Architectural Acoustics
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Lecture – 14
Acoustical Absorbers

So, today we will be further continuing with Acoustical Absorbers. We have dealt with the different types of acoustical absorbers particularly the frictional absorbers, the panel absorbers, and the resonators. And we have seen how they are to be put into our structure integrated with our structural system so, that we can actually achieve a good amount of absorption.

We have also seen how with the variation of the width with the variation of material in fill inside it, we can keep on changing the amount of absorption and for different frequencies.

And from there we could have a good understanding of acoustical absorbers and how they are to be placed, to get effectively effective amount of absorbance whether to put it on the ceiling or on the wall and we also worked with some slit slat resonator, how to how it changes with the depth of the slats, with the width of the slat, and with the depth from the wall, but not in all cases.

We can have such structural system, which will be friendly with our particular space V design. We need our windows, we need to locate doors, we need to have movements of people inside set in case of a gymnasium or say a sports arena, we cannot get so, much of wall spaces or structural surfaces so, that we can actually apply such absorbers.

So, today we will try to see some more absorbers.

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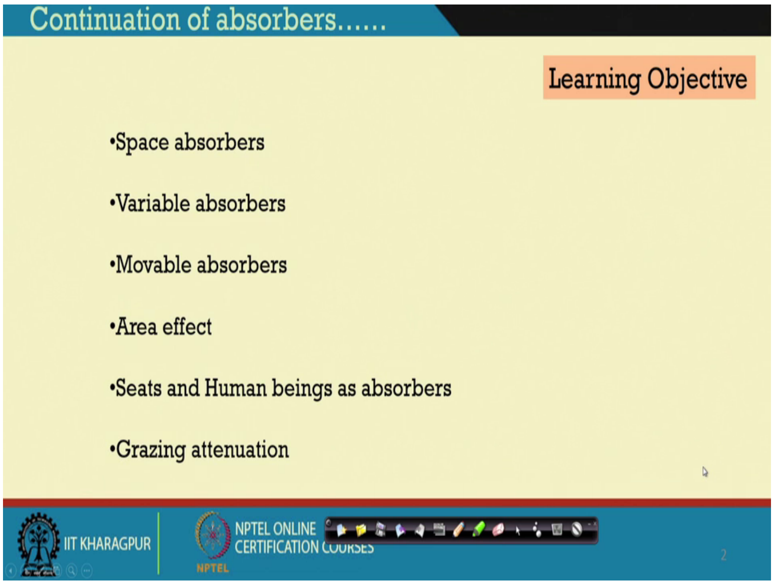

So, it is a continuation of the lecture of acoustical absorbers, where we see space absorbers, variable absorbers, movable absorbers, and after which along with and with it is application, we will see some more effects like area effect. And we know we are creating these spaces for people.

So, people have to come here. So, we have to know whether human beings are absorbers at al or not. Because, we have during winter we were coats, sweaters, woolen, which is of a different character other than, what we have during our summer which is cotton? So, that also changes the acoustical absorption within the room. And when this audience is of the order of 500, 600, 1000, then we cannot neglect it.

Similar with the seats, if you want some concentrated performance people are sitting and viewing. So, you have to provide seats in orderly manner, which also impart towards the acoustical absorption. We will try to see and learn through of these examples and we will also try to see, what is grazing attenuation?

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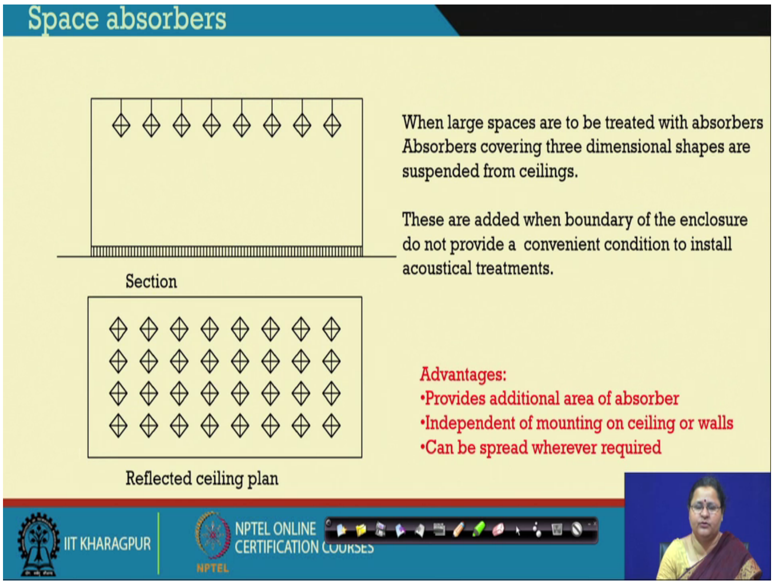

So, we will come to them one by one. So, let us start today's class. What you see here is the reflected ceiling plan? Where, you see some squares, which are hanging from the section from the ceiling. So, what are these elements doing? These are actually adding to whatever area we have we could generate within the space.

So, we have walls all around maybe they are not sufficient or they are not to be covered by absorbers, because people may be moving in an out through these openings along the walls. So, in case of such spaces we can actually add upped something hanging from the ceiling apart from treating the ceiling. We also have to know that this in these kind of spaces there maybe sources at different points.

So, these will actually give a uniform amount of sub absorption at the ceiling and not disrupted absorption, if even planned along the walls. So, these will cover the ceilings and when the boundaries of the enclosures are not convenient to install the acoustical treatments then we can adapt such absorbers.

So, the advantages are it provides additional area of absorber. Firstly, and it is independent of the mounting on ceiling or from wall. So, you can just hang it from the walls from the ceiling and it can be spread at wherever required. So, if your source is multiple, you are creating sound in the entire environment then in that case space absorbers is the answer.

