Architectural Acoustics
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Lecture – 12
Panel Absorbers and Resonators

So, today we will continue with the Absorbers. So, in the previous lecture we had discussed what are absorbers and we had a good understanding about porous absorbers; which actually behave like a as a fictional absorber which actually traps in sound and the sound moves through it and gradually sound gets attenuated within that system. And part of it gets reflected back to the towards the audience that is who are receivers.

Now, today we will also today we will look 2 more types of observers which are the panel absorbers and the resonators.

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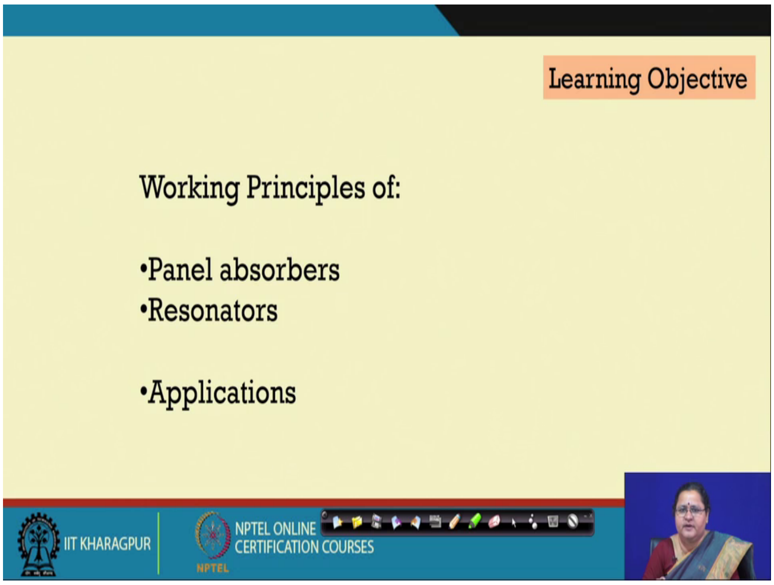

So, already I have; I have told you that virtual vibration the panel absorbers work. And similarly in resonators also the sound gets trapped into it and get resonates inside the system and gets lost.

So, we will get into the details of these and we will try to look into them one after the other. As we have already told that we consider the materials which are having absorption coefficients of around 0.2; we considered them as reflectors, but panel absorbers are nothing, but thin sheets or of metals or plywood or any kind of lamina that may reflect that sound, but in the process through vibration can lead to sound absorption, we will try to see that and its applications also.

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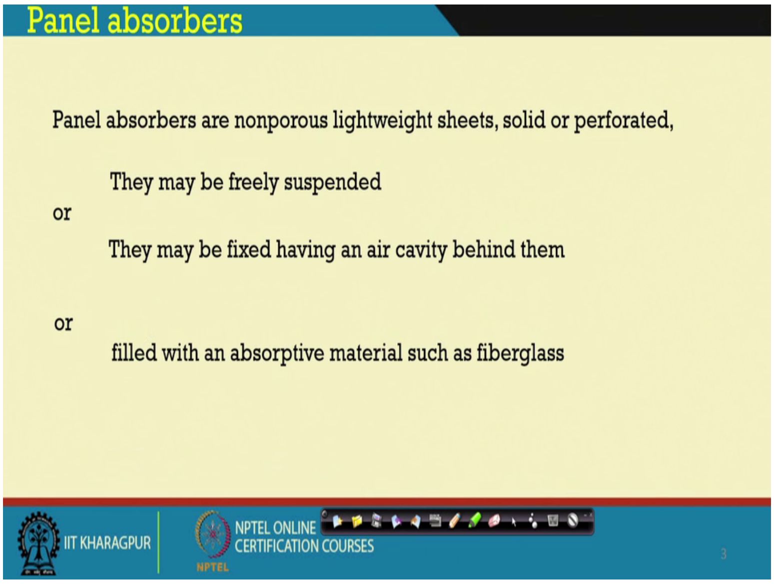

So, panel absorbers and nonporous lightweight sheets solid or perforated; they may be freely suspended and that may lead to some oscillating motions. So, if you think this as a panel that is a hole and if we can hang this, this material can actually move with sound I am just increasing and this can lead to fictional vibration and that may lead to sound energy losses. So, it may act as a reflector, but at the same time through the vibration, it is absorbing sound. They may be fixed; they may be freely suspended as I have shown they may be fixed similar to that of the porous absorbers what you have seen.

