Glass in buildings: Design and Application
Mr. Jaideep Vivekanand
Indian Institute of Technology, Madras
Department of Civil Engineering

Lecture - 76
A Case Study of Building Envelope in the context of Environmentally Sustainable Design_Part II

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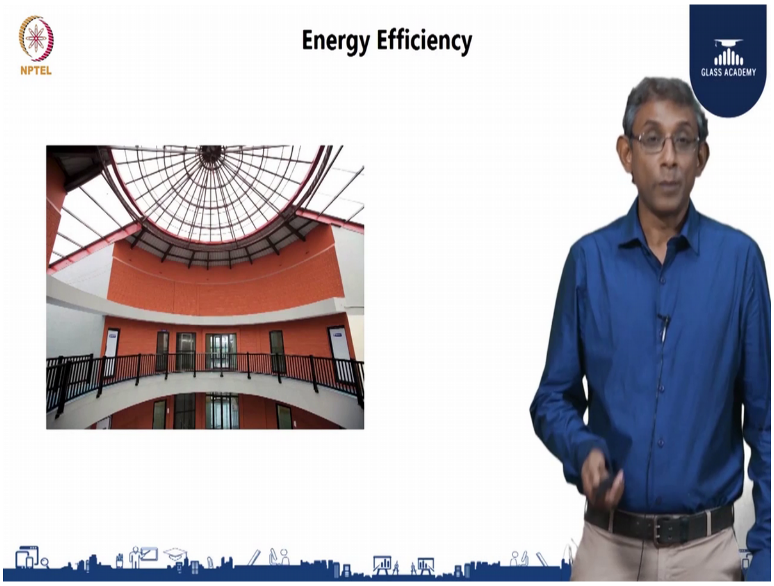

So I am going to take off from where architect Anupama left off and this is really shows way how a typical design project unfolds in our firm where initially the architecture team looks at the site a in addition with the environmental context comes up with the forms the spatial layout. And once that is frozen then the green building advisory team joins the project and also comes and works along with them to work on the finer aspects of the energy efficiency and the other environmental aspects of the project.

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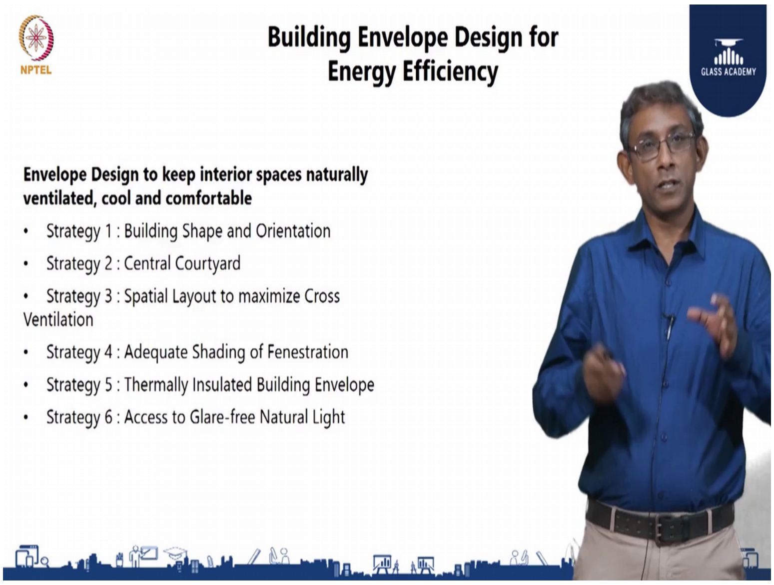

So, in this particular case study today we are going to specially focus on the building envelope design and the design was specifically done to ensure energy efficiency. Given that the facility was going to be primarily naturally ventilated we wanted to make sure that the building would be naturally cool and comfortable for the occupants without the use of extensive conditioning.

So, in this regard we used as many as 6 different strategies, you can think of them as passive strategies, you can think of them as building envelope strategies, but these were concious design choices that we made to make sure that the building stays cool and comfortable, which is very important for assuring the productivity and the well being of the occupants.

So, if you look out the strategies number one was; obviously, the building shape and orientation on this site. The second one which again architect Anupama already talked about is the central courtyard. It is a feature that is essential to keeping the spaces well ventilated airy and this is something that we have drawn upon from the historical design context of Tamil Nadu where central courtyard are key features of old buildings. The third strategy was the spatial layout of each space each regularly occupied space was done in a way to maximize cross ventilation.

