Climate and Built Environment

Lecture 6

Envelope

What is an envelope? The building envelope refers to the exterior facade and is comprised of opaque components and fenestration systems. Opaque components include walls, roofs, slabs on grade in touch with the ground, basement walls and opaque doors. Whatever is the external covering of your building is what is called envelope. Your exterior wall units, your roof your flooring and windows, openings, apertures, facing the exterior or in contact with the outdoor environment is called envelope. Fenestration systems include windows, skylights, ventilators and doors that are more than one-half glazed, contribute to envelope design. The presence of choosing your wall units, doors, ceilings, windows, contribute to thermal comfort of the indoor spaces.

Envelope design strongly affects the visual and thermal comfort of the occupants, as well as energy consumption in the building. As we know, we have discussed in earlier presentations, how U-value, thermal conductance, thermal resistivity of a material is very important. All of this contributes not only into creating a good environment for the occupant indoors but it also helps in saving the energy release. From an energy efficiency point of view, the envelope design must taken into consideration both the external and internal heat loads as well as daylight benefits. External loads refer to the amount of air temperature, the amount of solar radiation, relative humidity levels, wind speed, wind direction happening on the external causes the usage of additional energy sources to keep ourselves within thermal comfort.

Also there is a lot of internal loads which is acting inside the building. We are also dissipating heat towards the interior spaces. So, presence of number of occupants, presence of electrical appliances and the activity pattern that is being followed inside. All of this contributes to the internal load of the envelope. The commonly considered elements of ECBC envelope are; Walls, windows and roofs. All these elements contribute to energy efficiency of an envelope design.

Walls are a major part of the building. Envelope receives large amounts of solar radiation. The heat storage capacity and the heat conduction property of walls are key to meeting the desired thermal comfort conditions. Appropriate thermal insulation and air cavities in walls reduce heat transmission into buildings which are primary aim in hot regions. Depending on your climatic regions, you need to make sensible choices of your wall units. If your building is located in a hot air region, the outside temperature is very high and you don't need high temperature to come inside your interior. You need to build your walls in such a way that it will not conduct the thermal energy from outside to the interior.

The basic elements of the wall system are- exterior cladding which is the cladding you do facing the exterior of the building and drainage panels. There is a small gap between these two units which forms the drainage plan. Air barrier systems which is marked in number 3, these form the air barrier systems. Vapour retarder helps maintain certain amount of relative humidity levels, you might need vapour retardant which is used for places that demand to maintain the amount of relative humidity in the air. Insulating elements - the insulation which is present in pink colour is located little further away from your exterior cladding by an air cavity, this is to protect your interior spaces from exterior harsh climatic conditions. Structural elements - columns and beams that contribute and intersect with your wall are called structural elements.

Thermal storage and thermal capacity - thermal capacity is the measure of the amount of energy required to raise the temperature of a layer of material. It is a product of density multiplied by specific heat and volume of the construction layer. Thermal capacity refers to the amount of heat required to raise the temperature of the entire construction system. Say it is for a complete floor, how much heat is required to increase its temperature. It is a multiplication of the density of the material, the mass and the layers that are being used. The main effect of heat storage within the building structure is to moderate fluctuation in the indoor temperature. The main aim to use heat storage material is to avoid from having fluctuations in the indoor temperature. Say, suddenly if the morning temperature outside is 40 degree celsius and indoors is 40 as well and during the night 10 degree celsius inside and outside, human beings cannot adapt to such drastic differences in a short span of time. To avoid such fluctuations, we are using heat capacity materials to store the heat and dissipate whenever it is required. Thermal performance of walls can be improved in the following ways; Increasing wall thickness, providing air cavity between walls and hollow masonry blocks. Applying insulation on external surfaces. Applying light coloured distemper on the exposed side of the wall.