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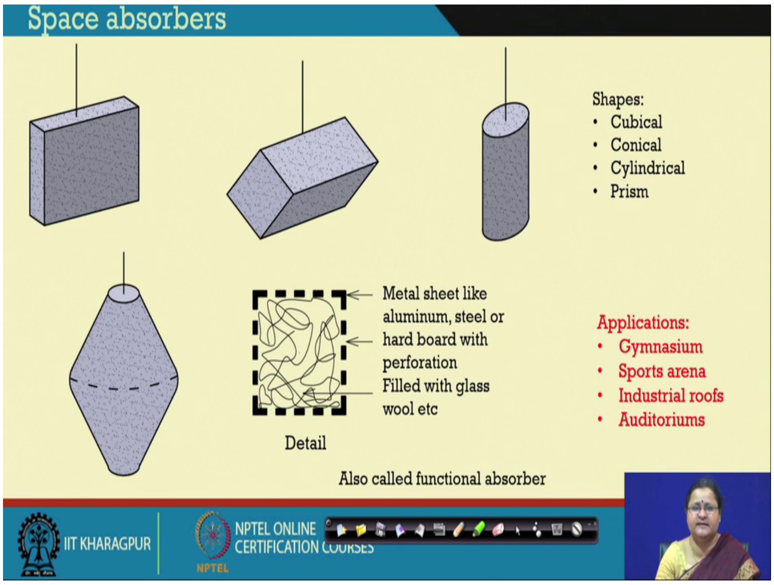

Now, these could be of different forms and what are they actually, they could be cylindrical, they could be conical, they could be double prism, they could be they could be cubical in nature, and these are also called functional absorbers.

So, if you see it may be a covering of a metal sheet in into which amount of absorber is pushed in, that is it may be filled in with glass wool and it is a metal sheet with perforation or it may be a hard board into which the infill has been put in. So, this infill actually absorbs and these perforations allow the sound entry into these space absorbers.

Now coming to the applications you will see wide applications in gymnasium, where lot of noise can be created by the users where whereas, you need to be heard from different points to different people at the same time. In sports arena, when there is a lot of clapping, lot of applause, for the cheering up going on you need to absorb such space absorbers.

Because, the human beings are actually encircling the whole area and it is the ceiling which can which is actually kept open, which can absorb the sound. Some industrial roofs, industrial roofs that is in industrial floors a lot of sound may be generated and you really practically do not have walls around it the walls are may be metal sheets a simple metal sheets. So, there is no structural wall in that case in that case the ceilings can be having such kind of absorber.

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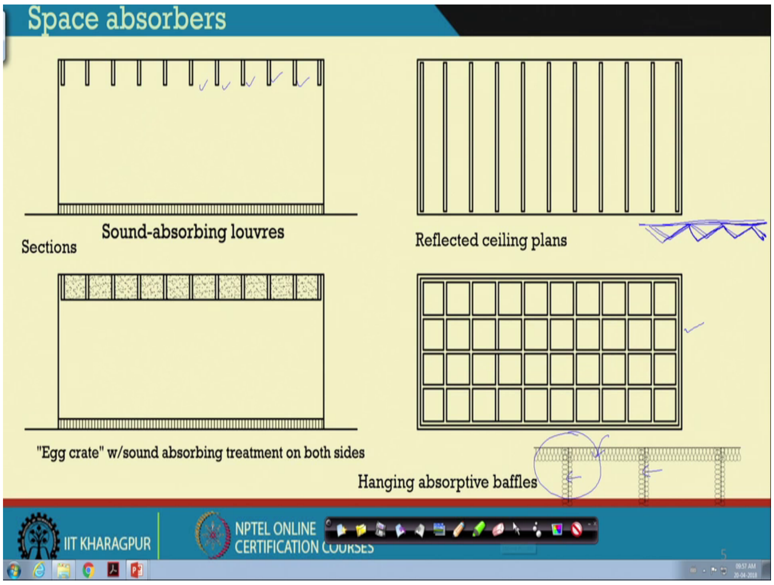

In auditoriums also we can add such absorbers to increase the area of absorption. We can also adopt space absorber so; we can increase the area by putting vertical, absorptive baffles not like the panel absorbers.

But, these are absorptive baffles as you can see here in the see here in this picture you can see the absorptive baffles. So, these are absorbing materials and these are also absorptive materials all along the ceiling, these are actually these elements. And, you can further increase by creating egg crate like ceiling arrangement.

So, by increasing the number of wall surfaces may in increasing the amount of absorptive surfaces, you are actually increasing the absorption capacity of the room. You can also have such (Refer Time: 08:36) pattern of ceiling on top of the on the ceiling.

So, these will actually increase the area, which was actually solved by this area will be increased by such projecting facade projecting elements. So, these could be of different absorptions and the absorption amount will be increased by this process. So, these all come under space absorbers. Here is a picture where you can see space absorbers, which were shown in the previous thing, previous slide, you see some space absorbers being hung from the ceiling.

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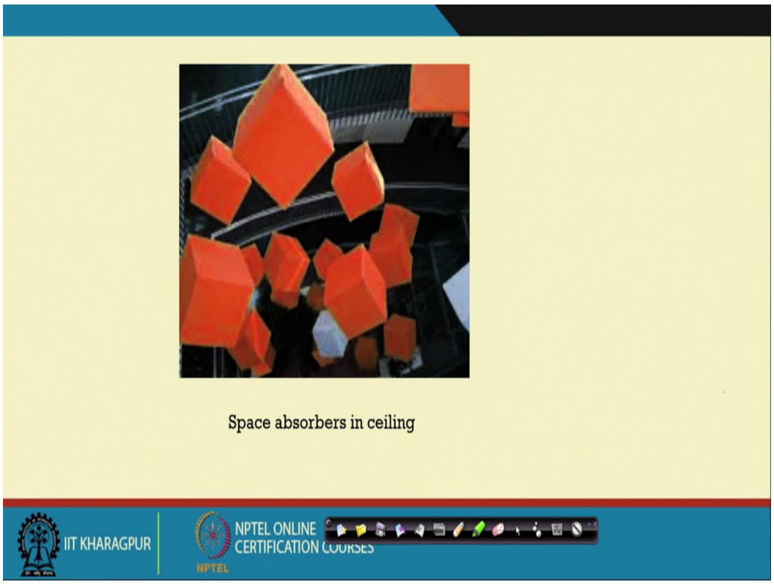