So, there to and fro motion will happen. So, we will come to those and it can be fixed with an air cavity behind that it can be fix with an absorber absorbing material behind it as you have seen in case of the porous absorbers if the material maybe fiber glass, glass wool, mineral wool as I have shown and those are not very good. So, if they are covered totally with panel absorbers, you can it serves the purpose of not getting being exposed to the people or the audience who are there.

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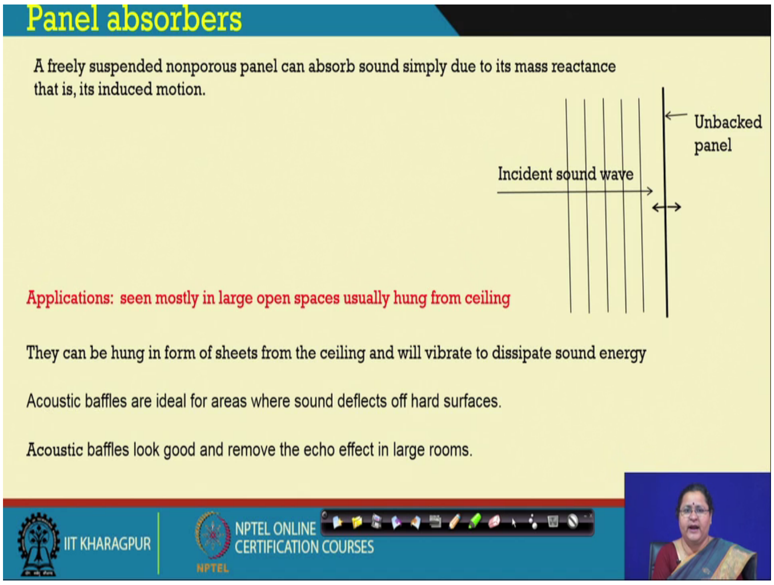

So, what is happening? The incident sound wave on an unbacked panel nothing is around it we will be set into motion as you can see the 2 arrows are there and it can the sound will simply due to mass reactance will induce the motion and that will help the system to vibrate and absorb some amount of sound.

So, it is mostly seen in large open spaces hung from the ceiling. So, they can be hung in form of sheets from the ceiling and they will vibrate dissipate sound these are also termed as acoustical baffles and are ideal where sound deflects from a hard surface. Acoustic baffles look good remove echos from large rooms particularly large ceilings where do we encounter such large ceilings being architects you must be wondering those are in arenas, gymnasiums, theatres, multipurpose halls and even in auditoriums.

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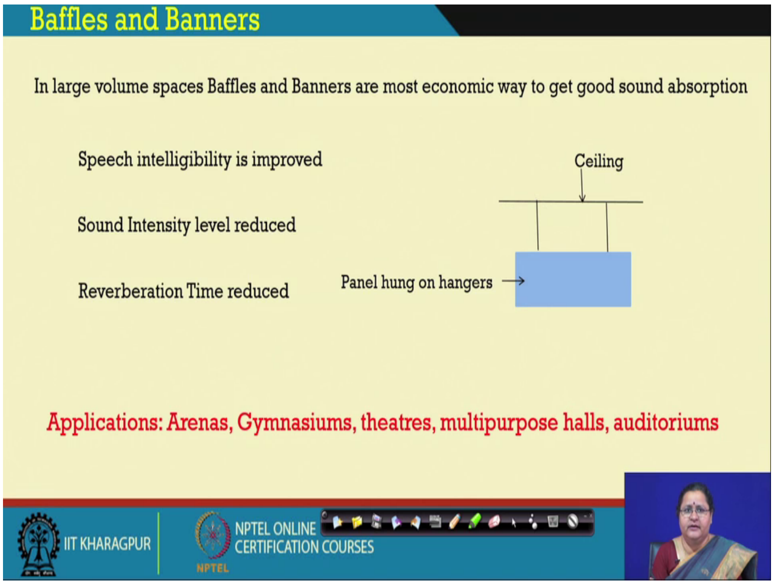

So, you see the panels are hung on hangers and if you look into the look into the other aspect; it improves the speech intelligibility, it improves the sound intensity level, it helps in reducing the sound intensity level, it also reduces the reverberation time in the process. So if these kind of metal sheets are hung from the ceiling of gymnasiums, sports arenas which are very economic, but is very required where a louds large sound large clapping of audience happens then that kind of sound should not lead to echo, but needs to die down.