So, we wanted to make sure that because it is a naturally ventilated building there will be breeze moving throughout the day and keep the interiors airy. The fourth strategy was wherever fenestration happens; we wanted to make sure that it was adequately shaded. This again in a tropical zone in a warm and humid zone is very important that the direct sun ray does not fall on fenestration also does not fall on the walls because that is where most of the heat gain is going to happen. The fifth strategy that we used was making sure that the building envelope is insulated.

This includes the walls; obviously, the fenestration and also the roof to make sure that internal heat gain is minimized. The sixth strategy was all the regularly occupied spaces should have access to glare free natural light. Often times it is seen especially in contemporary buildings where there is a lot of glass used. Yes there is a lot of light coming in, but often it comes with so, much glare, but again forces the use of internal shearing.

So, these were the 6 strategies that we employed in this project to make sure that the spaces inside are cool, comfortable and give a productive environment for the students and the faculty.

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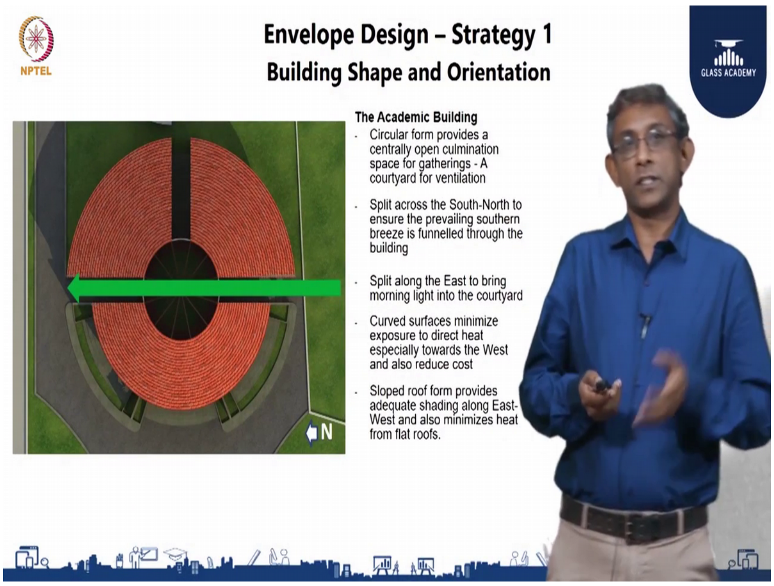

So, first strategy again Anupama has already talked about it, but I just walk you through in the context of energy efficient design.

So, again the circular form made sure that there is no direct heat gain on any facade and specifically the way the forms are cut out. The smallest segment faces the west which is where in that particular area is a lot of heat gain. So, we ensure that the west facade is the smallest also curved. So, this helps minimize the heat gain from there. The breeze waves as Anupama talked about brings a lot of airiness into the central courtyard and from there it moves into the various rooms.

And again a the sloped roof which is very traditionally used in a hot tropical place like India is that through the day the suns direct exposure does not keep falling on the flat surface. So, this is again a key strategy in making sure that the heat gain into the building was kept at minimum.

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The second design strategy that we used was again something that Anupama has referred to, but this was the central courtyard. So, the open central courtyard from a usage point of view was a key aspect of bringing in socialization interaction amongst the occupants, but from an energy efficient point of view there were two aspects that we looked into here.

So, one is that the courtyard itself is open on the top and this forms a stack effect. So, as the air inside the space gets hot and heated up it rises and then finds a way out. This in turn keeps forming a circulation. So, the breeze comes in from the openings and goes up. So, this whole thing keeps the central courtyard airy and comfortable the second part was the conscious decisions to keep the openings into the courtyard along the prevailing wind direction. So, the wind comes in from the south exists through the north and in that process spreads into the courtyard and funds breeze into the regularly occupied spaces. So, this was a second strategy that we used.