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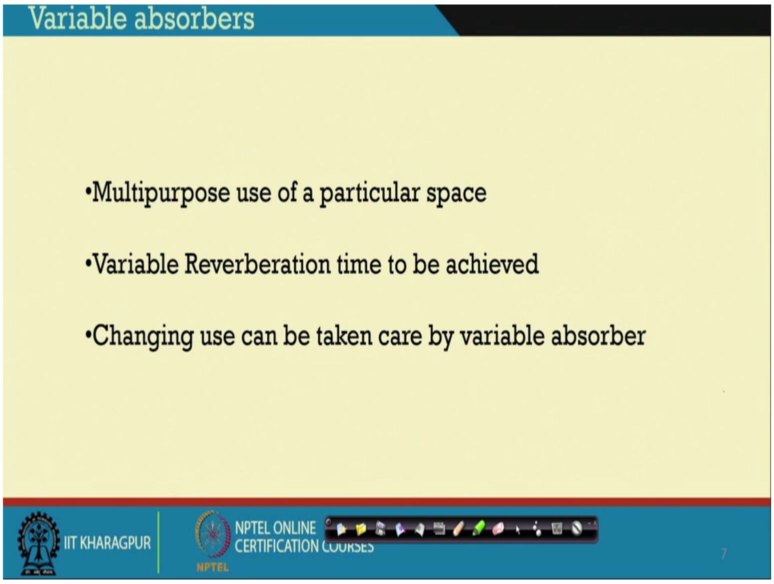

Now, coming to the variable absorbers; it is not always possible for us, to create specific environment for specific purposes particularly when the spaces are being. Say in a school we can have a multipurpose hall, where actually different kinds of performance can take place it may be for speech the principle or some visiting guest can come and give some lecture. At the same time we can have some small functions going inside and it is not really always possible to keep on changing the space. So, we can actually adopt some mechanism to change the absorption of a room within staying within the same place.

So, for different reverberation time that is required, which has been discussed in earlier lectures, that reverberation time varies with the performance happening here happening inside the space. So, we can actually change the reverberation time by putting in different kinds of absorber. So, how to adapt it? It is not a difficult task. So, you can change used by taking care of by putting in variable absorbers and by guiding the absorbers and you can actually work with the different reverberation time.

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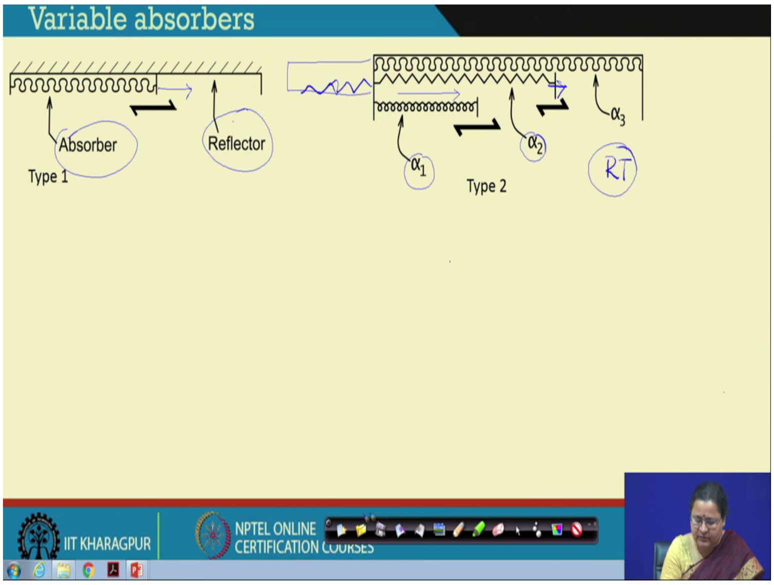

So, let us see; see here in type 1 and type 2 actually there was an absorber here and some portion was reflecting sound, by sliding in another item from this edge. So, this must be stacked inside some place here from which this is actually this is actually sliding out. So, once it is pulled it can cover up this entire area.

Even this absorber that was in the type one could be pulled further to cover the reflector on top of it maybe this kind of absorber can be put in. So, maybe another absorber, to create another layer that is alpha 1 alpha 2 alpha 3 and even the choice of reflector could be there to have changing reverberation time.

So, this RT determines how much of this whether alpha 2 should be required or alpha 1 to be required or a match of mix and match of the different alphas can be required, that is worked out from the reverberation time from the Sabine's formula and you can actually keep on changing.

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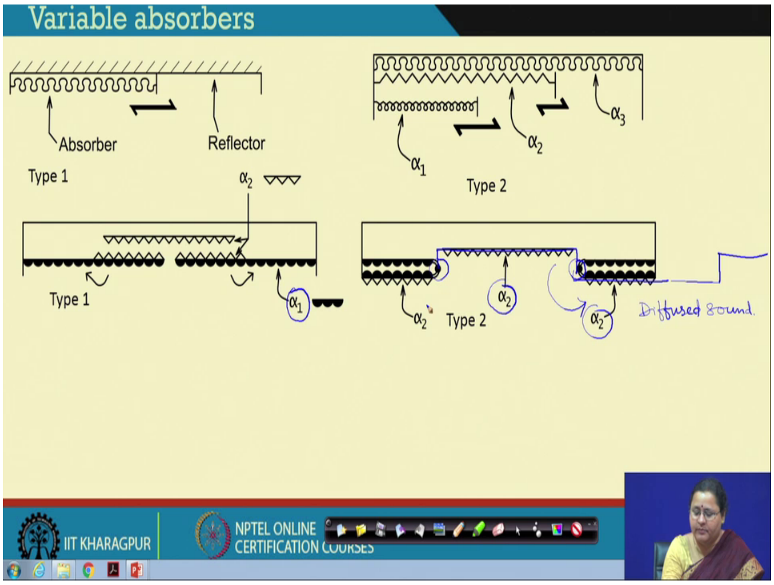

So, let us see some let us see some more examples. So, one was to slide out slide in things re absorbers now here you see you can actually have hinges. So, this is position 1, here you see this is position 1, which where you have a particular alpha 1 as the surface.

Now you have a hinging mechanism, which can actually fold in the top surface partially. So, partially and cover it. So, you can actually hinge and you see it is the same alpha 2 which was inside has been exposed. So, you see with a small recession inside actually you have got similar kind of thing.

So, you can actually follow on with the wall and this actually can lead to defused sound diffused sound also. So, that is also important for getting good quality sound. So, this kind of element can actually keep on change help in keeping changing from alpha alpha 1 to alpha 2 and again once it is done you can fold back to your alpha 1 stage.

