Course Name: Architectural Approaches to Decarbonization of Buildings

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Week: 10

Lecture 2

Building Envelope types

Dear students, so we had a series of lectures on renewable materials, non-renewable materials, its impact on embodied carbon, embodied energy, operational carbon. and also the global warming potential of these materials. The next 3-4 classes, we will look at low energy envelope. Now, why is this important topic or why is it a relevant topic? we are looking at architectural ways of decarbonizing buildings. Now, in India, most of the building energy operational use, it happens because we try to create a comfortable indoors and we end up using active means of heating or cooling the building. Now, in order to prevent this or what is the reason this happens? So, electrical energy is consumed in a building primarily because we want to make the indoors comfortable and the indoors are either too warm in a hot climate and therefore we try to use air conditioners to make it cool.

or in a cold climate the indoors become very cold and therefore we tend to use a heater. So, the most of all this happens because of the building envelope. So, and there is another component which consumes a lot of electricity towards this that is the HVAC system. Now, design of HVAC system is not the prerogative of an architect, but it is the prerogative of a mechanical engineer.

So, we would not talk about that, but the building envelope design is a major, it is one of the most important reasons for indoor ingress of solar radiation or heat or making the indoors uncomfortable. And its design is completely in the hands of an architect. Over the course of this series of lecture, we have seen how simple passive architecture can be used to make the indoors comfortable. But today we will look at how envelopes can be designed. And when I say envelope design, low energy envelope design, we are moving into something very interesting because of the onslaught of technology, because of so much scientific knowledge about how heat gets in and how we can control it.

how we can optimize day lighting and heat because if you look at energy intensive buildings like say an office building, a lot of electricity is consumed towards day lighting

in offices and that increases the operational carbon of a building. If you have to decarbonize the building, you need to understand the latest in design of envelopes to reduce the operational carbon in the building by optimizing indoor heat and daylighting. So the next three or four lectures would focus on these with case study because it's a very advanced topic. I would not look at it too technically but it is my duty to introduce this domain to you so that you become aware of all that is happening around us. So Let us look at this.

There are two different types of building envelopes. One we call as a tight envelope and that is designed for maximum air and thermal control. Now it has a very high performance insulation, airtight construction and it has energy efficient windows. Now think of it like a well sealed flask, thermos flask, minimizing energy loss and maintaining a stable indoor temperature. This approach prioritizes energy efficiency and often relies on mechanical ventilation system for fresh air.

Now, this is when I talk of all this I have approached it from the point of view of the outdoor being very cold. Have the same analogy to understand what happens when the outdoors is very warm. The other one we will call as a loose envelope. So, in a loose envelope it promotes natural ventilation it is porous. And it promotes breeze movement inside which is actually an intentional air leak and it relies less on mechanical system.

This is often found in buildings which are large volume and high occupant density allowing for natural air circulation and reducing the reliance on any active means of heating or cooling like a HVAC. However, in cold climates it can be drafty and less efficient in controlling indoor temperature and humidity. When the outdoors is very warm say like in a warm humid or a hot humid climate this can also bring in hot draft inside. So, the breeze which comes inside itself it is so warm and hot. that the indoors can become nastily uncomfortable because of warm air combined with humidity.

So, basically these are the two types of building envelopes. Whereas, there is another way in which you can see and that is static and dynamic building envelopes. Now, the building envelope comprises of walls, roofs and all that is there on the walls which is windows, ventilators and these play a very critical role in the building's energy performance and an occupant's comfort. Traditionally, envelopes have been primarily static. like how we use in our regular building.

You have a wall, you have a window, you are privileged to have an operable window. When you want, you open the window. When you do not want, you close the window. When you feel very lazy, even though you have to open the window, you keep the window closed because you take an effort to go and open the window. So, traditionally

these envelopes have been primarily static and they employ fixed elements and materials to achieve thermally comfortable indoors or to have a thermal control.

So, if it is if you find that hot breeze is getting inside you close the fenestration or the window. However, with increasing focus on sustainability and adaptability, now dynamic building envelopes are emerging and they are becoming a game changer in today's advent of technology. Here you can see two pictures. The first is a static building envelope which has some features of simple passive techniques. All of these are aimed at reducing the operational carbon.

