Architectural Acoustics
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Lecture – 11
Introduction to Acoustical Absorbers

Today, we are going to start Acoustical Absorbers. So, by this time you all have learned the basic physics a part of it and I have already given some understanding on room acoustics, where we dealt with sound within a closed place which was subjecting reflection diffusion and we also talked that some part gets absorbed into the system.

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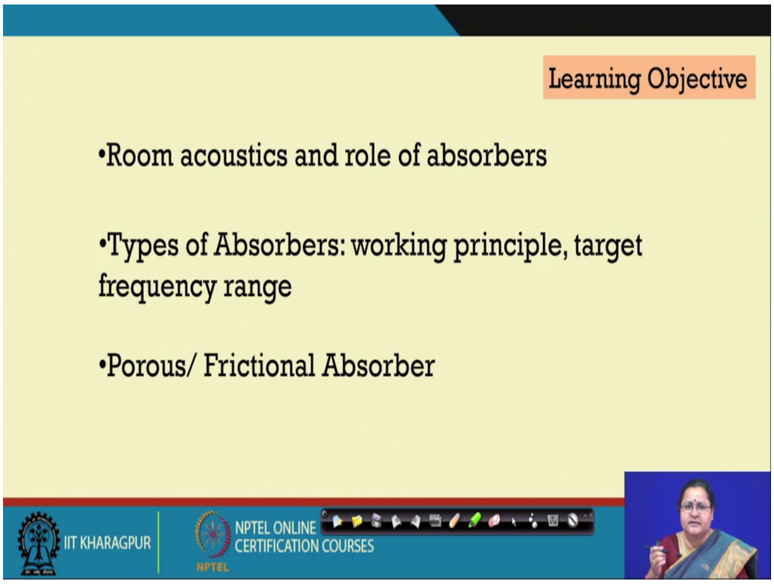

So, we will elaborate on that further through the next few in the next few lectures and after having the understanding of room acoustic, we understood that we have to tame the sound and bring it make it useful for our purpose. So, we do not want unwanted sound, we do not want delayed reflected sound; so, we have to take care of it.

While discussing that, we had also discussed that we can change the shape, we can go for desired structural system to get the diffused reflection, but that may not be possible in all the cases. We may be given a place which has to be treated and made it more friendly so, far acoustic is concerned.

So, we will go into the different types of absorbers, we will look into their working principles and; obviously, as I always stress upon we need to know the target frequency which we have to tame. Because in your earlier lecture you have heard of noise reduction, coefficient and all, but that is a cross understanding for getting a good quality of sound we have to even go to the frequency level that what frequency needs to be covered, needs to be absorbed and what frequency can be left for the audience.

So, we will elaborate mostly this time on the porous or the frictional absorbers though we will first try to come into water absorbers.

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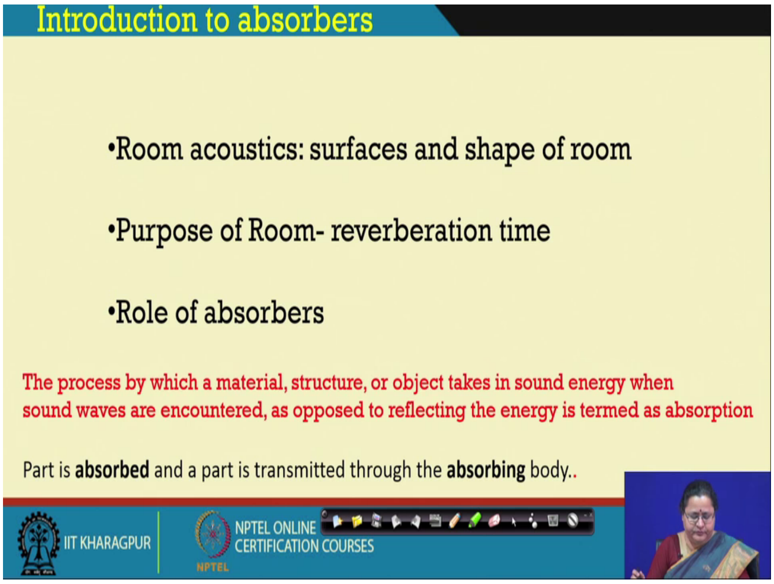

So, in room acoustics we had learnt how the surfaces behave, how a shape behaves and we can actually reduce flutter echoes, echoes when it is a big space, we have to take care sound in we have to redirect sound in different ways, we can actually cut down the ceiling we can frame something, but that is only possible when it is an isolated individual building say for case of an auditorium. But within a class room can we change the ceiling shape? Yes we can do it with some false ceiling false attachment. So, we have to understand how we can reduce the unwanted sound through the phenomena of absorption?

So, here we have to first understand what is the purpose of room and reverberation time which has been already covered in the previous lecture? We will go into details into those, but we will try to focus more into understanding how the absorbers work? And then we will again have a lecture on the reverberation time and the types of the room etcetera. So, the role of absorber is to take care of the unwanted sound.

So, the so, part of the sound which gets absorbed, it remains within the system or it is transmitted. And the process by which a materials structure or an object takes in sound energy when sound waves are encountered as opposed to reflecting some of its energy is termed as absorption.

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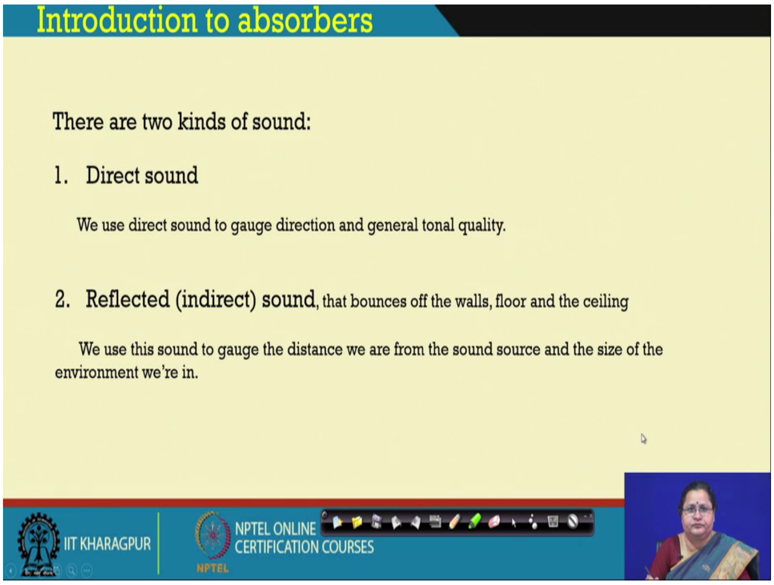

So, we had dealt with two types of sound one is direct sound one which is reaching you directly. So, and the other is coming as an indirect sound which is reflected from the side walls from the top, from the floor all other objects within the surrounding and is reaching you. Direct sound gives understanding of the general direction under tonal quality whereas, the reflected sound we gauge the distance from where the sound source is and from where the sound is coming that gives perception of the shape and size of the room.