So, this sound intensity level can be controlled if ceiling is full of such kind of such kind of panel panels which are called baffles and you can see such demonstrations.

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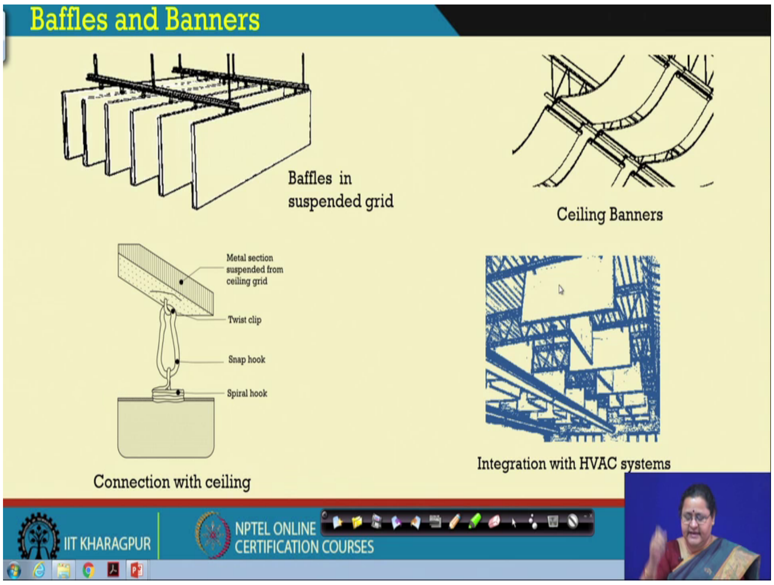

So, you will see baffles suspended in ceilings of gymnasiums where can such where do we see such ceiling banners? See these are mounted from the structural system, which are usually of iron, iron trusses those are suspended and you see on the lower part they are having the convex shape.

So, they are actually acting as sound reflectors and diffusing the sound into the audience mostly in auditoriums. So, you can have these ceiling banners, which can create such kind of such kind which will be set on vibration will taking some absorbs some amount of sound and will put in or throw diffused sound in into the system. So, the audience will receive diffuse sound and at the same time some portion of the sound will get absorbed.

So, there can be different methods of mounting you can see one kind of mounting with the ceiling and you can also avoid some air condition based sound, which can be moving through the ceiling by placing such baffles or banners.

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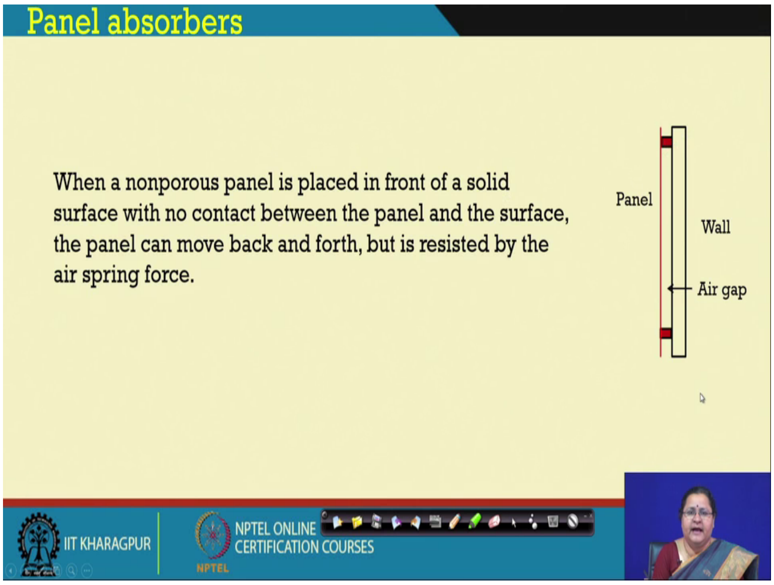

So, when they are not suspended directly; these non porous panels is placed in front of a solid surface with no contact between the panel and the surface the panel be the panel can be moving back and forth, but is resisted by the air spring force.