Remember that why we are studying this so that we understand how to reduce operational carbon. Operational carbon is reduced by usage of less electricity towards enhancing endothermal comfort. one of the ways which is the static building envelope. If you see all the openings here are shaded. The adjacent mass shades the wall.

Hence you find that you have a lot of shaded walls Which will avoid heat getting through the walls. Heat absorption through the walls is minimized. But will this happen throughout the year? Because the position of sun changes then what happens? So there will be some months in the year when this envelope may not perform to its best. It may perform to its best for most parts of the year or during the critical part of the year. But it will not perform best to all parts of the year because of the sun's movement whereas the facade is static.

Whereas now you look at the adjacent picture which is the dynamic building envelope. Here you can see that the building has certain elements which are dynamic and movable. So the elements are movable, dynamic and These can be made to move based on the day lighting and shadow, solar gain requirement. Suppose it's a winter month and you want solar radiation to enter inside, all the windows could become dark as in this shape. Number one, giving maximum exposure to the wall and allowing maximum solar radiation to come in.

If you want to control the solar radiation, you can go in for option two where it is controlled the solar radiation, the area of the window through which solar radiation can enter inside is controlled. If you want further control, you can go for option 3 and then if you want very less solar radiation and some amount of light, you can go for option 4. if you want very very minimal or almost no solar radiation and extremely less daylight, then you can go for option 5. When I say you can go for, I mean to say that the facade chooses based on how you program it to allow optimization of daylighting and solar gain. So, you have optimized ingress of solar radiation and daylight.

So, this is a dynamic building envelope and we will see a little bit about it in our next four classes including this one. Right, so now a static envelope relies on fixed materials and elements. That is it has the traditional way in which buildings are built. It has a fixed wall, fixed windows, fixed shading device and if you need any insulation it is fixed. And it regulates heat transfer and light penetration based on the natural way in which solar radiation will enter in.

It comprises of high performance materials in the form of the probably insulation to avoid infiltration like fiberglass or rock wool or foam and it minimizes heat flow through the walls, roofs and floors. Now airtight construction is done by sealing the gaps and cracks and it prevents unwanted infiltration and therefore the thermal performance gets improved. Energy efficient windows can be installed by having double or triple glazed windows with their emissivity can be very less based on the coatings that you use on the glass which will result in the nature of heat gain or loss that you would want in the building. The shading devices could be horizontal shading device, vertical fins, There could be louvers, there could be blinds, there can be overhangs and so on offering different passive control over solar heat gain as well as glare. So, this is the conventional way in which building envelopes exist today and we call that as static building envelopes.

What are its advantages? Now, these are simple design and the construction is very simple. These are conventional. They have static envelopes which are well established and therefore, it has been built over and over a period of time resulting in cost effectiveness. It is low maintenance. Because it has fixed elements which require minimal upkeep.

There is no motor involved in it. There is no mechanical system involved on the facades. These are effective in stable climates. That is in regions with consistent weather patterns. Because these static envelopes can provide sufficient thermal control.

they do come with a disadvantage that they have limited adaptability. These kind of static envelopes, they struggle to adjust to changing weather condition as well as occupants need. Their potential for overheating or under cooling happens because the fixed elements do not respond to the changing outdoor climate or microclimate. Because of this, it can result in high energy consumption because the requirement of indoor cooling may become high during certain months. And the requirement for day lighting can become high for certain periods of the day or for certain times of the year.

And all our focus on this is because these can become high energy consuming things. And therefore, the operational carbon and operational energy of buildings having this kind of envelopes can keep on increasing. What happens as an offshoot? This keeps on

continuing. So, operational energy keeps on increasing in these buildings. And therefore operational carbon also keeps on increasing in these buildings over a period of time.

There is no provision to reduce it. And therefore as architects and designers we need to address this issue. and ensure that we try to design envelopes which respond to outdoor climate and weather so that the operational energy of the building is minimized and it gets once you minimize it then over the years you will only have minimum use of operational energy. Let us look at what happens in the dynamic envelope. Now dynamic envelopes they incorporate elements that will change when the outdoor environment changes and as a response to the outdoor environment say if it becomes very if the solar radiation is very intense and you want to cut solar radiation then the building facade will respond accordingly. In a cold climate when the solar radiation outside is intense the envelope will allow the solar radiation to get inside the building.