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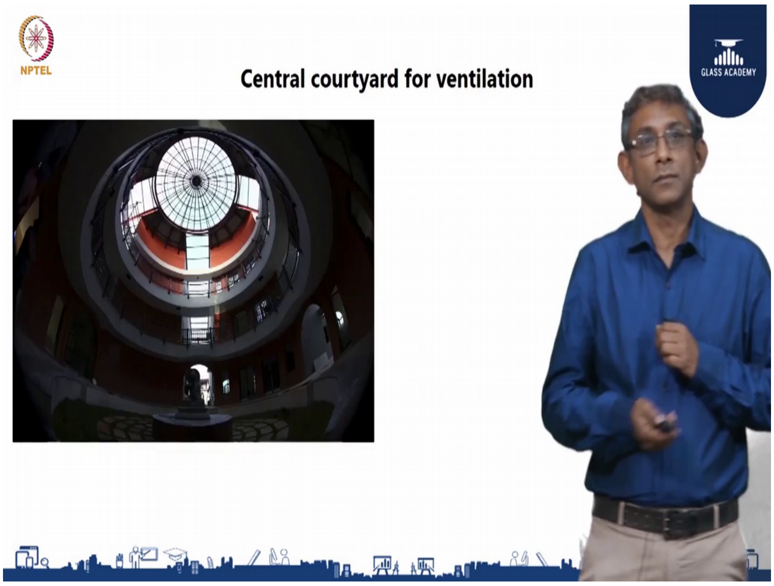

Here is an image of the central courtyard. So, that gives an idea of how the space looks and feels. So, I as Anupama mentioned there is the statue of a Buddha right in the middle that brings a visual focus into the centre. There are 3 levels the ground the first and the second and the courtyard on the top. While the central part of the courtyard itself is a has a glass cover to avoid rain there are openings on the sides.

So, the hot air can go up and then exit from this side. You can see from this behind the Buddha statue is the opening towards the east and that is again a direction from which natural light comes in and then as the sun moves up, it comes in through the top and then moves on to the west and that is where the built form on the west shields the harsh sunlight during the afternoon part of the day.

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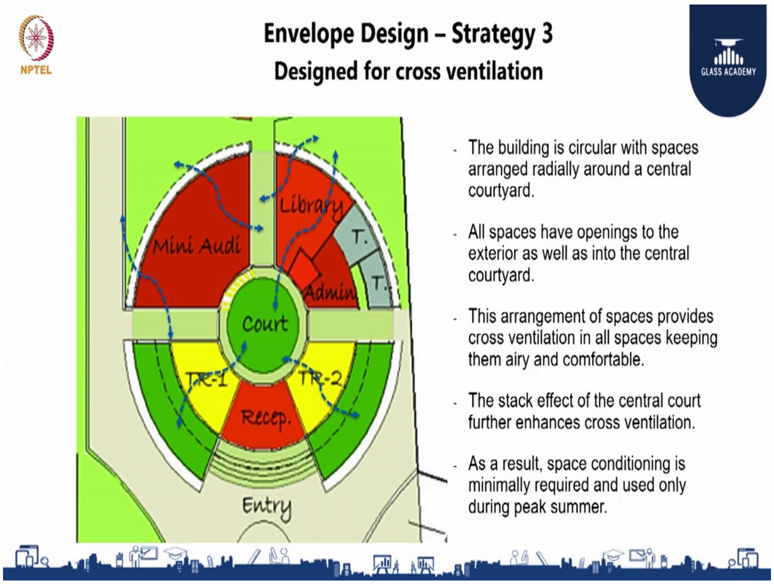

The strategy number three that we used was ensuring that the spatial layout of all the regularly occupied spaces lent itself for good cross ventilation. So, as a we you know the building is circular and it has a central courtyard and all the regularly occupied spaces are arranged around it. So, if you look at anything for example, the training hall number 1, it has openings towards the exterior as well as towards the courtyard. And then when you open out the fenestration, the breeze naturally comes in and flows from the outside into the courtyard or vice versa depending on the time of day and the breeze direction.

So, this arrangement of spaces makes sure that cross ventilation is happening there is also natural light coming into those spaces. So, keeps the interior generally comfortable at adding to that the stack effect of the courtyard makes sure that hot air whatever forms goes up and exits out and because of this kind of an arrangement space conditioning was kept to a minimum and any how generally used only during peak summer days.