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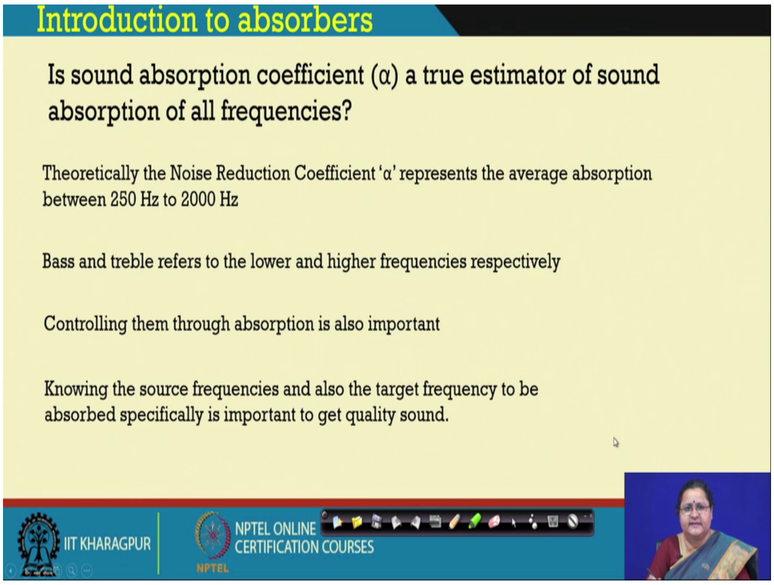

Now, we have told you regarding Professor Bhattacharya has told you regarding sound absorption coefficient, which is an estimation of how much sound how much sound can be absorbed by an object. But is it a true representor or true estimator of the sound absorption of all frequencies may not be at all cases.

So, theoretically noise reduction coefficient which is represented by alpha is between its absorption coefficient is studied between 250 hertz to 2000 hertz, but what happens on the bass side or on the treble side; that is on the lower hint or the higher in respectively. We also have to know what kind of absorbers can absorb the bass frequency or the higher and the higher frequencies; apart from knowing the regular absorbers which are used.

So, controlling them through the absorption is very important knowing the source frequency and the target frequency that has to be absorb is of specific importance to get good quality sound within a room clarity is also important. So, that is estimated through the reverberation time. So, we have to know each of the tools to become a good architect, good acoustical designer.

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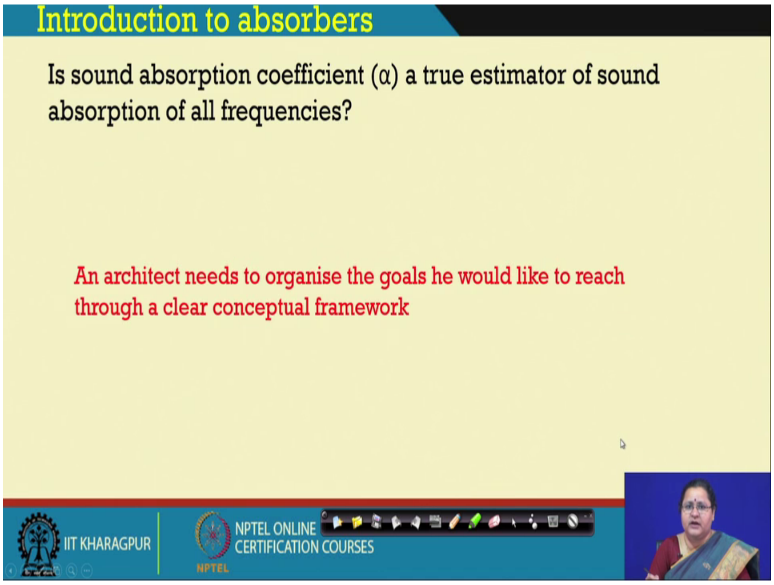

So, an architect needs to organize the goals he would like to reach through a clear conceptual framework. So, you need to know the reverberation time, you need to the need to know the, what kind of performance will happen in the room, what are the target frequencies that are to be trapped in? So, after getting a good understanding you have to go into the understanding of the selection material and gradually you have to know where to put it. So, we will gradually move into the subject deep into the subject and we will not go deep into the physics.

Because everything has a good understanding basic understanding of physics and those are all in books. So, how does an absorber work?

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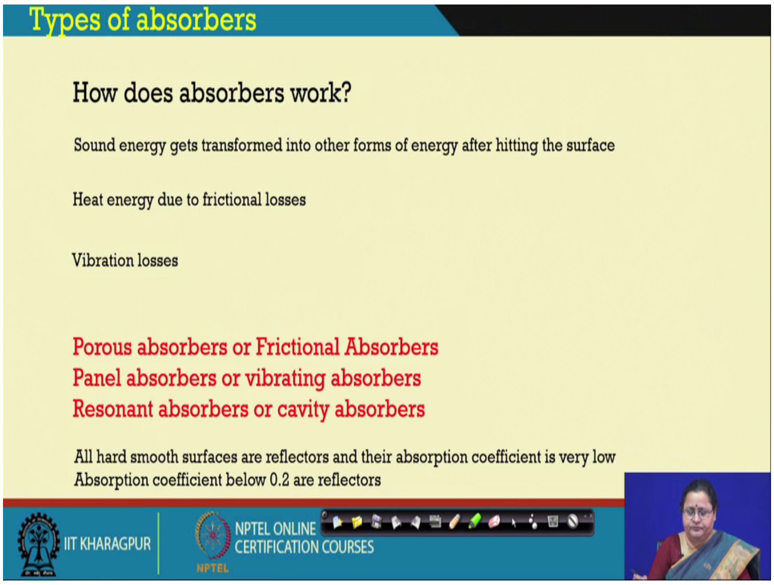

Sound energy gets transformed into other forms of energy that is the basic principle. So, it is transformed into another form of energy is once it is heating the surface. So, on heating a surface on impedance it is actually getting transformed into other forms it may be heat energy, it may be due to heat may be generated due to frictional losses, sound may bent into a system or there may be vibration and sound energy may be converted to a vibrational; vibrational energy. So, there will be vibrational losses and that will lead to the sound attenuation.