So, what we can see here? This panels is having an air gap behind it and this panel is set to a to and fro motion between in between with the because of the presence of this air gap. So, let us see it at a closer distance. So, what is happening when the incident sound is falling on top of it?

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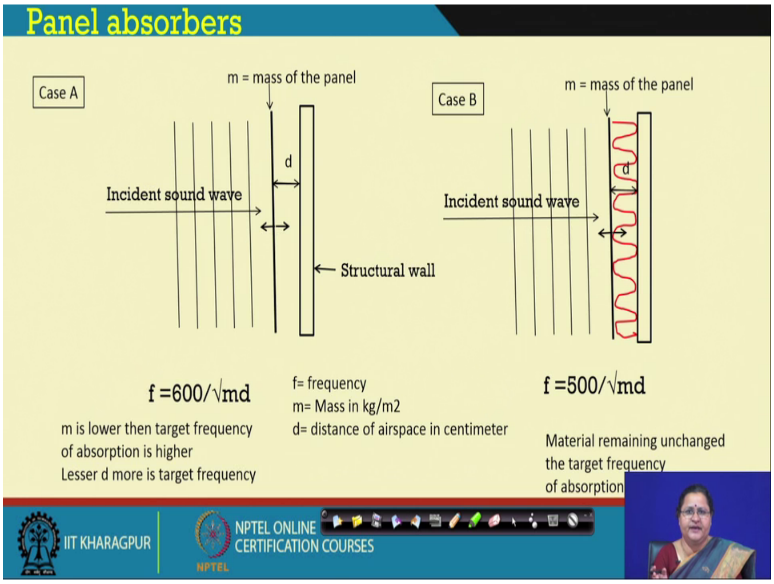

It is set the mass of the panel m is set in a to and fro motion which is supported at the 2 points and this is placed at a distance d. What we see that lesser is the d closer is the panel towards the structural wall, we see the frequency will frequency that is targeted will be more and more. So, this equation this simple equation has been calculated out through the principles of sound physics; I am not going into the details of that neither you require it, but what you are what understanding is required is that if you want to want to target a particular frequency; you can change m or d.

So, either the distance can be changed or the mass of the panel can be changed. So, if it is if it if m is high that means, your denominator is high. So, denominator is high means 600 divided by higher denominator; you will get a higher frequency trapped. So, you can at the same time you have to understand that sound energy should be sufficiently enough to move that. So, you cannot go for a very high mass item you have to go for thin item within which a little change in mass m can decrease the frequency; if the mass is higher or by changing the d that is increasing the d which is also at the cost of the space.

Because d is against the structural wall that is if you move some few centimeters here and there the total calculation of the sitting arrangement say can change. So, you have to make a solution in between your choice in between your mass and your distance from the structural wall while you are doing the space planning that is the sitting arrangement of that area; keeping that in mind you have to decide upon the d and the m and you can actually go for trapping in lower or smaller frequencies and you can effectively increase that just by putting absorber inside it.

So, that helps in further reduction of sound and here we get the equation that is 500 divided by root over m d. So, what we see just by putting a padding that is a absorbing material inside it which is a fiber glass, fiber glass wool or mineral wool in stuffing inside it; you can change the frequency to a further lower extent which is which is our objective frequency. So, the material remaining unchanged the target frequency can be changed from case A to case B just by adding in absorber.

