Course Name: Architectural Approaches to Decarbonization of Buildings

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Lecture 2

Low Energy Envelope Part 2

So dear students, we had seen in the last 3-4 classes about low energy envelope. We started with an introduction to low energy envelope and went on to look at case studies about how such envelope are designed and how they have a X factor. Today's session will be a concluding session on low energy envelope wherein we will be discussing about the architectural strategies, its advantages and its limitations. So, a building envelope is critical in determining energy efficiency in its buildings. Because it is the shell of the building that acts as a barrier between the conditioned indoor and the outdoor environment, nearly 50 to 60 percent of heat transfer and heat exchange happens through this building envelope and can result in 26 percent of the total building load of the energy due to the heat gain. The energy performance of different envelope components such as walls, roofs, floors, ceiling, windows, it affects the energy required for the building's heating and cooling and indoor comfort, ventilation and natural lighting.

The design variables such as geometry, glass reflectance, the thermal mass, the shading devices etc. also affects the energy performance. Improving these design factors can result in 46.8% reduction in yearly space cooling energy consumption in hot climates.

46.8 percent reduction through just simple passive techniques and further reduction due to smart envelopes. Or the 'x factor' of the envelopes can have a tremendous impact on the operational energy and operational carbon of the buildings and as we know The pool of buildings that is required is humongous in India. And if all these buildings follow these principles, a lot of operational carbon emission can be reduced. If we look at the advantages of low energy envelopes, Low energy envelopes have enhanced adaptability because the dynamic envelope can adjust to changing outdoor conditions and also the requirement of the occupant.

So if the outdoors is very warm, the dynamic envelope can change itself to ensure that solar radiation ingress is cut. And if the occupant needs daylight, it can provide sufficient daylight for the occupant's requirement and this leads to enhanced comfort and efficiency. Also, this envelope design can have reduced energy consumption because there is precise control and targeting over heat transfer and natural ventilation which can minimize our dependence on the HVAC systems. The increased occupant comfort which comes along with dynamic envelope can provide optimal comfort in terms of temperature and in terms of day lighting all through the year. However, there are certain disadvantages of this envelope.

The first is the higher initial cost. Dynamic systems are expensive than the static systems because there is another layer of envelope involved and also there is some complex technology also involved. Not only is the initial cost higher but initial embodied energy is also high. This also leads to increased maintenance moving parts and sensors require high maintenance and repairs too because sometimes this entire envelope system dynamic envelope system may be comprised of multiple mechanisms or multiple mechanical systems involving moving parts and even if one part gets repaired one needs to immediately maintain that part or repair that part. There is technical complexity involved and unless the technicalities of this along with specialized expertise it may be difficult to operate these systems.

Choosing the right building envelope. The choice between static and dynamic envelope depends on many factors. These include the climate. In very stable climates, the static envelope might suffice but that is not how nature works. There is hardly any climate in the world which is stable and comfortable at the same time.

And therefore, dynamic systems offer greater benefits in regions with very large outdoor condition swings. The benefits are more because the building is designed for a particular climatic condition. But when there is a wider swing in either the temperature or any of the other parameters, these dynamic systems they aid and come to play to neutralize the extremes. Second is you need to consider the building type and usage. Office buildings have fluctuating occupancy and they may benefit most from the dynamic elements as compared to smaller or less energy intensive buildings.

Office buildings have more fluctuating occupancy, they are energy intensive, their requirement of day lighting and thermal comfort is far more complex than say a residential building. Hence, when given a choice, an architect should be able to exercise for which building typology these dynamic envelope systems work most. The budget and maintenance considerations is another factor because static envelopes are generally cheaper and require less maintenance. But dynamic system, they offer long term energy savings and enhanced comfort. Also, a lot of cost benefits can arise out of this.

As I said, when it comes to energy intensive buildings, having dynamic system helps and therefore can be more beneficial. Now, if we look at the heat dominated building envelope, heat dominated areas receive a lot of solar radiation. The walls act like thermal storage. Hence, we need better insulation to minimize the thermal losses and natural daylight is used. Facades have increased glazing areas to allow for natural light and light shelves that redirect light into interior spaces must be used.