So, porous absorbers or frictional absorbers we term them as is one type of absorber; we have panel absorbers which can vibrate and absorbs sound. And we have resonant absorbers or cavity absorbers, which can trap in a particular type of frequency or a particular frequency of concerned. So, we have class we have three kind of classification apart from which we have space absorbers or functional absorbers which can be use now and then.

So, we will, but the principle is all within the scope of all these three absorbers. So, we will come to one by to them one by one; we will start today with porous absorbers or the frictional absorbers and we consider most of the substances which have a absorption coefficient below 0.2 as reflectors

So, they are absorbing very little amount of sound and we treat them usually as reflectors.

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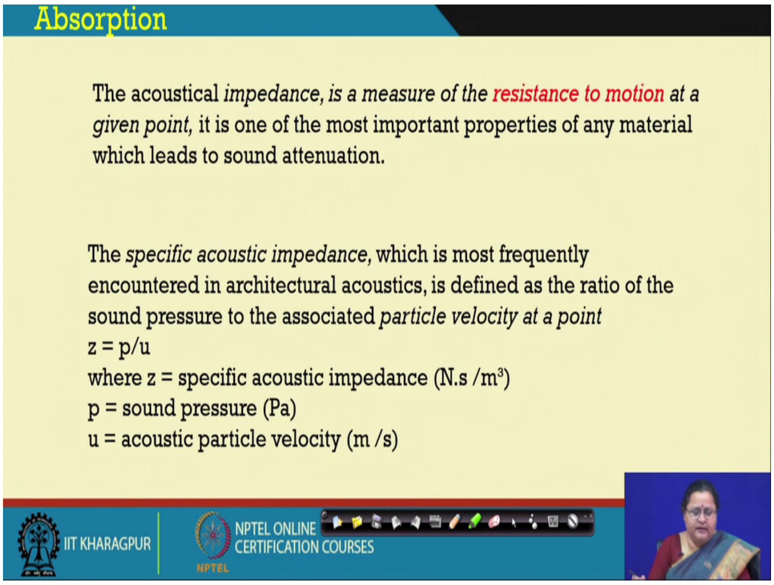

So, when the acoustical impedance; it is a measure of the resistance to the motion of a given at a given point. It is one of the most important properties of a material which leads to the sound attenuation. So, when a sound energy is falling onto a body then it is impede and it is resisting the motion of the air particles and that is creating the attenuation of the sound.

So, the specific acoustic impedance which is most frequently encountered in architectural acoustics is defined as the ratio of the sound pressure to the associated particle velocity at a point. So, whatever is the sound pressure and whatever is the particle velocity determines the acoustic impedance. And the individual materials have their individual properties of this resistance that gives us table of absorption coefficients. And then for particular frequencies it has a detail and we can consider our octave band and we can go into the deeper studies and from there the noise reduction coefficients are reported.

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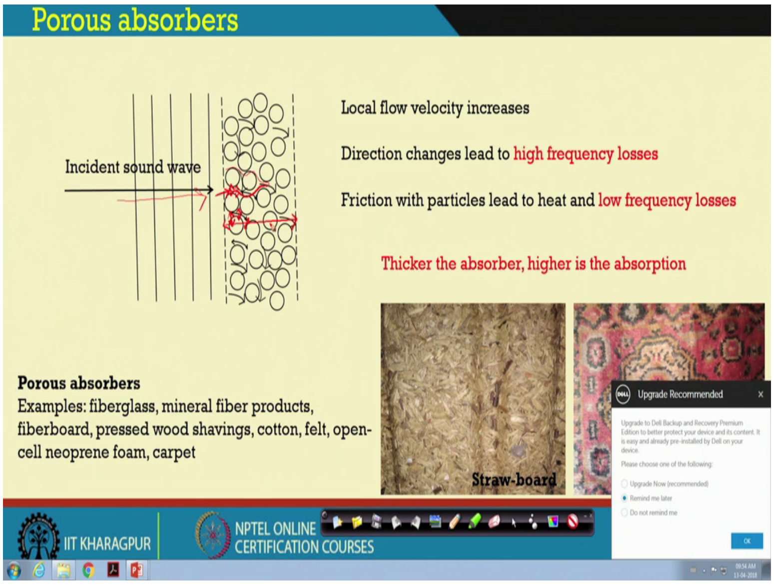

So, let us see what happens in case of a porous absorber. So, when the sound which is incident is falling on it as you can see; the sound actually moves some of it passes through these gaps. Some of these will move in between these; so, there will be losses. So, direction change will lead to high frequency losses; so, the local flow velocity will increase here once it is passed into it and it will gradually move inside it, it will try to bend into it that is what is the, high frequency losses happened this way.

And the friction with the particles lead to heat energy and that leads to low frequency losses. So, thicker and at the same time the distance from the beginning to the end that is the depth of the absorber is also very important. So, the more is the depth, more is the attenuation of the sound within one way it is falling into the system.

So, we have examples these are usually vegetable fibers that is that is biological fibers made from pressed wood shavings, cotton, felt, open cell neoprene foam, carpet which we have and on the other hand we have mineral fiber glass, mineral fiber products and so on.

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So, this is what is mineral fiber, which can be used as an absorber but as you all know to other subjects that this is made of glass this is sorry; this is glass fiber and these are very fine fibers of glass which cannot be kept exposed.

So, we do not prefer such material rather we go for the strawboard which you can see in the picture. And we also have carpet which is already which is a floor application which has a application on floor only; we usually do not we have fabrics we have cottons and many other things, but what I told? The thickness is also very important. So, we have some more examples like fibre board cork sheet strawboard which are.

Student: Madam what a cross board (Refer Time: 13:16).

We have cork sheet, strawboard etcetera the pictures are in front of you.