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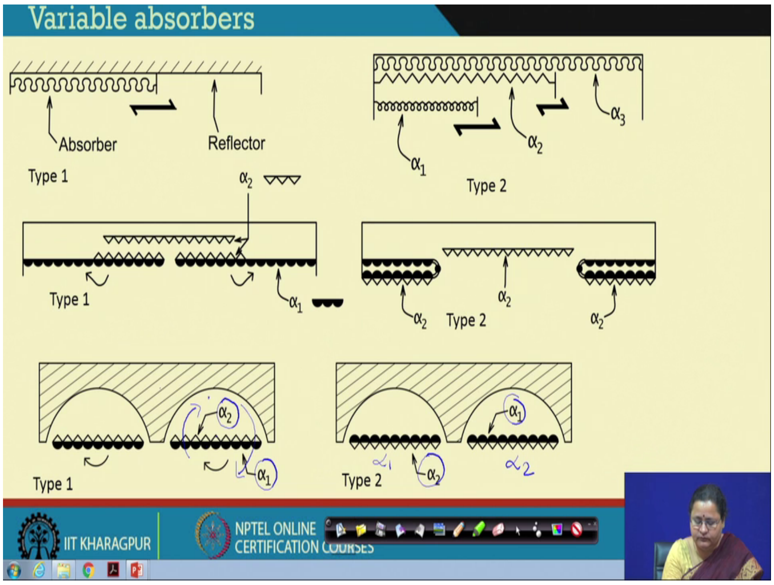

You can have another type, you can have rotating things. See on the upper side it is on the, which is not exposed is alpha 1 and outside you have alpha 2. In the first case it was alpha 1 outside and alpha 2 inside.

So, you have a structural system onto which actually there is a provision or a circular space where actually you can rotate the entire thing and have different layers of absorption. So, you see there is air inside it there is another layer of absorber inside it and with an expose different kind of absorber. So, all 3 members actually behave together to give you a resultant absorption value.

And this is; obviously, keeping in mind the reverberation time you have to make the choice. You can keep one as alpha one you can keep 1 as alpha 2. So, you may rotate them alternately you can rotate them all together you can keep them in their original position. So, you can have 3 options even you can rotate every third, every fourth, and you can keep you and you can keep on changing the absorption values.

So, what are we adopting?

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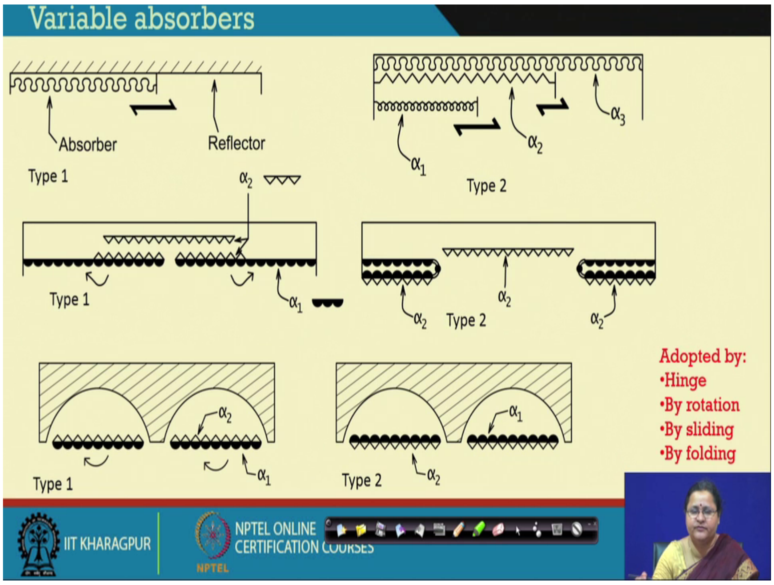

We are adopting different kind of absorbers within the same environment by mechanism by mechanical means that is by rotation, by hinging, by sliding, or by folding. So, this way actually you can keep on changing the internal absorption coefficient, internal total absorption, that is based on the absorption coefficient and you can keep on having different reverberation time for different to suit, different purpose, this is another example.

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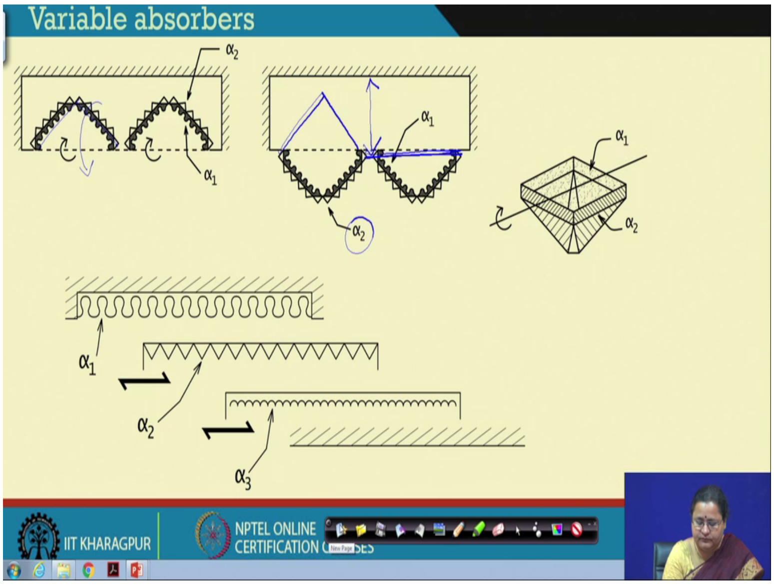

So, here actually you can have these surfaces which have which are pushed inside they can rotate and come down having another absorption coefficient outside. So, you are rotating against a particular rod here, you are rotating it and you can do it alternately you can continue the same way what I told? But these should be there should be enough space to house the rotated portion.

So, you need this particular gap from the ceiling or from the wall to mount such items. Now here is another example.