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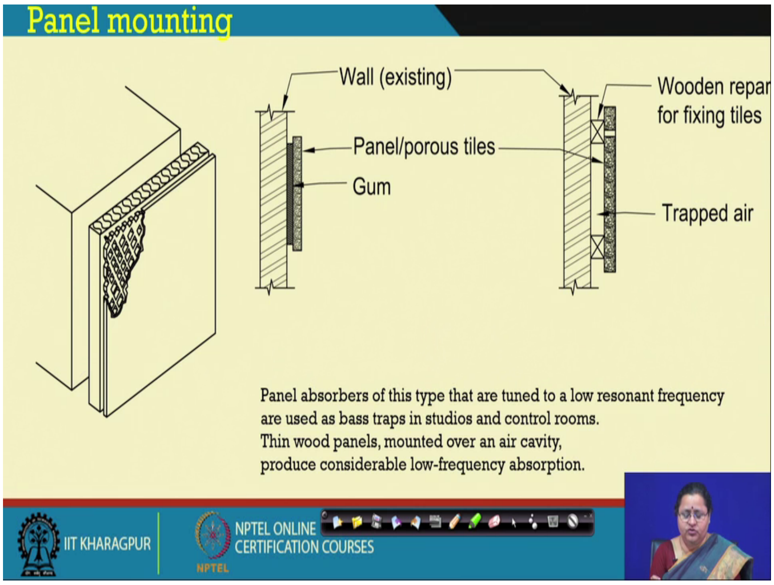

So, that is what we can do; similarly, mounting the panel similar to that of porous absorber. So, we can mount it with this mineral wool in one of these pores, we can mount it without anything that is air on top of it.

So, this will give 2 different graphs, this will give 2 different graphs and the panel absorber of this type are usually used to tap low frequencies and they are used also in studios and control rooms.

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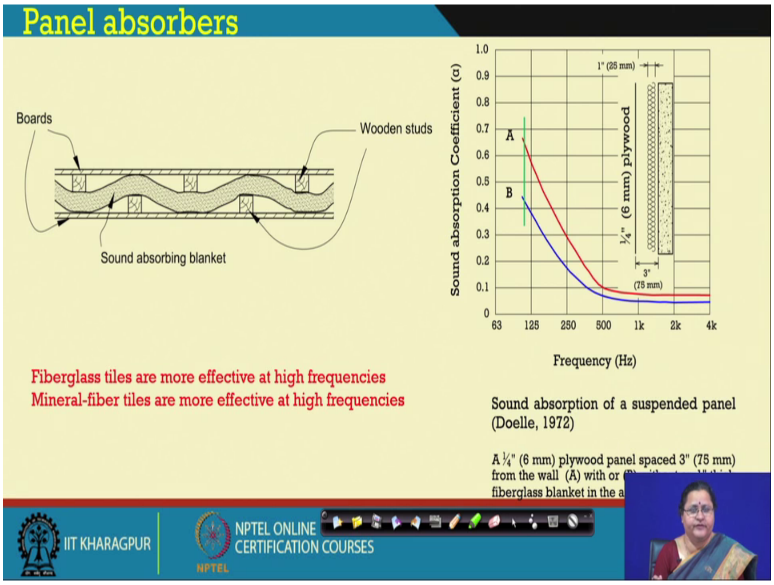

So, here you can see how the difference is happening if you see the point a and the point B; A is with the backing that is with the packing of fiberglass blankets inside it and B is without it. So, at this low frequency range that is between 63 to 125 quadrant you can see that A is behaving far better than B.

So, you can also as I have shown you how to stack in mineral, mineral wool blanket they come in bats that is big sheets, they can be actually put into or stuck into such framework which is shown in your left hand side. And it is also observed that with change in this particular filling in material that is fiberglass and given a choice of mineral fiber, we will see fiber glass is more effective at higher frequency and is are more effective at higher frequency and mineral fibers are less effective; that is more effective in lower frequencies, I think there is a typo error here.