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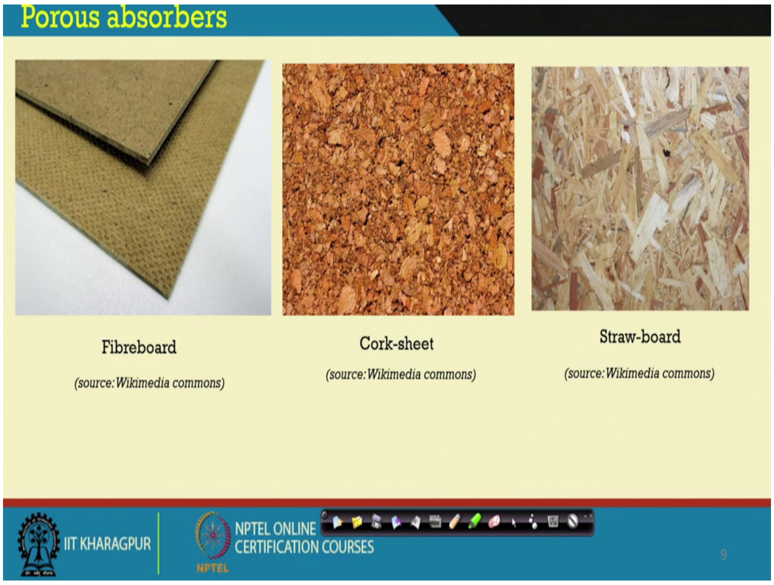

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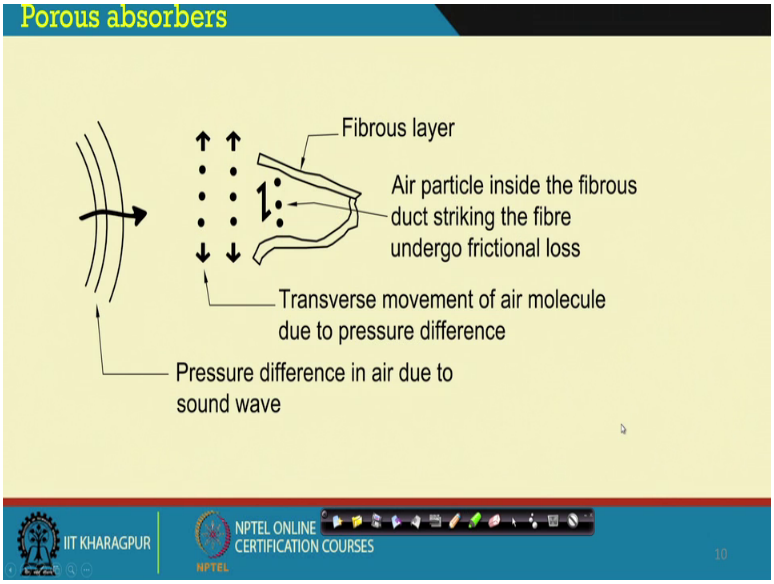

So, actually if you go I have; we have tried to make a figure out of it. So, the this is the transverse movement of the air molecule due to the pressure difference and this pressure difference that was t; which was which has caused due to the incidents of the sound energy which is coming from this end. And this is the fibrous layer into which the air particle inside the fire fibrous duct is facing the boundaries of that within that fibrous material and it is heating and getting frictional losses and in this way the sound energy is getting reduced.

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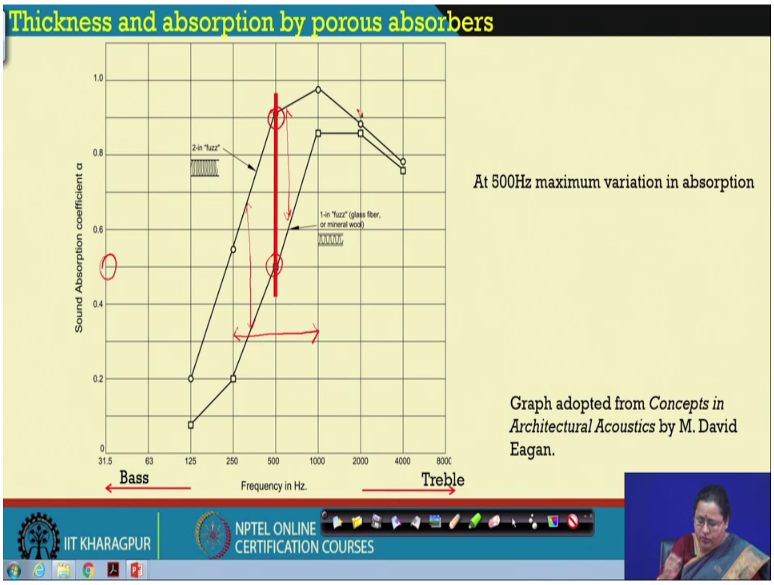

So, if you look into as I talked about the thickness just in before two slides; if you see if you have a absorber of absorber of 2 inches that is 50 centimeter; we saw we an absorber which is 1 inch that is less in thickness; you can we can the plot is plot is put forward in front of you where you can see that up to 500 from 250 to 1000; almost there is a sharp change in absorption. You can see the absorption lies between somewhere 0.5 and it is moving up to almost one in case of in case of 1 inch absorber and incase of a 2 inch absorber.

So, it is 0.9 here in case of a 2 inch absorber, which is of the same material and which is of the order of 0.5 when it is thickness is around 25 millimeter or 1 inches. So, you can see this variation is quite high to a noticeable extent from this between 250 and 1000 and gradually this is tapering down.

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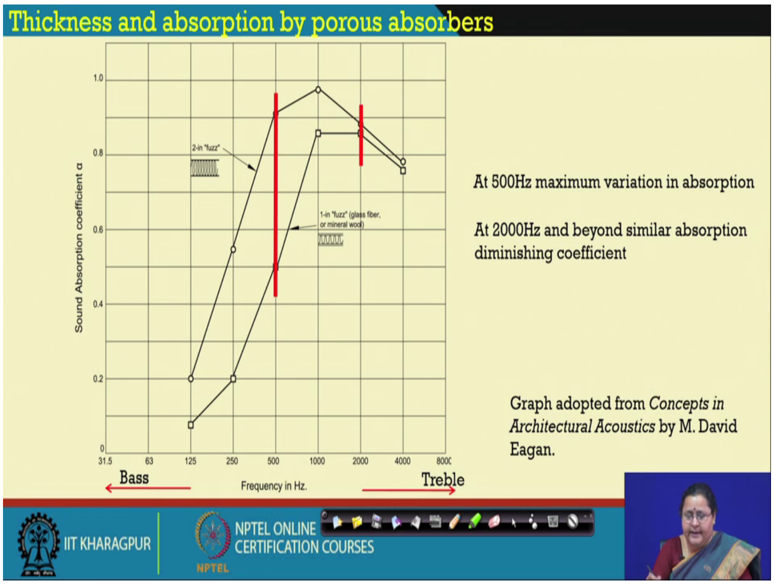

And we are getting almost close results with the different thicknesses when we are at around 1000 hertz of frequency. So, it matters the thickness matters when we are trying to tap; while we are trying to absorb sound between 250 to 1000 hertz and around 2000 hertz this thickness really does not matter.

So, why will we invest more? If we are only to check the high frequency sound that is the frequency beyond 2000 hertz, if we are not supposed to take care of sound between 250 to 2000 we are not going to select the thicker absorber, but we will go for a thinner absorber. So, this is when it is the individual absorber is considered.