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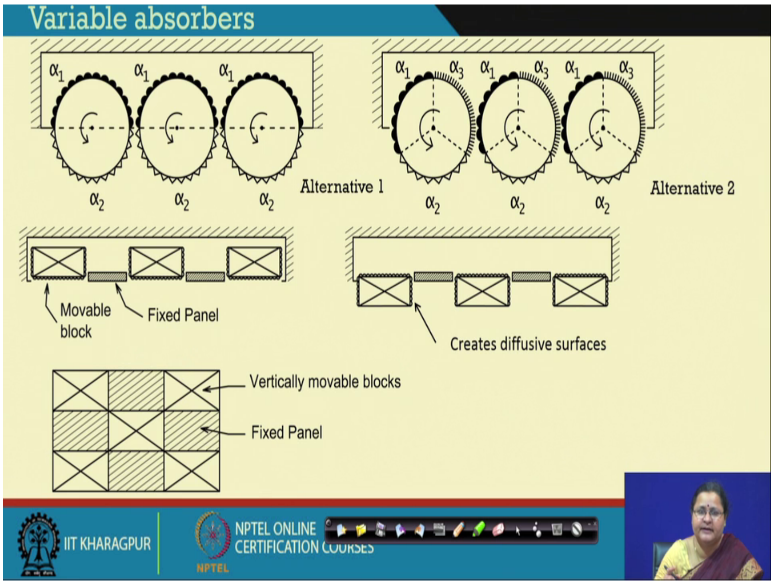

You can actually rotate and have 3 kinds of absorption the first figure shows 2 kind of absorption. So, if you rotate by 180 degree in the first case for the alternative 1, you can get a different alpha 1 coming out. So, if you rotate by 180 degree you have alpha 1 and the alpha 2 enters inside.

Similarly you can have 120 degree rotation and you can have select lesser aperture and you can have alpha 2, alpha 1, alpha alpha 1, alpha 2, alpha 3 a combination of 3 absorbers. So, just by rotating the drum which has been installed you can actually keep on changing your absorption inside the inside the space.

You can also have movable blocks you can see these are particularly in the ceiling areas, where when the fixed panels are there the movable absorbers can be rotated or can be brought down and diffusive surfaces can be increased. So, actually you are playing with the reverberation time, playing with the diffusive surfaces, by creating such kind of patterns.

So, if you keep in mind and be little innovative you may find a different solution for your particular space and that is where architects need to be innovative. So, you can actually I have given you number of alternatives how to vary absorbers and you can see that you can create patterns, you can generate patterns with different materials.

You can actually rotate and create a different kind of a look inside or the environment inside, but keeping in mind the basic principle that how much absorption you required and what is your target reverberation time?

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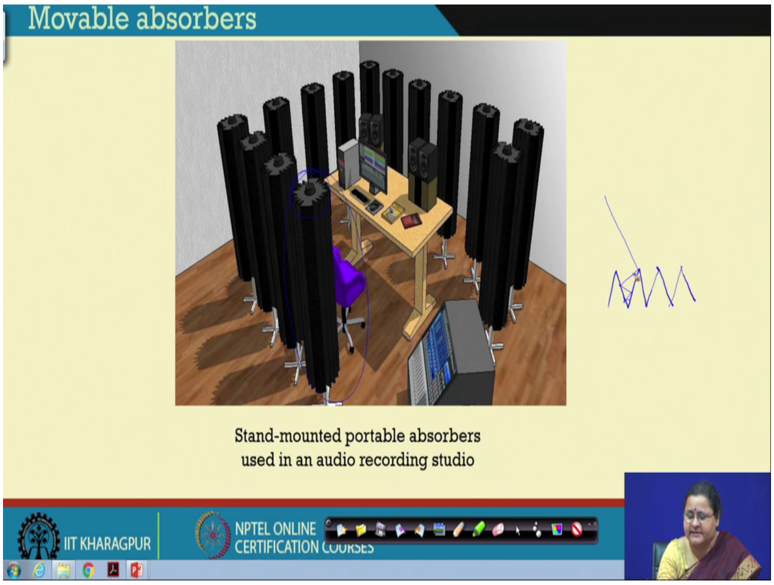

So, once you understood these we are left out with another type which is the movable absorber. See in recording rooms it is very important that you are heard 100 percent when you are recorded voice is send outside. It may be a music particularly in case of music you can have different types of music performed within a same recording room, it is not possible to achieve reverberation time of very low amount within a space.

But you can further increase or decrease your reverberation time as per your choice by bringing in items which are movable in nature. So, you can bring in 5 of these, 10 of these, you can take out 4 of these you can bring in another 20 as per the need. So, these are actually nothing, but movable items which have absorber all along it, you can see the surfaces, you have see you can see the wedges, which form the surface, which were discussed earlier, when the sound comes here it is it actually totally gets into it and dies down. So, there is not at all any reverberative sound coming out it is dying inside.

So, you can see the wedge kind of arrangement for these movable absorbers and this is how these kind of movable absorbers can be brought in into a recording environment and can be made use of effectively. So, once we have learnt all these.

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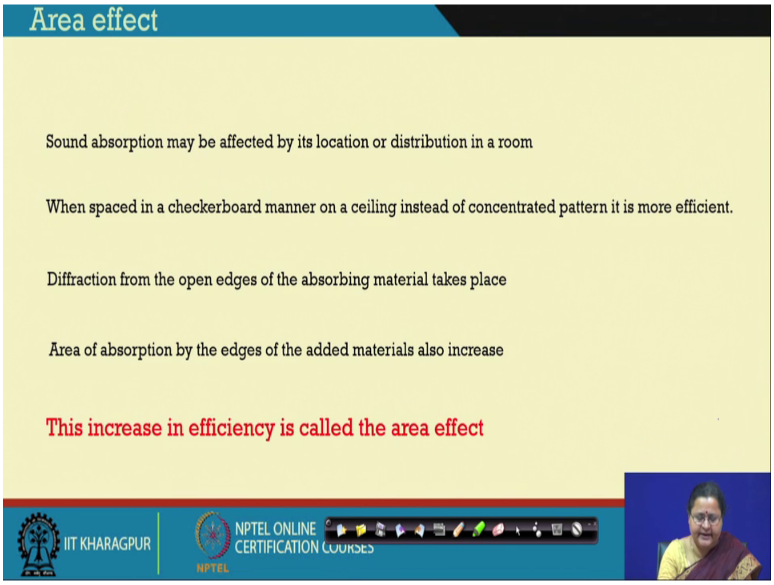

Let us see what is area effect? So, now we have discussed so, far that absorbers are required and you have to actually put in inside the room or the space, which you are designing in a very effective way. So, that your sound wherever required is trapped in or absorbed and you are getting a good quality sound inside.