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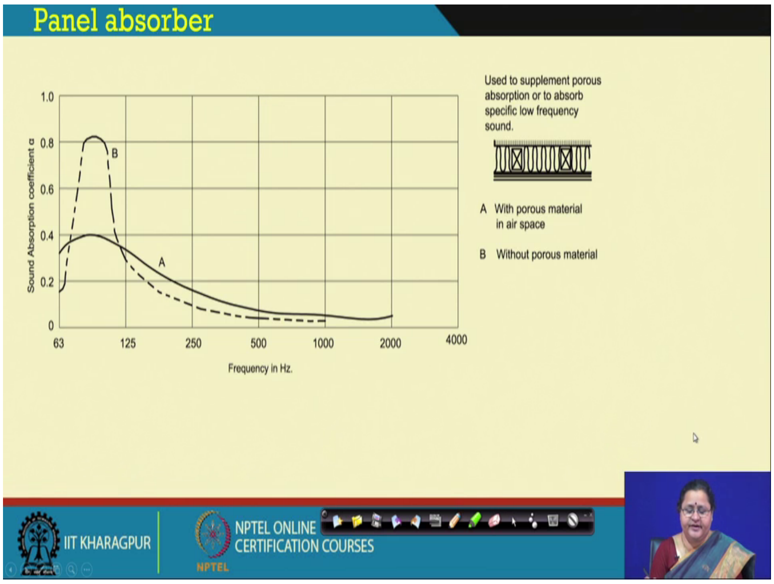

And this is the graph that has been generated through experiments which also speaks of the same thing.

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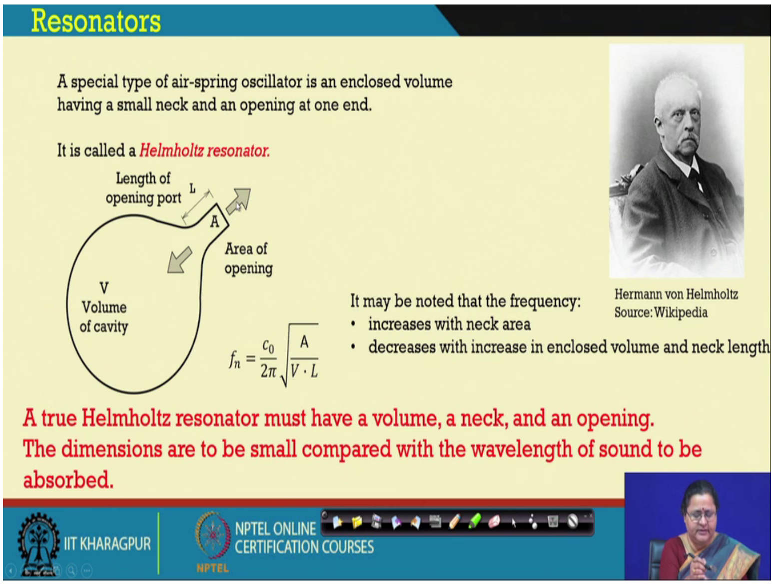

So, after this understanding of panel absorbers we go to the resonators; in panel absorbers we saw we can trap in frequencies of in the lower end which was not possible for the porous absorbers to do. Porous absorbers are more effective between 250 to higher that is 2000, 4000 hertz, but panel absorber is a choice for 250 to lower part, but if we are going for specific absorption; specific frequency absorption we will see that resonators at the best feet.

We have Hermann Von Helmholtz the picture of him here and he has actually found this. It is a special type of airs spring oscillator is it is enclosing inside a volume having a small neck and an opening at one end. So, you can see this is the small neck here is the open here is the opening, where from the sound is entering into the cavity. And the frequency which it can trap is dependent on the volume of the cavity that is how big the cavity is and inside that the sound resonates moves between the walls unless and until it dies down. So, it has a bearing on the distance that is the length of the neck and the volume inside and the audi face that is the hole through which the sound is entering into it.

So, all these 3 form the equation which gives the target frequency under c 0 which is the velocity of sound in that case for air we consider we considered 340 meter per second and we can find out our target frequency, but is it possible to put such things everywhere? We have to look into how we can make use of this into our system. So, ; so, we have we can take help of these resonator into our system by creating objects which will be helpful for us.

We see this long portion that is the neck and this length has a bearing where within the formula also. And if we have perforations then we can actually gauge the length of that the thickness of that material plus some allowances on the front through which the sound actually gets channelized into the cavity and it inside that it has resonance that is rebounding in between the surfaces and it dies down.

I have mentioned in victorious in the book of Vitreous I have mentioned that inverted pictures were kept below the audience; if you remember you can go to the lecture 1 and you can again revisit that was the principle over there in Hagia Sophia also church there were such circles, which were visible which were also believed to be used as resonators; so, they had a good understanding during that time also.