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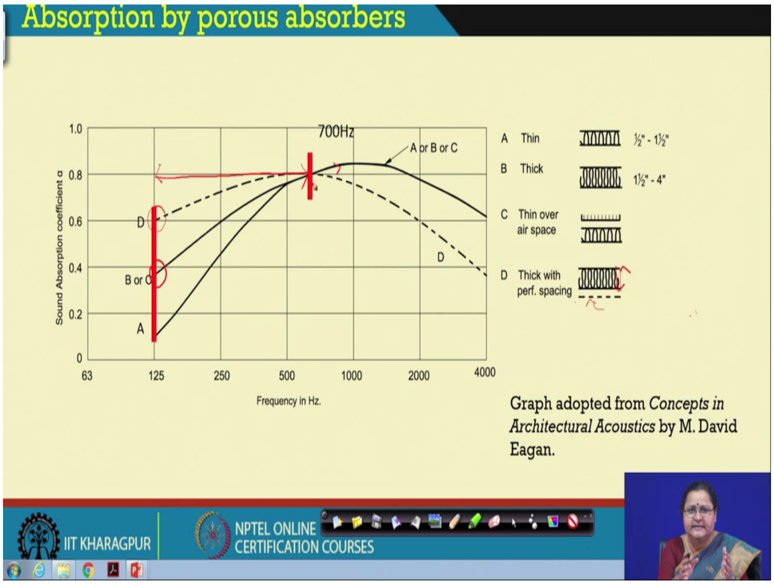

But absorbers can also be assembled into a system. So, depending on the mounting condition that is depending on the; if we mount the absorber directly on the wall or directly on any surface it behave somewhere; when we are mounting it with an air gap it behaves in another way. So, if we now look to this graph we will see that if you see the conditions on your right hand side, on your left hand side rather you see the line which is drawn for a thin absorber versus a thick absorber versus a thin over an air space that is a gap. So, we are seen that the three graphs A B and C A B and C; B and C are starting from the same area and almost following the same track.

So, you see B is having a thicker dimension whereas; C is just put with a air gap. So, B and C are behaving the same and if you can afford to put a small space between where it is applied through a system then you can save the money on the thickness. So, you may not go for a higher thickness, but you can just put it with an air gap from the structural wall; structural member. Whereas, in case of a which is thin, which is directly put on the surface where it is to be put we see that it starts with around 0.1 of the absorption coefficient.

Whereas, this starts B and C starts from the from a little higher that is around 0.4 whereas, when B around 0.4 whereas, the point B which we will be discussing in later course has another addition of a perforated sheet in front of it and it is the thick member also. So, this is one item and that is another perforated sheet in front of it that is leading to D starting from 0.6 as its absorption coefficient and following the graph with B A A B or C after around 500 degree centigrade even with the lesser absorption.

So, if our target frequency lies in this particular zone we have to plan accordingly. Effectively B and C after B and c matches with the graph A after 500 hertz little beyond 500 hertz. So, considering the frequency that we need to absorb is very important while selecting these absorption absorbing materials.

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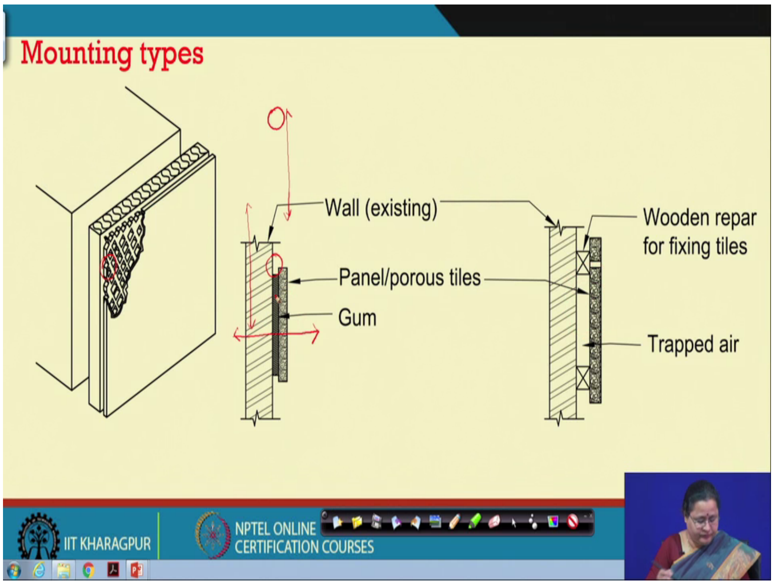

So, how can we; so coming to the mounting type if you are mounting it with an air gap; you can actually take the advantage. Whereas, if you mounted directly to a structural system by testing it with an adhesive, you get a different curve; so that is what has been demonstrated what is that is what has been demonstrated here.

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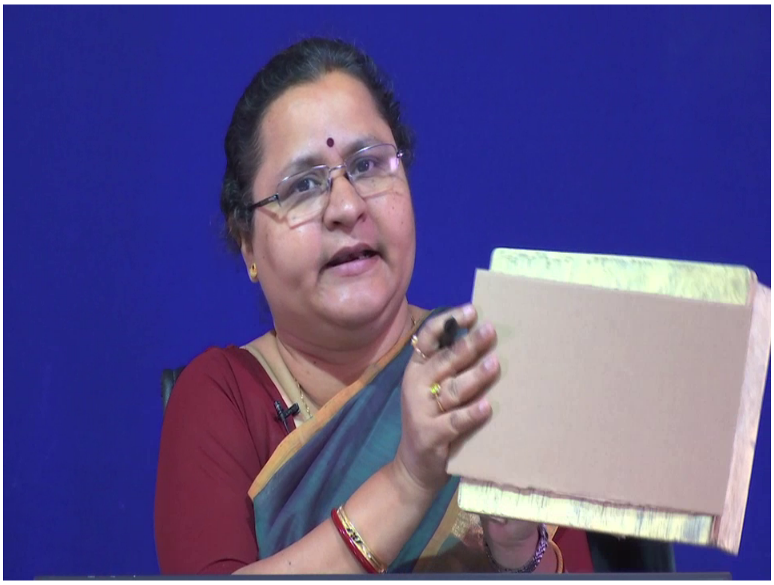

So, if we have a system like this; you can put it put your absorbing material directly on it you can put it put directly on it or you can put it with an air gap. So, if you can put it with an air gap; you will get the advantage of having the air in between.