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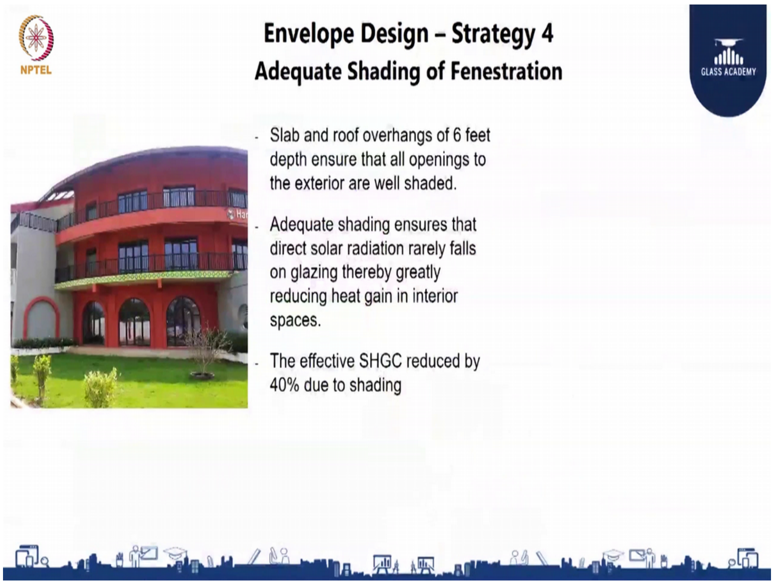

Strategy number 4 is adequate shading of fenestration. So, what we saw here was a there was a need to have lot of openings to bring the natural light also ventilation, but given that how could we make sure that the internal spaces do not get heated up. This is something that is very well known to people who have cars. When you have a option to park you rather park it under a shade, then keep it open similarly whatever fenestration we create should be well shaded in a tropical place.

So, here what we did was we decided to overhang the roof and the slabs at various levels to make sure the adequate fenestration covering is achieved. This again then turned into a functional usage which added to the charm and the usability of the building. So, for example, wherever the slabs were extended out those becames balconies step out spaces.

So, between classes or during seminars the occupants have a space to come out enjoy nature, then go back in a it also definitely adds to the aesthetics of the building. But the main and important point is that the shading makes sure that direct solar radiation is not impacting the fenestration or the walls for that matter. Then this in turn makes sure that its only secondary heat a through conductivity and not through radiation that gets into the spaces.

This also ensures that there is no direct sunlight and light going into the spaces, which again reduces the glare in that space makes it much more comfortable gives adequate light, but keeps it at a comfortable lux level. What we did was the slab overhangs where about 6 feet and this led to a reduction in the SHGC which is a solar heat gain coefficient by forty percent.

So, this allowed us to also make sure that we can select a glass that has a the right amount of solar control, but has adequate a visual light transmission also. So, this was the fourth strategy that we employed.

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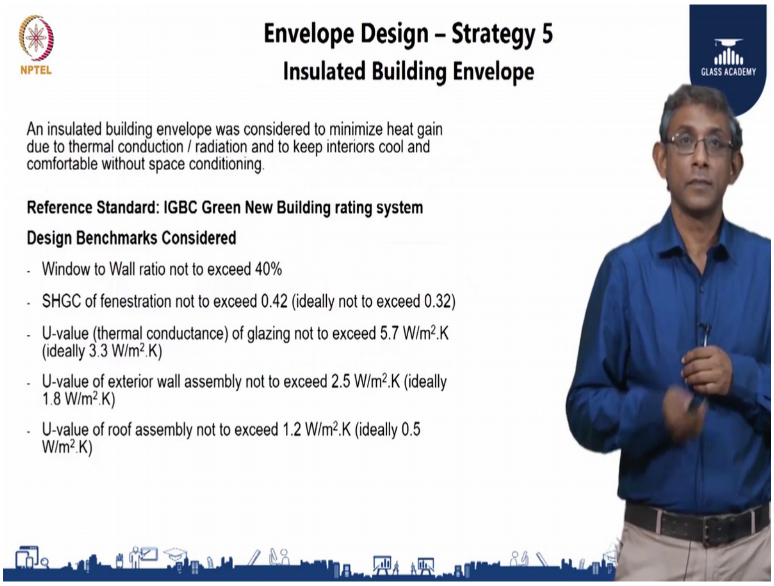

Moving on to the fifth strategy and this is a formed a core part of the envelope design was to make sure that the building envelope was a well insulated. A in this a regard we had a reference to the IGBCs green new building rating system. So, given that the building was meant to be naturally ventilated. We wanted to make sure that the envelope heat conductivity of aspects the well in line with this rating system.

So, some of the design benchmarks we considered were number one the window to wall ratio was not to exceed 40 percent. When you do that you a have a little more leeway in some of the other factors where it is a required to bring in enough light; directly this leads into the solar heat gain coefficient of the fenestration.

So, as per the standard we should not exceed 1042 what this means is that if solar radiation is falling on a piece of fenestration 42 percent of the heat the infrared part of the radiation can come in to the space, the rest is kept out. While 42 was the minimum level as per the standard the ideal level was 0.32.