This kind of envelope also responds to an occupant's need. The occupant can decide whether he wants the solar radiation to get inside the building or not. Therefore, the building performance gets optimized and the indoors remain comfortable. These have various components.

The insulation is variable. So, you have materials like switchable glazing. You have electrochromic windows. So, electrochromic windows will change the color of the glazing depending upon the solar radiation outside. When the solar radiation increases and you do not want ingress of solar radiation, the glazing becomes darker. Or you can use phase change materials that can adjust the thermal properties based on the temperature or the light.

So the material will change itself based on the outdoor conditions. You can have automated shading systems. That is you can have the shading devices which could be louvers or vertical fins or blinds which will automatically change as a response to the outdoor solar heat gain or glare. This can happen throughout the day. On a particular day from morning to evening, the position of the louvers or vertical fins or blinds will keep changing to ensure that you have indoor condition as per the occupant's desire.

In terms of either solar radiation or day lighting. You can also have natural ventilation systems in the form of smart vents and dampers which control air circulation based on indoor and outdoor conditions. You could also have integrated renewable energy systems that is you can have photovoltaic panel or solar thermal collectors which are found or embedded on the building envelope itself and when solar radiation falls on the envelope it traps the solar energy and you get renewable energy for the building. So, the envelope acts like it has life. The envelope acts as if it is a living being because it generates

electricity, it generates energy by means of having embedded photovoltaic panels.

So, now you can have dynamic photovoltaic building envelope say if you look at this figure all that we had talked of so far features here you could have devices you could have shading suppose this is a shading device then based on your requirement in the summer for the same condition in the summer this shading device closes itself thus preventing solar ingress preventing solar gain because it's summer outside Suppose you want to have some view outside, the shading device facilitates by being mobile you have a lot of view to the outside. The shading device could also be placed such that it tracks the sun's direction. So, what happens since it is summer and if this is the solar radiation angle, the solar panels which are also a shading device, they track the sun sun's direction and tap maximum amount of solar radiation as the if the sun moves this could also rotate and move this way if this is the direction solar direction or if this is the solar direction then it can move this way. And therefore, these can be this kind of a dynamic and envelope for a building like this will optimize on Ingress of solar radiation. So, you can control how much sun you want to enter inside the building to make the building warm.

Or daylight. You can control how much you want the opening to be to allow daylight and glare. And third is tap solar energy. So, a dynamic facade can do all of these and in the winter you can position your openings such that you allow the winter sun to get inside. You allow day lighting to enter inside and you can also position the panels. So, that it tracks the sun's direction and taps it to the maximum possible.

So, this is how dynamic facades will function and accordingly you have small motorized or small mechanical systems which will facilitate it. So, the building envelope will consist of individual modules which will be mounted on rods like this which you have seen in the previous slide. Which you have seen in the previous slide here you can see these braces and So, what happens is it is mounted on these lightweight rod which is a structure which is supported on the facade and the outer layer is the glazed panel which can be moved. So, we will not go into the technical details of this we will only get into the conceptual things. So, by having dynamic facades will be able to optimize solar radiation.

In summer, you can cut the solar radiation. In winter, you can allow the solar radiation, can optimize daylight and control glare either through the throughout the day as well as throughout the year besides you also have an option of generating solar energy. The impact of all these three will be on reduced use of operational energy. The energy required to facilitate a building's indoor thermal condition will get reduced and this will result in reduced operational carbon throughout the life of the building- throughout the life of the building lasting for at least 50 years. Imagine the amount of reduction in

carbon dioxide emission due to this and therefore, imagine the positive impact it will have on the environment. We will stop this class today here with this brief introduction about envelope, static and dynamic and how these are related to operational carbon and how these can aid in reducing the operational carbon by controlling the ingress of solar radiation, daylight and probably even generate solar energy.

So, we will stop with this and continue in the next class. Thank you.