In a cool climate, Appropriate shading techniques can be employed to protect from direct solar gain and we should use insulation to reduce solar heat gain. The design must be facilitated for natural ventilation with wing walls and natural daylight should be used in such a way that solar heat gain is minimized. Whereas in mixed climate, we must have shading devices to protect facade from direct solar radiation during warm days. While passive solar design for heat during cold seasons. Using natural daylight with increased wall areas and with shading devices will benefit most.

Let us look at the strategies for low energy building envelope. The first one is insulation. The ultimate shield against unwanted and unnecessary heat flow Insulation materials come into force because they actually insulate the building from unnecessary heat movement. Fiberglass, rock wool or foam, these are the first few line of defense when it comes to insulation. These act like a barrier or a sweater to the building to bring warmth during winter and cool air during summer.

What we should look at is, we should look at higher values of R value for better performance. Next strategy is air tightness. When you are looking at a conditioned building, it is known that a lot of electricity is wasted and the load on the system which heats or cools the building falls due to unnecessary wastage arising out of infiltration. Sealing up of cracks and leaks around windows, doors and other openings becomes critical. It is like plugging the holes in a sweater or in anything that is actually protecting you.

There are special membranes, tapes and sealants which help achieve air tightness and in ensuring the insulation performs optimally and reducing drafts and discomfort. Third strategy is use of energy efficient windows. We should use double or triple glazed windows with low emissivity or low E coatings which are more like sunglasses. The low E coating reflects infrared radiation keeping the heat out in summer and warmth in during winter. Consider windows with high visible light transmittance to maximize natural daylight while minimizing unwanted heat gain.

Appropriate use of shading device is very important. What we do is shading devices in the form of sun shades which are horizontal shading devices vertical fins, louvers and blinds. They act like awnings blocking the solar radiation before they hit the windows.

These can be fixed or adjustable allowing you to fine tune solar control throughout the day and through the seasons. It's like strategically tilting your awning for optimal shade and the same thing applies even to dynamic facades.

The dynamic facade should have overhangs, louvers, blinds which blocks the solar radiation. and yet allows daylighting as needed before it hits the windows. This can pitch in and save a lot of electricity. Use of natural ventilation happens when windows and vents are strategically placed to create cross ventilation. promoting air circulation and reducing the reliance on HVAC systems.

The dynamic envelope can comprise of components which can streamline and direct wind movement inside the buildings. One must definitely not forget to adopt the principles of passive solar design. Orienting the building's window and incorporating thermal mass elements can harness the sun's warmth in winter and it can prevent overheating in summer. At the same time, when you are designing for a hot humid climate, you must consider that there should be adequate ventilation. and therefore openings and opening sizes along with its location becomes an important criteria.

Green roofs is yet another strategy The green roofs are roofs which are covered with vegetation and they are extremely beneficial because they increase the insulation between the outdoor and the roof. The roof is one of the envelope elements through which maximum solar radiation penetrates inside. The intensity of solar radiation on a horizontal roof is much higher than that on the walls. Having green roofs provides insulation. However, one must take care of stormwater management through the green roof.

Also, the green roof acts like a living blanket to the building. and it reduces the impact of urban heat island effect. Urban heat island is an effect where it is found that dense areas of the cities have an overall temperature of at least 2 degrees higher than suburban areas. That is because of the radiation from the roof and the roads. They cause the high air temperature in dense city areas.

Green roofs helps in dissipating the urban heat island effect. One must consider cool roofs which are nothing but coatings. or special materials like white ceramic tiles and these can significantly reduce the amount of heat absorbed by the roof and it lowers the cooling needs. It is like a porcelain glass with a tea inside. We know that the outside is still manageably warm.

And therefore, having cool roofs prevents the outside heat from entering inside. Building envelope integration is like we must not think of the envelope as an isolated element considering its holistic performance. Integrating all these technologies and strategies for optimal synergy is the key and hence one must consider integrating these strategies along with dynamic envelopes. If we look at the future of low carbon construction in relation to building envelopes, we can say that the future of low carbon construction, particularly when it comes to building envelopes, it paints a picture of sustainability which meets cutting edge technology. Hence, we need to now dwell deeper into what this landscape might hold.