If you want to increase the performance of your wall, if you are located in a very harsh climate, it requires the wall to be highly sealed to protect your interiors from the exteriors. You need to have good amount of thickness, the material used should also be of good value and the air cavity which you keep between two elements in your wall has to be good enough such that it reduces the heat transfer from the exterior to the interior and interior to the exterior, depending upon climate. Application of insulations on the external surfaces. If you want to protect your interior from the exterior, it is ideal to keep your insulations outside facing the exterior and applying distempers. The more darker the colour you apply, the more the absorption of solar radiation. If you are located in a higher location that has higher air temperature, you must paint your building in a much lighter colour because the heat capacity of white colour is very less.

Walls-insulation; Thermal insulation is of great value when a building requires mechanical heating or cooling insulation that helps reduce the space-conditioning loads. What is the use of insulation? If you are using insulation, you are avoiding day to day fluctuations which means that the demand for space heating or space cooling due to its presence. Location of insulation and its optimum thickness are important. In hot climate, insulation is placed on the outer face (facing exterior) of the wall, so that the thermal mass of the wall is likely coupled with the external source and strongly coupled with the interior. Depending on your location, if its a hot climate, the insulation is ideal if its placed outside, if it's a colder region, its ideal to keep the insulation on the interior. You need to protect the hotter temperature from the cold temperature outside. It happens visa versa for a hotter climate region. Thermal properties of these materials are given below. These are different commonly used construction materials; Brick, Mud, Stone and Timber with their conductivity, specific heat capacity and density has been mentioned. This can be chosen according to the climatic zone that you are going to design for.

Air cavities within walls or an attic space in the roof-ceiling combination reduces the solar heat gain factor, thereby reducing the space-conditioning loads. The performance improves the void that is ventilated. If you are keeping an air cavity, it is almost as keeping an insulation. By keeping a small gap between two materials, you are actually protecting from the heat transfer that can happen between one element to the other element. This is very beneficial if you are located in a harsh climatic region. These air cavities can be ventilated if you are keeping on your roof as an attic space which can be used as a storage as well and can decouple from external environments. Heat is transmitted through the air cavity by convection and radiation. A cavity represents a resistance, which is not proportional to its thickness. Cavity is like a resistance that is added to a material to reduce the heat transfer between the two objects. For a thickness of nearly 20mm the resistance to heat flow remains nearly constant. Ventilated air does not reduce radiative heat transfer from the roof to the ceiling. This is ideally for roof to ceiling where you must ideally have more than 20mm air cavity. The radiative component of heat transfer may be reduced by using low emissivity or high reflective coating i.e aluminium foil on either surface facing the cavity. If you want to increase the performance of the heat transfer that is going to happen in the air cavity, you can fill it with aluminium foil near the highly reflective coating. With aluminium foil attached to the top of the ceiling, the resistance for downward heat flow increases to about 0.42k/W, compared to 0.21m2k/M in the absence of the foil (Bansal, Hauser, Minke, 1994). This presence of aluminium foil can increase or trigger the heat flow that has been happening from the roof to the ceiling.

Moving on to windows, these are very important components of the building envelope in addition to providing physical and visual connection to outside. It also allows heat and light in