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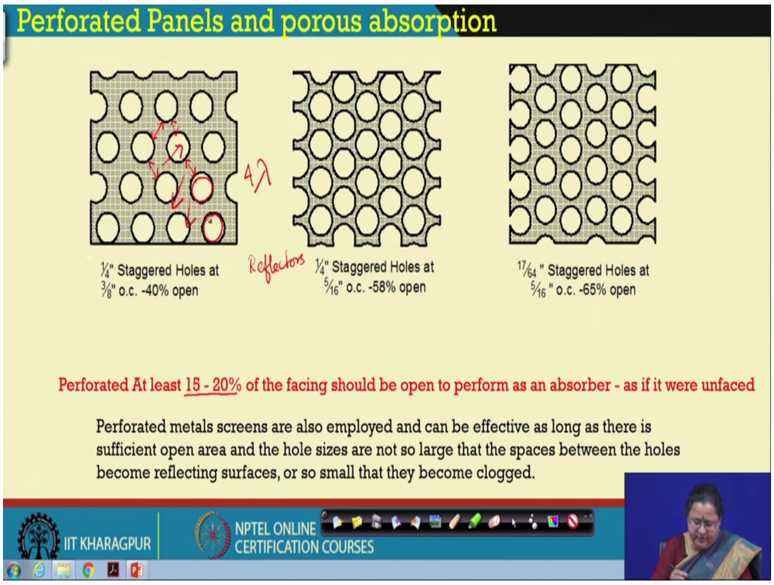

Now, we come to the other interesting part which is shown in the graph D shown by the graph D which has a perforated spacing in front of it. So, these are some of the perforated panels or which also help in porous absorber. So, we had I had shown you mineral hole which is what a glass hole which is not very safe for human beings. So, it has glass fibers which we can inhale and have problem. So, we cannot keep it expose like this though it has a high absorption coefficient.

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So, we can actually cover it with a porous of with perforated surface which can come on top of it and it can actually hide that material behind you.

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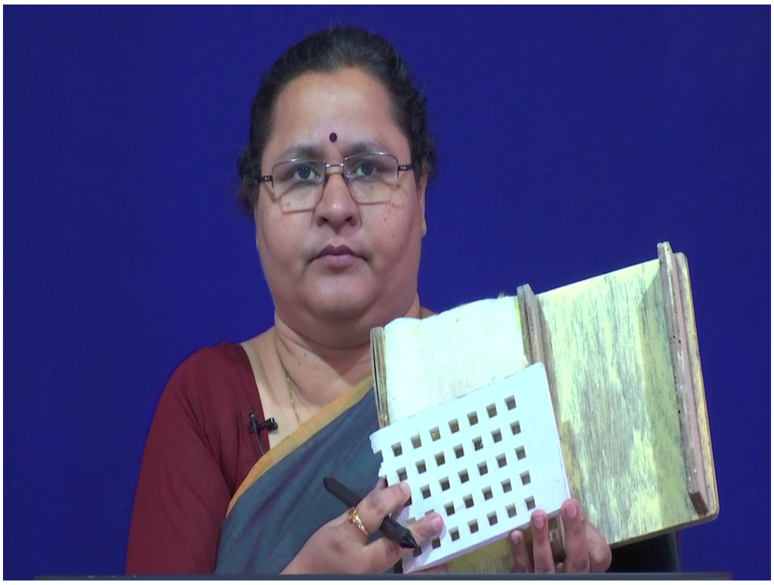

So, if this entire system is put inside; if this entire system is pushed inside it along with a perforated cover covering; it will behave the same. We can also put this perforated panel here when where there is only here then the graph will be different. When we have this mineral hole inside and we are putting this perforated panel on top of it, the behavior will be different.

That has been shown in the picture that has been shown in the earlier graph. So, the graph D is what I showed you with a absorber as well as another; another perforated sheet on top of it that gives you the curve the graph D, which shows that at the lower end, which shows that at the lower end that is at 125 hertz; we see a good amount of absorption still happening.

So, now what has to be taken care? If the perforated panel is stopping your sound to enter into that fibrous material whatever is put inside it then your purpose is not solved. So, we have to be very careful on how big are these perforations. So, it is found out through experiments that around 15 to 20 percent of holes should be there to allow the sound enter into it. So, if you have around 15 to 20 percent of opening then it will behave as good as it was without the without the covering. So, perforated metal screens are employed may be employed for this purpose, but here we usually use Gibson boards which has lot of perforation into it, but one should be very careful that the gaps.

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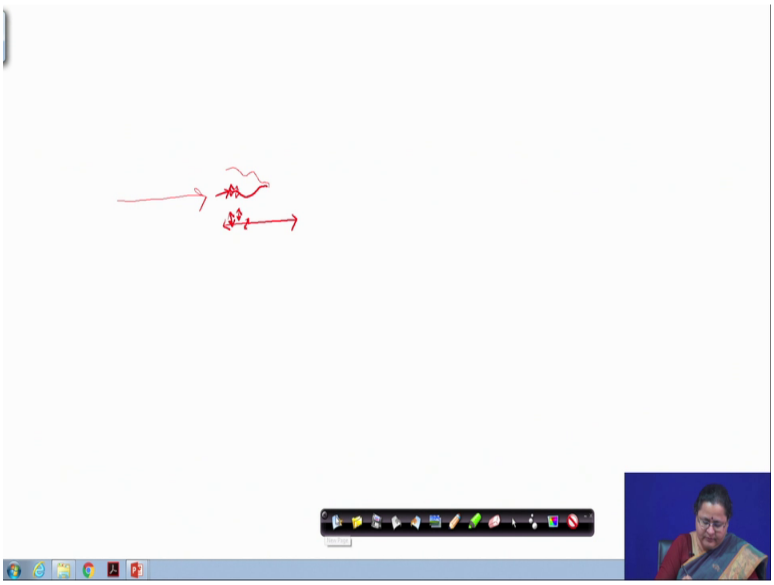

One should be very careful that these gaps between the perforations should not act as reflectors. Because if these are very big with reference to our lambda that is the wave length that is if these are of the order of hole lambda these will act as reflectors.

So, instead of sound getting into that sound will be reflected out from that. So, we have to be very careful while looking into how big, how much is the percentage of perforation. And also we can go for very small perforation, but you have to keep in mind that while updating the facility that is it is a lecture room or recording room or something. If you paint over these panels that is perforated panels then these holes may get little smaller and that can reduce to the; reduce the entry of sound into the absorption process.

So, we have to be very careful on the clogging of these holes and the size of these holes and we have all these things available in the market where the perforations are reported.

