees per m^2 and unit cost of electricity 4 rupees. So, I know additional I have to pay 1,15,200 rupees to install that EPS

And yearly saving is 8348 kWh that much of unit and if I multiply with 4 because 4 rupees is the unit of electricity I have taken. So, 33000 will be my annual saving I have to put 1,15,200 and annual saving is 33. So, the payback period is almost like 3.45 years. So, 3, 5, 4, 5 years after I will be in gain I will be in gain whatever I have invested as a rupee I will get back. So, this is the first type of analysis as the economic analysis.

The second economic analysis I am doing here is for the energy payback and the carbon payback. The energy payback, you see, is given. The density of the EPS is given, the embodied energy of the EPS is given, and also the embodied carbon of the EPS is given. So, first I found out how many kg of EPS I required because I know it is 0.75 in thickness and I know the dimensions. So, how many cubic meters, and then I multiply with the density—this is the density.

So, this many kg, and then this is the embodied carbon—sorry, embodied energy—this is the EE. I multiplied it with the 190, which is kg. So, this much is the embodied amount of the energy that I have—the initial embodied energy of extra I have to provide, that is the first E, after and before that particular thing. And the embodied energy of the EPF installed is—I have converted it into kilowatt-hours. The same thing I have to convert to kilowatt-hours. The embodied carbon is now this much because the 35 is the embodied carbon EC, which is coming here from here—embodied carbon 35 kg of CO2 equivalent (E stands for equivalent) per kg. So, 190 kg into 35.

So, this much—sorry. So, this much amount is my embodied carbon—embodied carbon. And the annual savings is this much: 8384. So, that I have converted to megajoules, and from the megajoules, I have also converted how much is the equivalent carbon. So, now, I can easily go through this. I am finding out this—this is my extra amount of extra amount of the initial embodied energy required to install EPS and this much is my the savings. So, my payback period is almost like 1.26 years, but here it is please note that

everywhere I have written that this is not the exact value this is I have taken some kind of approximate value and added some kind of a construction materials also with this density embodied energy and the embodied carbon. So, this one 10526 divided by this 8384 is gives me almost like 1.6 here and second case what I have to do is embodied carbon case this is the this is the annual saving this much carbon and this is the extra carbon this is something like 6650 this two has to be ratio down. So, the 6650 is the extra amount of carbon that was imparted in the in the in the building because of the retrofit and 2945 I think I can let me go back a little bit yes 2945 kg of CO_2 is the annual carbon reduction. So, that is their annual carbon reduction sorry that is there.

So, it goes almost like the 2.26 years is the payback period from the carbon point of view. So, that is ends the module number 7. We will go to the module number 8 next week with the energy generation. Thank you very much.