So, what we wanted to do was make sure whatever glass product we choose that along with the shading that we create makes the a solar heat gain coefficient not go more than 0.32. The next factor we considered was again another aspect of the glazing which is the U-value or the thermal conductance for somebody who is may not be familiar with this term a U-value is the extent of heat that can go from one side of a surface of a piece of object to the other side a in 1 square meter of area when the thermal gradient from one side to the other is 1 degree Celsius. So, this gives a way to quantify how thermally conductive a certain object is.

So, in this case the as per the standard the maximum heat gain that you should allow through glass was 5.7 watts per meter square Kelvin. So, what this means is that in every square meter of glass if there was one degree centigrade difference from the inside to outside not more than 5.7 watts of heat should go through. This also leads to the fact that going back to the window wall ratio. So, more extent of fenestration you give that is the kind of heat that can flow through the glass.

The fourth aspect we look at was the thermal conductivity of the exterior wall system. So, while we make sure that the windows do not exceed 40 percent of the built form the facade. We now need to look at the thermal conductivity of the wall itself. So, here again as per the standard, we should not exceed more than 2.5 watts per meter square Kelvin and ideally not exceed 1.8 watt per watts per meter square Kelvin. And the last aspect we looked at was the U-value or the thermal conductivity of the roof which again in a warm and humid region should not exceed 1.2 watt per meter square Kelvin and in ideal case should not exceed 0.5 watt per meter square Kelvin.

So, to just explain why there are two benchmarks we are looking at. As per the IGBC green new building standard, which draws upon the ECBC or the Energy Conservation Building Code of India. These this strategy is typically called a prescriptive method where a the rating system or the standard gives certain benchmarks and U as a designer will try to keep a your a buildings benchmarks below this as per the case b.

So, here there is a minimum which is looked at as a mandatory requirement and an ideal which is looked as an enhanced requirement. So, ideally we should be achieving the enhanced requirement, but at the least we should be conforming to the minimum benchmark. The some other things that we need to look at is sometimes when you are trying to achieve the ideal benchmark. There is a cost associated with it and specifically in this project where cost consideration was a key a factor that we had to consider making sure that we meet and adhere to sum of these benchmarks without greatly shooting up the cost was a key consideration.

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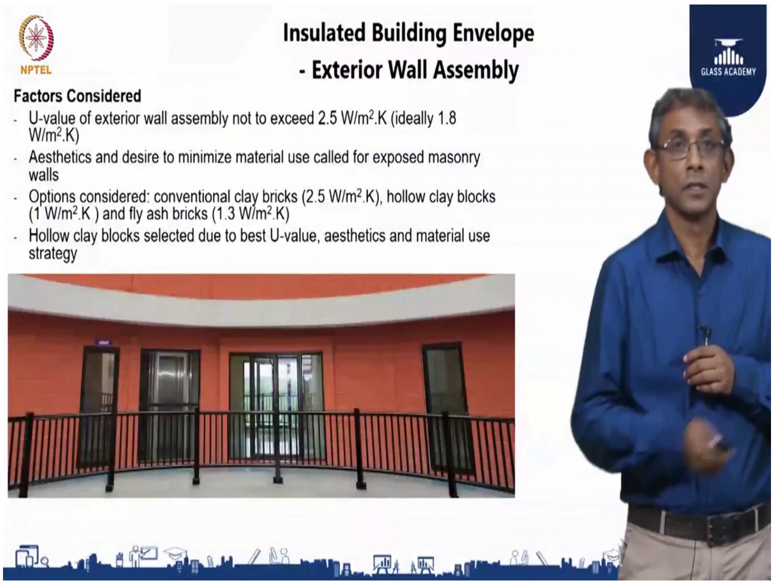

So, if you look at the exterior wall assembly, what we again considered was number 1 as I mentioned earlier the thermal conductivity. So, in the ideal case we should not be exceeding 1.8 watts per meter square Kelvin, but at the minimum we should not exceed 2.5 watts per meter square Kelvin.

The second aspect that helped us choose a proper wall material was the aesthetics which being rooted in the cultural context of the space call for expose masonry a and this was not the only reason. The other reason was to consciously and have a sensitive material use policy where we said we will not use material unnecessarily. So, again avoiding plastering of these walls make sure that a polluting a material like cement it is minimized.