and adds beauty to the building. Windows do not only add to energy efficiency point of a building but it also adds to the beauty of the building, also allows a good amount of daylight to come in and natural ventilation to keep us in comfort levels and to keep us connected with the outdoors. Solar radiation coming in through windows provide natural lighting, natural air and heat gain to the space inside. Thus, significantly impacting the energy usage of the building. Solar radiation which is penetrating through the parts in which passive solar radiation is required and it can be cut down in places which are experiencing higher summers. The main purpose of a building and its windows is to provide thermal and visual comfort to the occupants and if this can be achieved using less energy, so much the better. This also provides outdoor views keeping you connected with outdoors and also adds to visual comfort. If you are sitting in a closed environment for a long duration, you will feel sick sampling syndrome. Your building must have the minimum number of windows to keep you connected towards the exterior spaces. The recommendation according to IS is 3362-1911 code of practices for the design of windows for light and ventilation, there should be sufficient air motion in hot-humid and warm-humid climates. The presence of openings and windows become very important in hot and humid or warm and humid climates where the humidity level begins to increase if the air is trapped in a particular space. Hence, there must be constant air exchange happening because of the presence of huge openings or fenestrations. In such areas, fans are essential to provide comfortable air motion indoors, fenestrations having 15% - 20% of floor area are found adequate for both ventilation and daylight in hot and dry or hot and humid regions. There must be constant air motion present within the occupied environment. Ideally, the window must not be less than 15 or 20% of your floor area to maintain constant air changes. This is ideal for hot and dry and hot and humid climates. Fan becomes an essential because air speed or air velocity that are present in these climatic conditions are comparatively lesser. Natural light is also admitted into a building through glazed openings. Thus, fenestrations design is primarily governed by requirements of heat gain and losses, ventilation and daylight. The important components of a window are the glazing systems and shading devices. Glazing systems and shading devices become an integral part and serve to satisfy the needs of the occupants using the interior spaces with daylight, ventilation, heat gain and heat loss.

Primary Components of a Window

Primary components of a window which have significant impact on the energy and cost the building for which guidelines are provided in this section are as follows; Window size, placement, Glazing that should be chosen and the frame, the shading external and internal.

Window size and placement: Height of window head - the higher the window head, the deeper the penetration of daylight. The daylight increases as you move higher, keeping higher window levels will enable higher penetration of daylight inside your spaces. It will also restrict you from

operating on the higher end. It is ideal to keep mobile windows limiting to certain heights say 7 feet and above that if your space requires good amount of daylight, it is better to go for fixed glazing system which cannot be operated above certain levels because of height restrictions. Some of the windows are stripped windows which is being horizontally laid or windows which have good height. The height from floor to the bottom of the window is called Sill level and this is called the window height and this level that comprises the top of the window is called lintel level.

Sill height - height from floor to the bottom of the window. The optimum sill for good illumination as well as food good ventilation should be between illumination workspace and head level of a person. Carrying out any task, the suitable work plane levels are to be 1.0 to 0.3m high respectively. Depending on such factors you need to decide your sill heights. Strip windows provide more uniform daylight. Punched windows should be paired with work areas to avoid creating contrasts of light and dark spaces. If you are going to have a striped window horizontally placed, that is going to light up your room more evenly or uniformly. But if you are going to have punctured openings or random openings in your walls, some spots are going to be much more brighter whereas some spots are going to be much darker. So you need to decide which kind of window design will suit your needs and you need to choose wisely.

Moving on to Glazing system, the window size should be kept minimum in hot and dry regions. The primary properties of glazing that impact energy are; Visible reflectance affecting heat and light reflection. Thermal transmittance or U-value, affecting conduction heat gains; Solar heat gain (affecting direct solar gain); Spectral selectivity, affecting daylight and heat gain; so depending upon which climatic zone, you can choose the type of glazing system to be used. For a hot and dry climate, where the solar radiation is very high, the windows or percentage of glazing system to be used has to be very minimum. Also, the glazing colour affects the thermal and visual properties of glazing systems and thus, energy usage. If you are going to keep a dark coloured glass on the exterior of a hotter region it is going to absorb a lot of heat energy and eventually start dissipating it inside to your interior spaces through conduction and long wave radiation. Hence, according to the climatic condition you need to change the colour of your glazing systems.

The primary properties of glazing systems that impact energy are; visible reflectance, Thermal transmittance, Solar heat gain and Spectral selectivity, Glazing colour; the same we just saw, has been summarized under glass as well.