So, if you are asked to put in absorbers of a certain area which you have calculated based on the reverberation time calculation from the Sabine's law, you get some area A. Now you have to distribute it in your space, if it is to be distributed should we put it at one end.

Let us see what happens? Now, based on the put based on putting the absorber in different locations, we can get different effects and that is called the area effect. So, when spaced in a checkerboard fashion on the ceiling instead of a concentrated pattern, it is found that it is it is more effective.

So, I will give you a simple example just after this slide and the diffraction what happens actually, when you are actually putting in the absorbers. The diffraction from the open edges are happening which is adding to the absorption. And the and the edges are actually absorbing the material to absorbing the sound also to some extent. So, the area of absorption by the edges should be added while we are making such calculations. And this increase in the area increases the efficiency of the absorber and that is called area effect.

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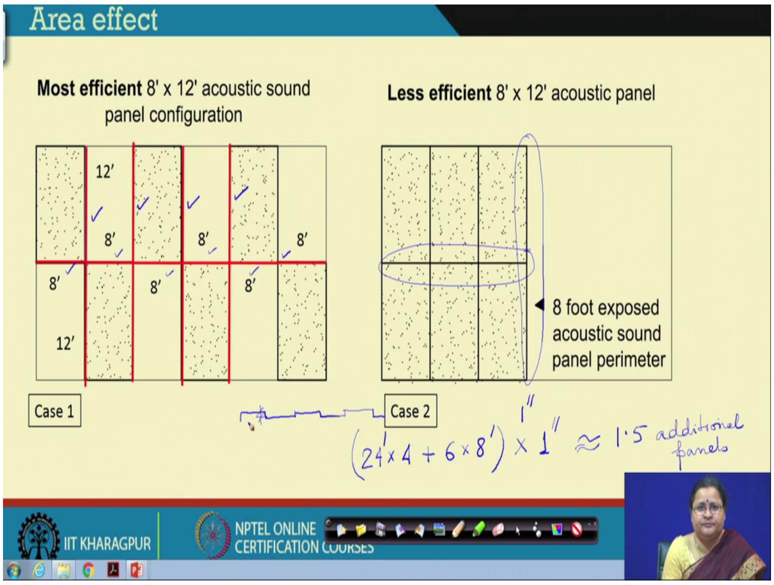

See let us see a ceiling where 8 feet by 12 feet boards 50 percent are 50 percent of the ceiling has to be covered which you see in case 2. So, 6 such boards of 8 feet into 12 feet of absorptive materials are taken in.

So, if you are actually distributing in case as in case 1, you see you are actually increasing the edges by some 12 plus 12 24 feet into 1 2 3 4 times and edges of 8 feet are exposed 6 times, which is not at all found in this case. Here actually there is no open edge and here only once the open edge is there whereas, here you see 1 2 3 4 times the open edge is there and the entire 8 feet edge is kept open all around.

If we think a one inch absorber is put in here. So, if you see this is 24 times 4 plus 6 times 8 feet is added, which is to be multiplied with the 1 inch of area is added, which is equivalent to or equal to almost 1.5 additional panels. So, this is actually 1 panel and 1 half panel is extra just, because of these additional areas being exposed.

So; obviously, this is a more efficient plan for so, far as absorption is considered as well these are coming down at an interval of 1 inch, which is actually creating a diffusing effect of the sound which adds to the quality. So, we need to spread the absorbers as much as possible, if the area permits and we can actually get more effective absorption with a better quality.

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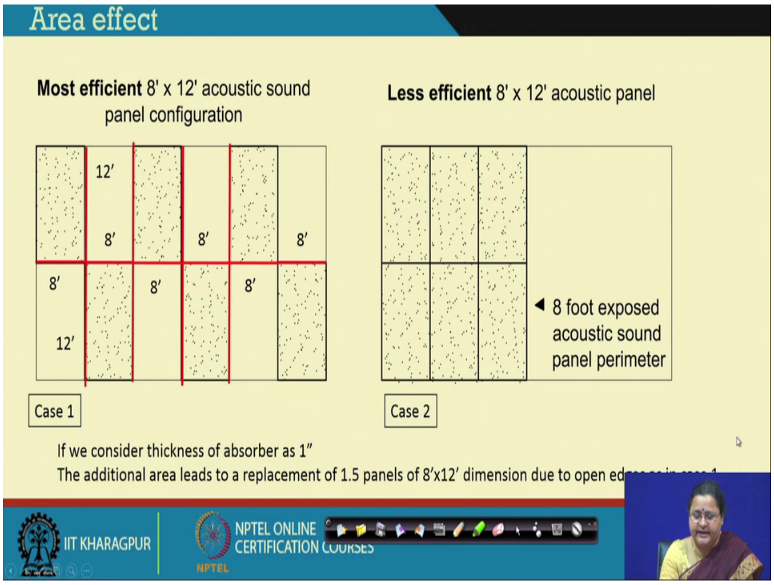

So, this is what has been shown through the case 1 and case 2 and you can yourself do it for some such items and you can see how this can actually affect the absorption coefficient, absorption coefficient and; obviously, that will be reflected on the reverberation time.

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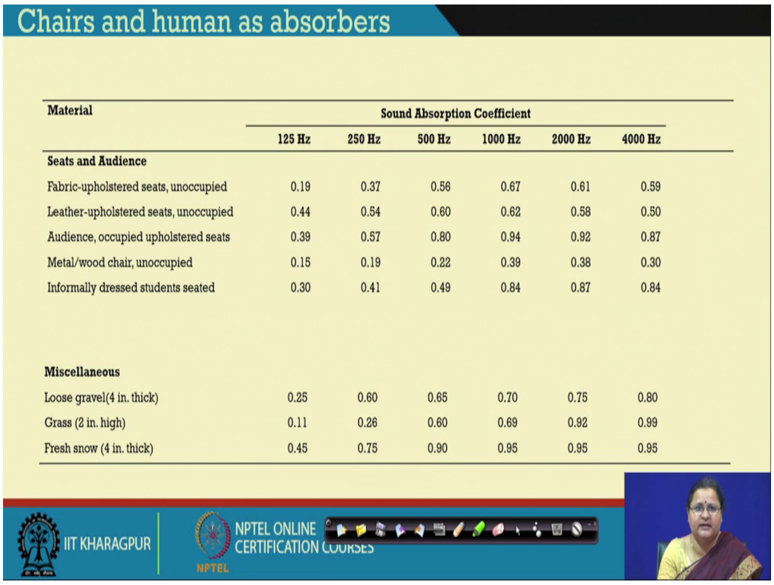

Now, coming to the human being as absorbers and chairs as absorbers, yes individually this is the chart which you can see in front of you, when there are some seats with some fabric in on it, we have some seats with leather on it, which are usually seen in spaces which we visit for particular function say auditorium.