So, these were two of the aesthetics and cost related factors that went into the selection of a wall material. Here we looked at 3 options a given these two factors, one was conventional clay bricks; the kind of bricks a kiln fire bricks that are normally available a. And generally the U-value of a wall 90 inch or 3 230 mm wall a plaster on both sides or plaster on one side would be around a 2.5 watts per meter square Kelvin.

We also looked at hollow a clay blocks or hollow terracotta blocks a. These are typically larger blocks which have several voids across the cross section its U-value if you look at plastering on one side comes to about 1 watt per meter square Kelvin. And the last a option, we looked at was fly ash bricks where a typical 9 inch fly ash brick wall a would lead to a resulting U-value of about 1.3 watts per meter square Kelvin.

So, we looked at these 3 and we obviously, wanted to go for the lowest U-value product. So, we looked at hollow clay blocks, it had the best U-value. It had the aesthetics that would suit the building and it also allowed us to leave it unplastered which also worked well with the material used strategy. So, the wall material that we used here was hollow terracotta clay blocks and this typically has a thickness of 8 inches or 200 mm.

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The next factor we considered was the roof assembly of the building. So, again the first aspect that we looked into was the U-value or the thermal conductance of the assembly itself. And here as per the standard we should not exceed 0.5 watts per meter square Kelvin and in the worst case not exceed 1.2 watts per meter square Kelvin. Again this is in the context of the region which is warm and humid.

So, given the climatic context the standard says ideally you should not allow more than 0.5 watt in every square meter of the roof. The kind of options we considered were Mangalore tiles which a worked well would work well with the aesthetics of the building

a. We could also look at an RCC roof or something like a metal sandwich roof with insulation in the middle. In this particular case, we went with the metal sandwich roof.

So, this is a cross section which has two metal layers with a layer of grass wool in between. The reason for this was number one it yielded the best U-value of 0.5 watt per meter square Kelvin RCC could have been used with some over deck or under deck insulation, but the form of the building and the that tricky shape makes it a little harder to use RCC in this form.

And again that was one of the reasons why Mangalore tiles was also not as suitable. And the final reason is that Mangalore tiles though aesthetically beautiful and do have some amount of thermal insulation. They do not come close to this kind of a value that we were looking for from the IGBC new green building standard point of view.

So, by now so, we selected the wall material we selected the roof material. So, we move on and a we are looking at the fenestration now.

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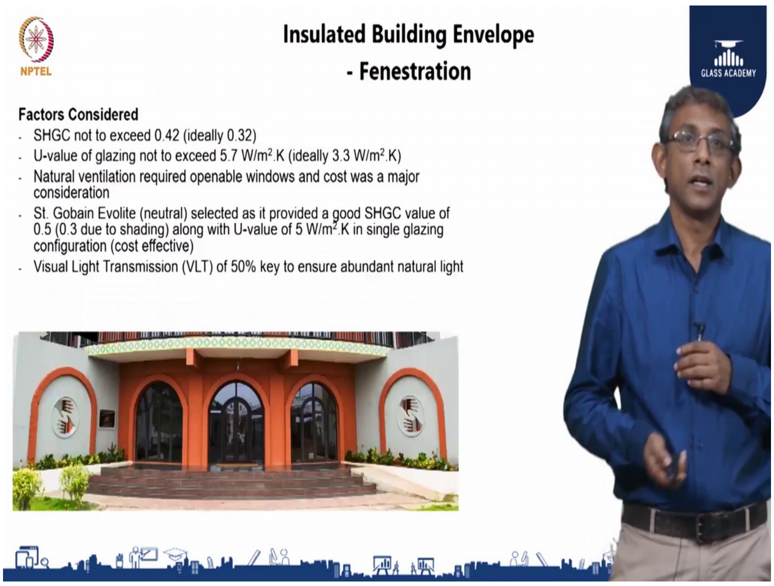

So, again some of the factors we looked at just to reiterate was that the solar heat gain coefficient should not exceed 0.42 and ideally it should not exceed 0.32 so; that means, that if a sun's rays were to fall directly on that fenestration not more than 32 percent of the heat gain or the solar infrared part should transmit through the fenestration.

The next part is the U-value of the fenestration and again according to the standard it should not exceed 5.7 watts per meter square Kelvin and ideally 3.3. Now the way you look at solar heat gain versus the U-value or the thermal conductance is this is that the first part the solar heat gain happens when there is direct incidents of solar radiation on that fenestration.