We can have a net zero facade. These are self-sufficient envelopes which generate energy as they consume often through integrated solar panels, wind turbines or green walls. Imagine buildings not just consuming but actually contributing to the electricity grid. When a building consumes energy equal to what it produces and when it does not take any electricity from the grid, we call it as a net zero facade. But if the building is able to produce more energy than it uses, we call it as a regenerative building.

Energy positive. It generates more electricity than it consumes. We must also not forget all the old concepts we studied in the previous section of this course. that is bio-inspired materials. Embrace the resilience and adaptability of nature. Do not undermine the use of natural and renewable building materials like bamboo, wood, algae-based polymers or even mycelium.

more on the other kind of materials like algae based polymers or mycelium in another course in another subject. For now just know that mycelium is a fungal root structure now replacing traditional concrete and steel with these structures will definitely go a long way in lowering the embodied carbon of a building. Sustainable, locally sourced and often carbon sequestering is great for the environment. Having adaptive skins and more static envelopes. Smart materials, nanotechnology and systems that adjust to the environment.

Maximizing efficiency and comfort. It's like having a self-tinting window. When the solar radiation is very high, automatically the ingress is cut because the window reacts to the solar radiation and tints itself. dynamic insulation that expands in winter and contracts in summer. It is a system and not specific only to a particular material and if that happens one would get the maximum amount of solar radiation when needed and it could protect the building from solar radiation during summer. Having bioluminescent facades can illuminate the building at night thus reducing the load on electricity.

Also consider advanced technologies like 3D printing because the precision with which the construction happens and at a very short time and waste gets reduced, all these can add in optimizing energy performance and minimizing material use. Using digital twins, which are virtual counterparts of a building, allows for real-time performance monitoring and optimization. These digital avatars can test, design, tweaks, predict energy consumption and even identify potential maintenance issues before they arise. One can consider AI powered envelopes, let artificial intelligence manage the show, AI algorithms can learn from building data and dynamically adjust the systems like shading, ventilation and temperature control for peak efficiency and occupant comfort. Additional exciting possibilities include nanotechnology like self-cleansing glass, self-healing materials like paint, which automatically repairs cracks, extending the lifespan of building envelopes.

Hydroponic farming, which can be integrated with vertical gardens. Bioremediation, which is like living walls and algae panels that can actively filter pollutants and even generate biomass for biofuel. Hence, there are number of challenges as well as opportunities when we look at dynamic facade. While the future holds immense promise, there are a lot of hurdles. Cost effectiveness, long-term performance, needing skilled professionals, advanced construction techniques, Monitoring building management systems.

These are crucial areas to address. But with increased collaboration between architects, engineers, scientists, policy makers, all these can be overcome. Investing in the future of low-carbon building envelopes is not just about reducing emissions. It's about creating a healthier planet, resilient cities and comfortable high-performing buildings for generations to come. It's a future where buildings contribute to, not deplete our resources. And with the quantum of buildings that are yet to come, one can imagine how much of energy can be saved or generated.

Hence, technology must embrace nature to create an environment which is conducive for tomorrow. So, in summary, We need to understand low energy building envelope. Building envelopes that are the outermost layers of a building separating the conditioned interior from the exterior and low energy envelopes must be designed to minimize energy consumption for heating, cooling, ventilation and optimizing daylight. There are different types of building envelopes like static and dynamic which we have studied. Static envelopes use fixed materials and elements while dynamic envelope incorporates elements that actively respond to environmental changes and occupant needs.

And then we saw technologies or strategies for low energy building envelope design. Some technologies and strategies include high performance insulation, airtight construction, energy efficient windows, shading devices, natural ventilation, passive solar design, green roofs and cool roofs. The future of low carbon construction with building envelopes. includes net zero energy facades, regenerative facades, bio-inspired materials, using adaptive skins, falling on to higher technology such as 3D printing, digital twins and AI powered envelopes. If we incorporate all of these then there is a future for smart envelopes.

Envelopes which give the users the power to control solar radiation, day lighting and generate electricity as a envelope itself. With this, we will be closing our session on low energy building envelopes. In the next session we will take up another interesting topic. For today this is all we have. Thank you.