And we have audiences occupying it there could be metals chairs, there could be wooden chairs, and some cases are in case of schools where we see, students who are little lesser in dimension from a normal adult and we see some variation in the sound absorption coefficient.

So, we can actually work out with these figures when we are working, but in case of auditoriums or in case of very planned areas the situation is something different. So, we cannot we have also need to understand, when these chairs or the human with the chairs are stacked in a proper fashion, the reverberation, the absorption does not remain the same.

I here also present some values which you actually experience outdoor, which has a relation with this discussion. So, I have brought in these figures also using loose gravels of around 4 inches, which we encounter in outdoors grass say around 2 inch high and or fresh snow.

These are referred in books because many of the books are written considering western country contest where fresh snowfall also adds to such phenomena. So, these phenomena which I am now coming to discuss, now going to discuss will actually have some relation. So, that is why I have put these data in 1 slide.

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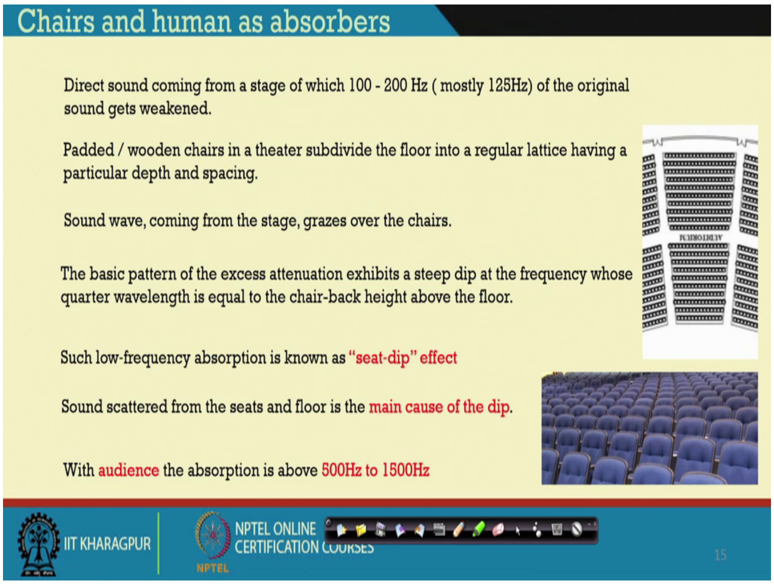

So, now when the chair are arranged some directs chairs are arranged within an auditorium in a very particular fashion the direct sound, which is coming from the stage is seen that around 100 to 200 hertz the original sound is getting weekend.

So, from the stage when someone is talking or performing or delivering a speech or a music it is seen around 100 to 200 hertz is getting vanished or very much weak or getting very much weak. So, it is getting attenuated. And, if you see the auditorium plan we see padded wooden chairs subdividing the floor into a very regular lattice having particular depth and particular spacing.

So, this rhythmatic thing so, this ordered thing is actually doing something wrong to the particular frequency, that is between one add something around 125 150 hertz and the original sound is getting lost. So, sound wave is coming from the stage are grazing over these chairs, grazing means like the goat or the cow grazes on the field.

So, it is like they are going close to the ground. And they are go it from once they are produced generated from the source they are going close to the through the top of the chairs, the sound.

And then the basic pattern of the excess attenuation creates a dip at the frequency whose quarter wavelength is equal to the chair back height.

So, not repeating the anthropometry we actually have the seat chairs at around 415 millimeter and the backs are around 500 600 of that order. And, if you see 125 hertz, if you go back to the table of my previous lecture lectures you will see 125 hertz is having a wavelength of around 8 feet. So, one fourth of that is 2 feet that is 600 millimeter.

So, the basic pattern that is observed is at around 125 hertz there is a dip, there is a dip of the sound and it is gradually moving. So, this quarter wavelength, which is equal to the chair back height has been experimentally found. And this can the sound rebounds from that surface and comes back. Sometimes it is explained in books that standing wave is created between chair to chair and there is a loss of energy.

So, such low frequency absorption is known as seat dip effect and sound scattered from the seats and floors is the main cause of that deep. So, the sound which graces cannot grace the heat touch air surface sum of it graces very lightly and particular wavelengths are getting stuck and creating the seat dip effect which is observed at low frequency area that is high wavelength high wavelength and one fourth of that wavelength, which is around 2 feet are getting stucked. So, with audience the behavior the same behavior is seen around 500 to 1500 hertz.

So, we have to be very careful to take care of these effects, when we are designing an auditorium

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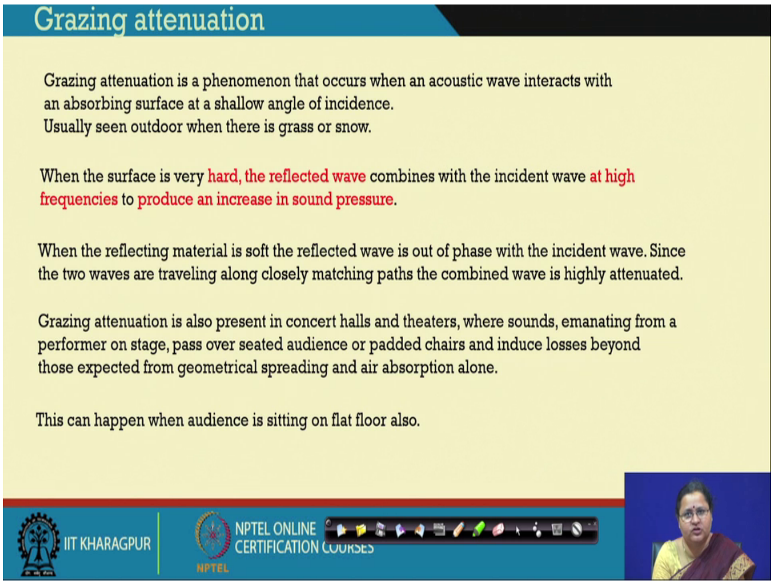

So, this phenomena is called grazing attenuation and this occurs when an acoustic wave interacts with an absorbing surface at a very shallow angle of incidence and it is usually seen this was first scene actually in outdoor incases, when there is grass or snow and the source sound is very low whereas, the receiver is also at a very low position. And hard reflective surfaces add to the original sound. And that that helps in increasing the sound pressure whereas, when it is soft ground then in that case it attenuates the sound pressure.