So; obviously, this is a key consideration during the day and again given the used case of this building which was primarily educational through the day. Now this was the key factor that we wanted to achieve the second part which is the thermal conductance that comes into play due to thermal difference or difference in temperature between one side versus the other side. So, in this case the difference in the outdoor temperature or the ambient temperature through the indoor temperature. Now given that a, this building was going to be naturally ventilated this required fenestration to be kept open for a large part and also given that we were not going to air condition most of the building the thermal conductance a aspect becomes a little less important than the solar heat gain.

So, what we decided to do here was we selected a product which gave a good SHGC value in this case the product had a value of 0.5 and then in combination with the 6 feet overhangs that we had provided. The effective solar heat gain coefficient comes down to 0.3. So, we were able to come under the ideal SHGC value a and a we were also able to come under the U-value a given that the products U-value was 5 watts per meter square Kelvin.

We could not achieve the ideal value of 3.3 because that would require double glazing and given that this was a naturally ventilated building where the fenestration be kept open most of the times and also the given cost which was a very important factor where a double glazed system would increase the window sections and then the cost we decided to keep adhere to the mandatory requirement and not the ideal requirement.

The last part of this is that the visual light transmission of the product was 50 percent which was a good balance in letting natural light come in versus avoiding glare. So, this led to the selection of the glass for the fenestration

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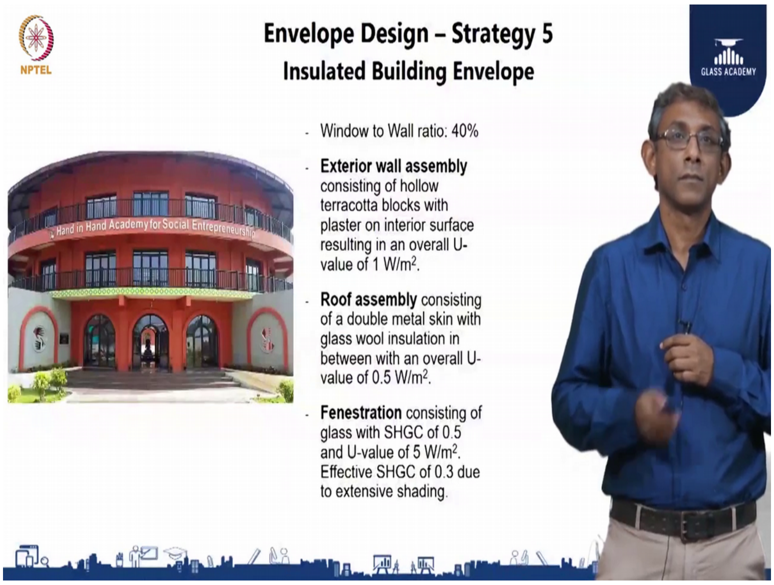

So, to summarize what we did in terms of the building envelope was the window to wall ratio was kept at 40 percent a. This was again in line with the IGBCs new a green new building standard the exterior wall assembly was made out of hollow terracotta clay blocks a with plaster on the interior surface and expose on the outside with overall U-value of about 1 watts per meter square Kelvin.

Roof assembly consisted of a double metal skin with glass wool insulation in between achieving an overall U-value of 0.5 watts per meter square Kelvin and lastly the fenestration consisted of well shaded French doors and windows with a glass that had a SHGC value of 0.5 and a U-value of 5 watt per meter square Kelvin with an effective SHGC value coming down to 0.3

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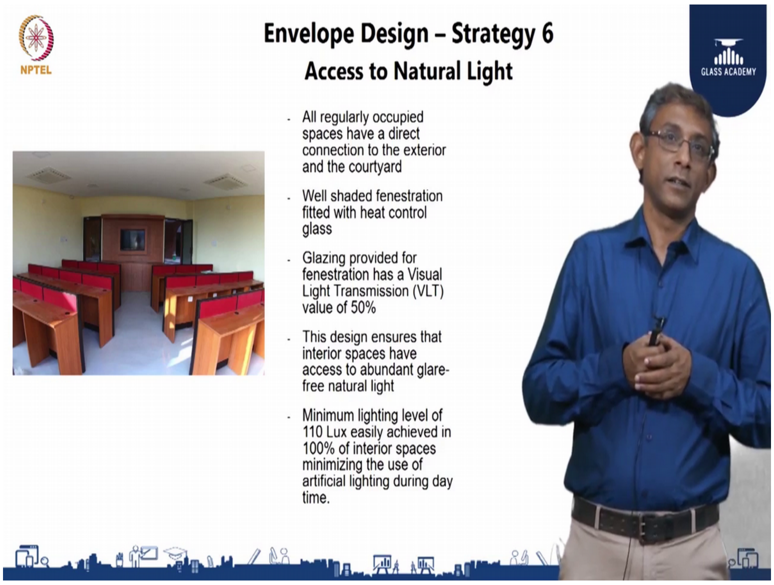