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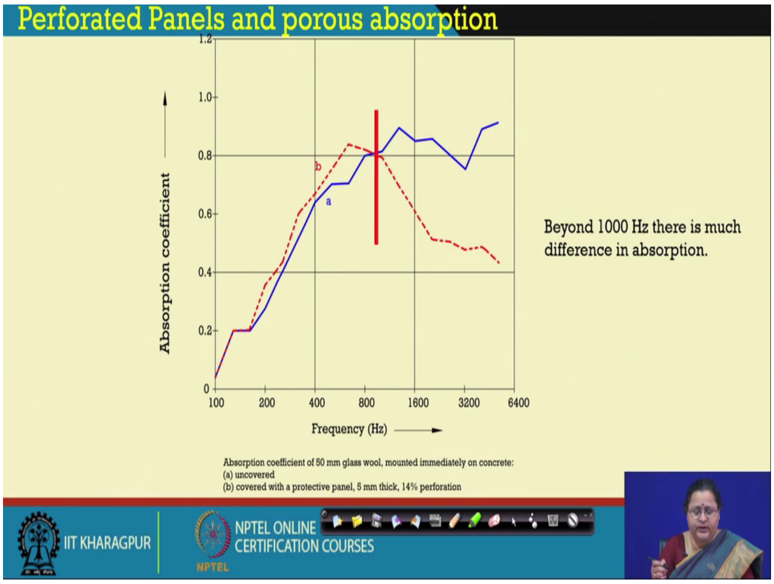

So, now we see here in that through experiments that it is almost behaving the same with a perforated panel and the porous absorber. See the blue line is the blue line is showing the uncovered line that is a and the red line which is in dotted is showing with the perforated panel on top of it.

So, beyond 1000 hertz we see that the perforated panel is not working whereas, the only the porous absorber is working whereas, in the case of the perforated panel the curve is decaying.

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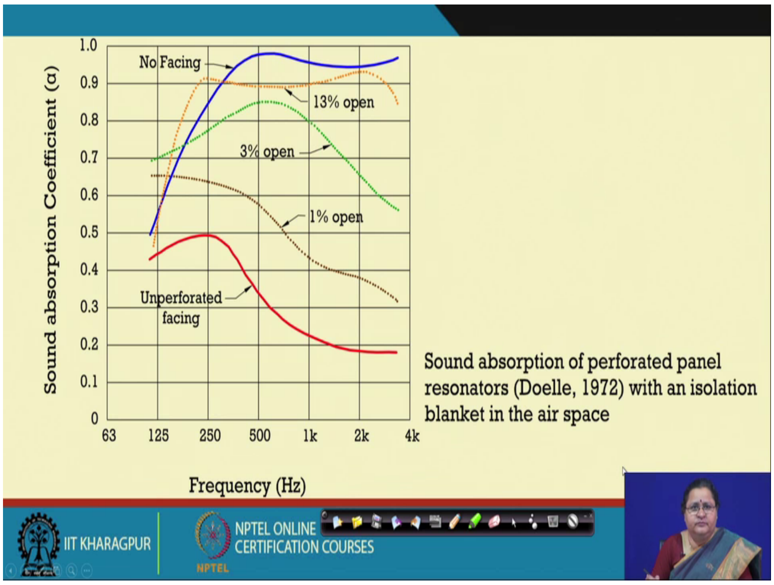

And as I told you the amount of perforation do have a bearing, but up to beyond 15 to 20 20 percent of perforations is acceptable and does not hampered the sound entry is well demonstrated through this graph. So, you see one is having unperforated facing that is something which is solid, which is facing it at the same time we see that with no facing which is the top blue line is almost matching with 13 percent opening which is the orange graph just below it.

We see drastic deterioration when only 3 percent of it is open and further down when only 1 percent is open. So, these were all conducted for the purpose of experiment. So, and (Refer Time: 27:53) is it is good to have beyond 13 percent. So, we say 15 to 20 percent opening within a perforated panel is acceptable or is considered as good as the absorber which is put inside is nakedly absorbing the sound.

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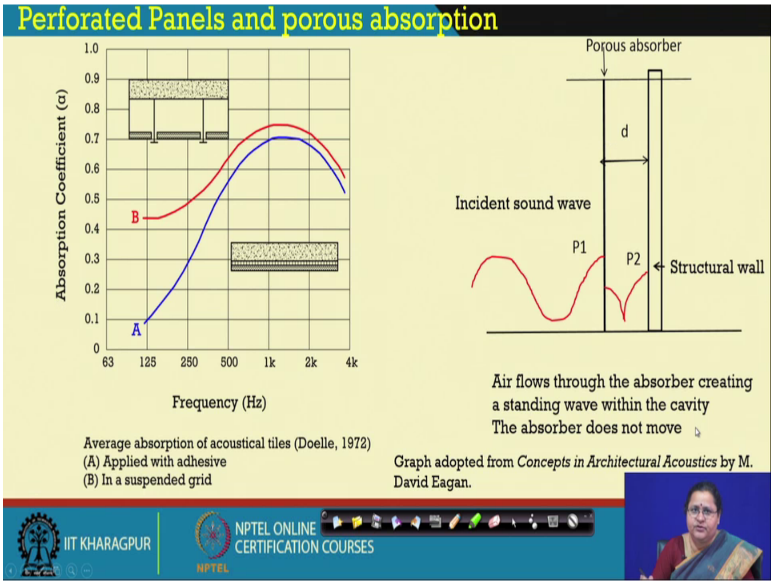

Now coming to the distance how far it is to be placed?

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So, here I was showing it is placed say considering; this as the thickness it is placed almost 2 inches in front. So, you are putting your absorber around 2 inches in front one is sticking onto it. So, there is no distance d 0 here distance d is a 2 inches and with you can actually change this thing and you can change the dimension of the thickness. So, how far it is put is also effecting the absorption coefficient, now if you see the two graphs A and B, which demonstrates very well what I intend to say; graph A is generated when it is stuck with the structural system, graph B is showing when it is suspended from a system that is if it is a ceiling it is suspended, if it is from the wall it is supported.

So, what is happening here? The sound wave which is heating the porous absorber a part of the sound energy is entering into the air space within the distance d and that remains as a standing wave within this small space. That is the pressure reduction from P 1 comes back we bounce as P 1 minus P 2 and P 2 remains inside it. And the part of the sound is also reflected from this surface. So, this P 2 is actually trapped inside this cavity and between the structural wall and then is later transmitted and then it is later transmitted to the structural volume.

So, the absorber does not move it is only allowing the sound and is generating this standing wave inside this cavity. And by this process it is reducing more amount of sound and absorbing more amount of sound and reducing more amount of the reducing the sound from the system more effectively than that of directly putting it on to the surface. So, here that is clearly shown.