Visible reflectance or daylight reflectance - this is the percentage of incident light that is reflected back. Most manufacturers provide outside reflectance, exterior daytime view and inside reflectance, the interior mirror image at night. This is like the amount of reflectance a

glass can have. It is like an additional coating to your glass which is made by a lot of manufacturers now a days. During night times, your windows will become highly reflective surface to the exteriors so that no one from the exterior can see what's happening inside. Whereas, it becomes the reverse at daytime. Treatments such as metallic coating increase the reflectance. Reflective glazing reflects a large portion of the solar radiation incident on it, thereby restricting heat gain inside the building, which is advantageous. If you are designing in a hot air climate, this kind of reflectivity is very much appreciated cause it can reflect a lot of incident solar radiation that is falling on the glazing system. Disadvantages are; reflective glazing allows visible transmittance and this minimum daylight integration. Even though it has an advantage of bouncing back the solar radiation, it reduces the integration of daylighting which is also very essential for any interior space. An ideal spectrally glazing admits only the part of the sun's energy that is useful for day lighting. It can be chosen ideally so that only the natural daylight will be transmitted inside. These are different types of glasses and its U-value and its percentage of visible light transmittance that happens. They are; Clear glass, body tinted, hard coated - solar control, Soft coated - solar control glass, Low E glass, Solar control + Low E. Low E is a coating that has been added to your glazing system. If it is a solar control + Low E coated glass, it can be beneficial to use it in hot air climates or climatic conditions with longer moments. Typical optical and thermal properties for high-performance glazing options.

Glazing types and materials - the advanced glazing includes double and triple pane windows with coatings such as low-E i.e low emissivity or spectrally selective, heat absorbing that are tinted windows and glass filled windows and windows based on combinations of these options. Depending upon the climatic condition, you can even go for double glazed systems or triple glazed systems which means that they are two glass panes placed little further away from each other, filled with air cavity, aerogaz or some type of gas, this becomes double glazing system. In a triple glazing system, there are three glasses separated in between with air cavities which are once again filled with gas or air. The creation of vacuum or partial vacuum in the cavity of a double glazed unit and the use of Aerogel to fill the cavity can lower the U-value considerably. Air space between glass layers, thermal resistance provided by the air cavity between the glass layers increase with increase in the width of the cavity upto 12mm. The higher the air cavity and double/ triple insulation, the lower is the U-value which are advantageous for colder climatic regions. If you are designing building for a place like London or Scotland, you can opt for double or triple glazing systems which will reduce your U-value and increase the resistance of the windows from fluctuating due to colder temperature at their exteriors. This is how single glazing is, there is one glass and this is your home, this is outside. When there is double glazing you have an insulation layer or a gas which is being kept in between two panes of glass, this is your interior space and this is your exterior space. Heat that is flowing, gets trapped inside your insulation and it is mostly bounced back towards the interior and only very small amount is

escaped outside. These are different types of glazing materials and different combinations how it can be used.

Latest trends in Glazing Units are - Switchable Glazing which will enable the user to change the optical or thermal property of sealed glazed units. The most useful and potentially applicable switchable property is the chromogenic phenomenon in which materials change their reflectivity and absorptivity. Examples of chromogenic process are thermochromic, electrochromic and photochromic material. These are latest trends developed in glazing which are capable of changing the thermal property of the glazing system. Next is, Evacuated glazing - Evacuated, sealed insulated glazing is designed to achieve higher levels of thermal performance by using a vacuum to inhibit any kind of conductive or convective heat losses. This ideal for kolla regions as well, to reduce the heat loss, we are going to keep two glazing systems that are going to be filled with certain amount of gas which forms this evacuative glazing system. Flip windows for improved performance in summers and winters. The double pane absorptive glazing system for hot climates have a useful feature for regions of hot & dry climate having both heating and cooling seasons. If there is a climatic condition that demands for both space heating and space cooling, this type of glazing system is ideal.

Next is, Solar Control Glazing. They are very effective against heat flow across the window but can reduce transmission of light inside the space. This type of glazing solar control, it reflects most of the incident solar radiation that has been falling on the surface of the glazing system but one disadvantage is that it reduces the ingress of daylighting.