The sixth envelope design strategy was access to natural light. So, given that a we are minimizing the heat and we are going to keep the windows open, we wanted to make sure that a all the spaces are well a have abundant natural light, but not to a point where it becomes a glare and then you are forced to use shades or other kinds of objects like blinds.

So, as I said before all a regularly occupied spaces have a direct connect to the exterior and also to the interior courtyard and along with that well shaded fenestration with heat control glass that makes sure that there is light without too much of glare and heat as I said earlier the glass VLT or Visual Light Transmission value was 50 percent. What this means is that if again the solar radiation falls on light 50 percent of the light would stay out whereas, 50 percent of light would come in.

But this should be looked at in the context of the kind of light or lux level, you need to do your tasks a for building of this sort as per the a green new building standard a minimum level of 110 lux was a what was minimal acceptable. And given the spatial layout the kind of a glass used, this was easily achieved a in 100 percent of the regularly occupied spaces. What this led is again minimal use of artificial lighting during the day and that is when the building is mostly occupied and used is again goes back into reducing the energy consumption of the building.

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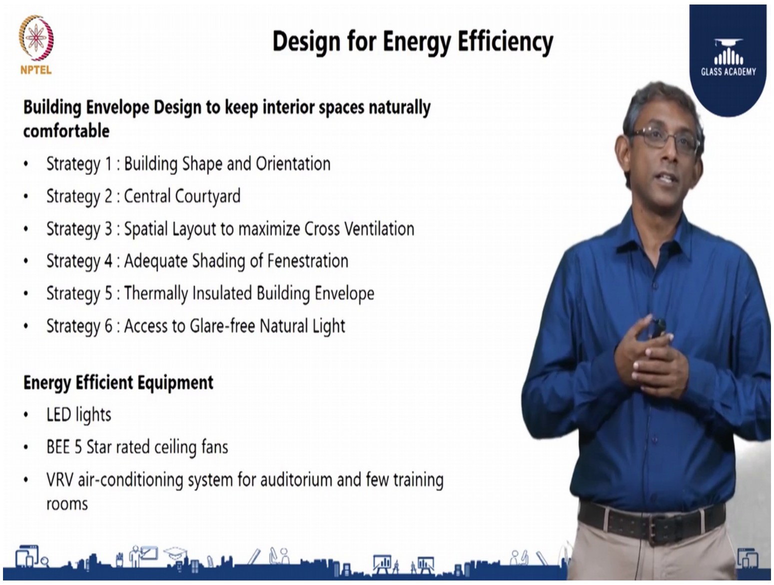

. So, just to summarize what happened. So, in terms of the design of energy efficient building, we looked at two things we looked at all the passive measures which means the measures that go into the building itself. So, again just to summarize, the strategy number 1 was the building shape and orientation; so, this the round shape with minimal exposure to the west breeze waves to the south which is the prevailing wind direction that was the first strategy.

Number 2 was a central courtyard which allows for a stack effect helps ventilation and cross ventilation. Number 3 was as part of the cross ventilation making sure that all the regularly occupied spaces have openings at least two orientations. So, in this particular case every space had an opening into the courtyard as well as an opening into the exterior environment.

This makes sure that there is a movement of breeze from one side of the building to the other; making all the interior spaces well ventilated strategy four was a adequate shade shading of the fenestration which was achieved by the slab overhangs and the roof overhang which again led to some very usable balcony and walkway spaces. Fifth strategy which we talked about in detail was the thermal insulation.

So, the walls the roof and the glazing they were all selected to minimize heat gain from outside into the spaces. The fifth strategy was access to glare free natural light. So, these were the passive or the building related measures that went into the building to keep its energy footprint low.

The other side of it was some of the active systems which means the lighting the fans or the air conditioning. So, some of those choices were led lights a BE 5 star rated ceiling fans and wherever minimal spaces which required air conditioning which is the auditorium and a couple of training rooms. A VRV air conditioning system was used which has a high coefficient of performance and has a low energy footprint.