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These are some of the pictures from our lecture halls at IIT Kharagpur; you can see this perforated sheet which I have already shown. So, behind it you can understand is this particular glass fiber that is glass fiber onto which this perforated are perforated panels are put in. And you can see there are various patterns also there are various patterns also to absorb you can see the long sleds.

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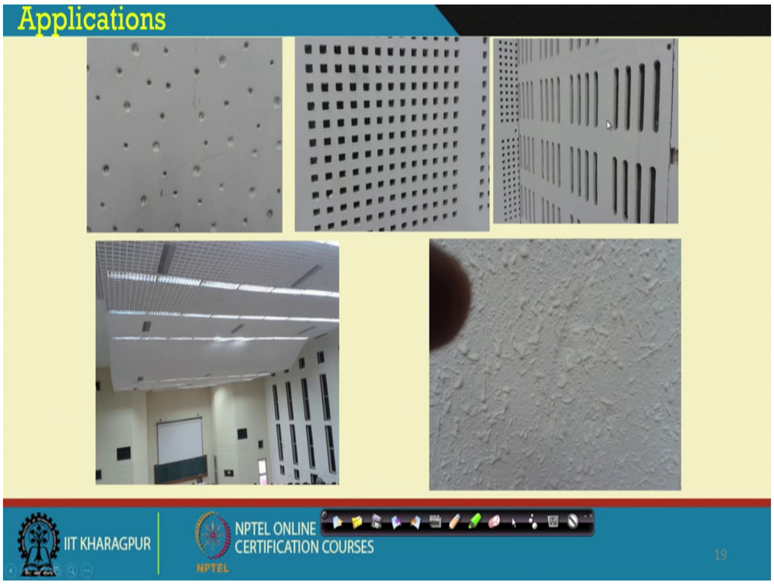

And these are these are for particular purposes. So, these are all commercially available knowing the reverberation time of the room; required in the room such kind of area calculations and such kind of installations, such kind of acoustical absorber has been installed in such spaces.

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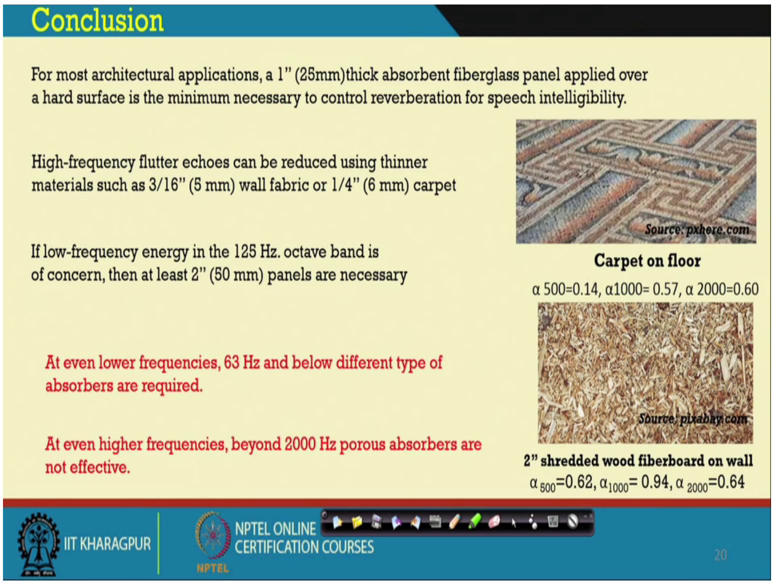

So, what we can conclude is for most architectural appliances applications 1 inch that is 25 millimeter thick absorbent fiber glass panel applied over a hard surface is the minimum necessary to control reverberation; for speech intelligibility.

High frequency flutter echoes can be reduced by thinner materials only. So, you could see that 2 inch thick absorber was not making difference considering 1 inch thick. So, whatever if it is thinner also it will be performing good for the high frequency part; if it is low frequency energy in the below 125 hertz then around 125 hertz we can go for 2 inch thick absorbers and placed at a mounted at a distance. However, further lower frequencies are not taken care by porous absorbers.

We have to think of other kinds of absorbers for lower frequency whereas, at higher frequency is beyond 2000 porous absorbers are not effective are effective, but not effective to the extent of changing thickness or changing the mounting distance and all so, they will absorb to a certain extent and beyond that it will not.

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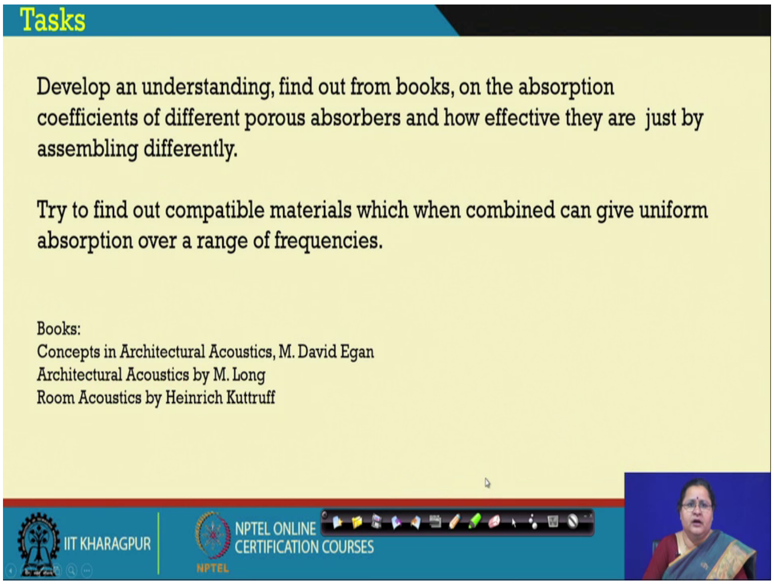

So, I would like to request you to develop an understanding from searching books on the absorption coefficient of different porous absorbers and how effectively they can be assembled in different ways to cover the range of frequencies.

And you can also find out that way the compatible materials which when combined can given an uniform absorption over a range. I had also mentioned here you see the carpet on the floor and the shredded wood fiber when at 1000; when alpha is 1000 when at 1000 1000 hertz frequency alpha is 0.94; for the fiber wood fiber whereas, for carpet it is 0.7.

If you go to 2000, when alpha is for 2000 hertz alpha is 0.6 whereas, it is 0.64; that is similar to that of the carpet. When we go to alpha at 500 hertz; we see the shredded wood fiber board is having 0.6; whereas, carpet is having only 0.14. So, we have to understand which material suits which particular frequency and that is the task, which I give it for you at the end of this lecture.