So, this is the phenomena which is called grazing attenuation. So, when it is heating at a very low angle a surface, which is absorptive in nature then the sound gets absorbed and it grazes at a very low energy level and some portion is lost. So, the some portion of the original sound is lost sometimes the reflected sound has a matching path and the combined wave becomes attenuated.

So, grazing attenuation is also present in concert halls and theaters where the emanating sound from the performer on stage passes over the seated audience or padded chairs and induces such losses beyond these beyond those expected from the general geometrical spreading and the air absorption etcetera, which we will be discussing later. So, this can happen when the audience is sitting on the floors also.

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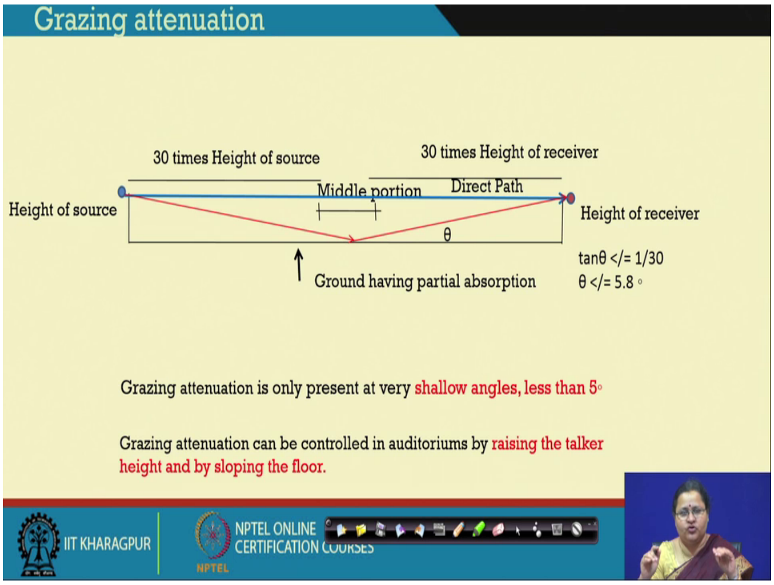

So, we have to keep all these things in mind and we try to explain grazing attenuation just a diagrammatically. So, this is the source here, we have the source here, we have the receiver here and we have the ground here, which is very which is partially absorptive. And the distance between the source of source and receiver is quite large. In this case when the direct sound is coming to the hitting the receiver, the reflected sound is grazing is when the direct sound is grazing almost very close to the ground. We see the reflected path along with it and if this angle theta is very low that is tan theta is tan theta is around 1 by 30, if the 30 times of the height of the receiver and theta comes out to be 5.8 degrees.

So, at very low angles or shallow angles when the sound source is at a very low level almost close to the ground and the receiver is also at a position very close to the ground, then such kind of effect happens. In our case what we saw the chair tops of the chairs are actually creating the grazing line between the speaker at the stage and the audience over there.

So, this grazing attenuation can be controlled by changing the height. So, the source height can be changed or the receiver heights can be changed so, by raking the floor. So, by raking the floor or by changing the stage height actually the things can be changed. The grazing attenuation can be avoided. So, you if you go to books you will see that with different heights of the stage and with different floor angles actually disgracing attenuation can be tamed.

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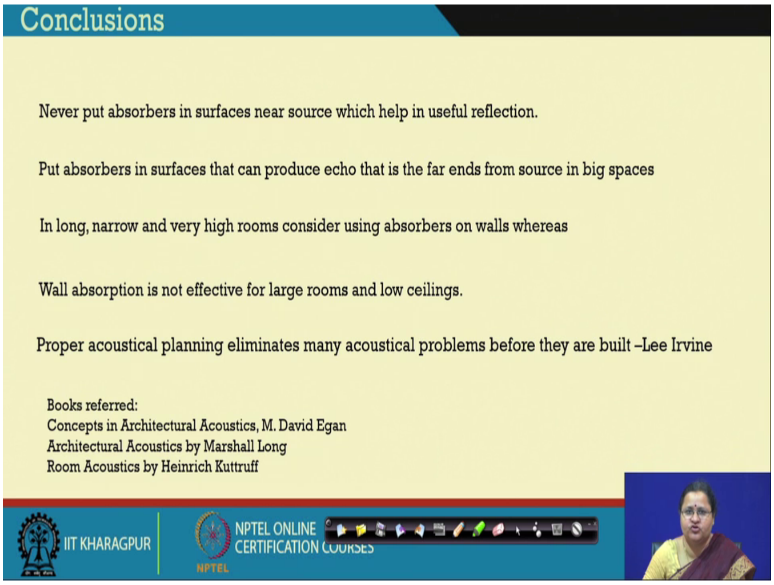

So, the conclusions could be drawn like this we are never to put absorbers in surfaces near source, which help in useful reflection this is summing up of the absorbers. So, we put absorbers in surfaces that can produce echo. So, that echo that is long delayed reflection long delayed reflection of sound, which is particularly at the far ends of big spaces, that is in case of auditoriums concert halls and multipurpose rooms.

In long narrow and very high rooms consider using absorbers on the walls, which we had shown through the graph earlier and wall absorption is not much effective for large rooms and low ceilings. So, far large rooms where seen the ceiling absorption providing ceiling absorption is important, and also at with the same time with these understanding we also had seen area effect.

So, we need to we also know how this absorption to be provided to have effective absorption and proper acoustical planning beforehand can eliminate many acoustical problems, before the structures are built this is said by Lee Irvine and this is very important. So, if you can plan what is the purpose? How will be the shape? Why you are designing?

So, when you are designing if these are thought into the process in the design process, you will overcome lesser amount of problems to deal with sound in the environment, which you are creating.