So, with increase of neck area we can increase the we can increase the frequency whereas, we can decrease the frequency with varying the volume or the length of the neck. So, if we are targeting lower frequency we must have very small a and in reality we do not have necks we have perforated sheets.

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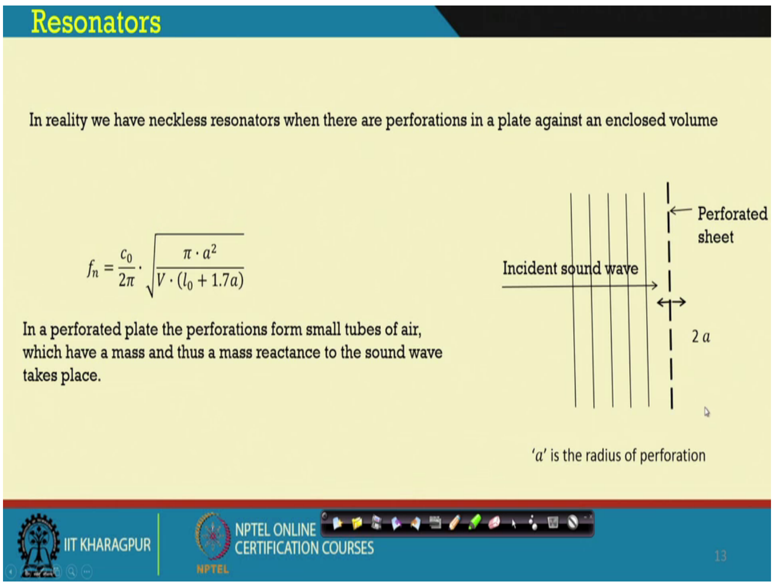

So, this perforated sheets and necklace where I told the thickness that is the thickness of the perforated sheet acts as the neck with the allowance of the sound getting channelized and getting out considering that has the neck length modified frequency calculation could be made. So, in a perforated plate the perforations forms small cubes of air which have a mass and thus a mass reactants to the sound wave takes place, this entire mass of air that moves into the cavity, which is created through the gap gets trapped into it gets resonated and gets lost.

So, that is the principle how the resonators work here you can clearly see that these are the perforations; this is the picture which you see is of a perforated plate unfortunately I could not get that for you.

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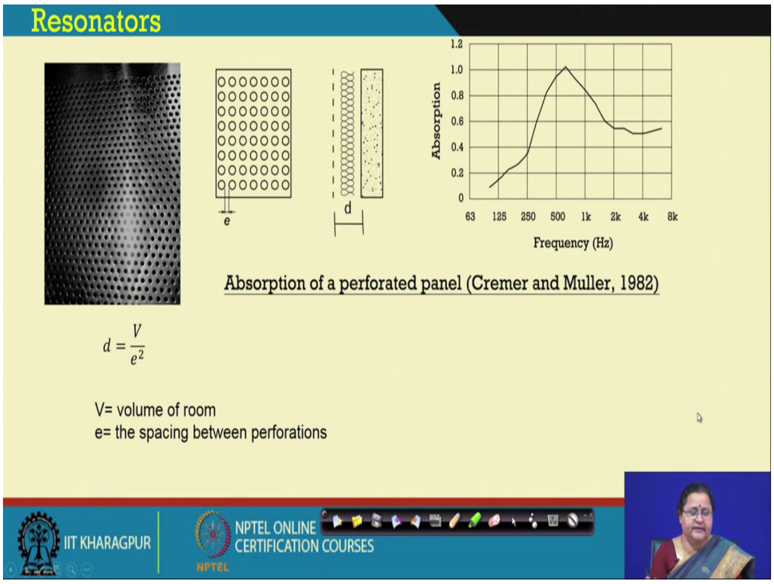

So, that I could have shown you it is a perforated plate and you can see the distance e also that is how close the perforations are also have a bearing with it.

The distance d how far it is placed is also having a bearing and inside it may be there is an insulation in the maybe there is packing of mineral fiber may not be it may be plane air then also it will resonate. V is the volume behind the behind the structural framework it is not the volume of the room.

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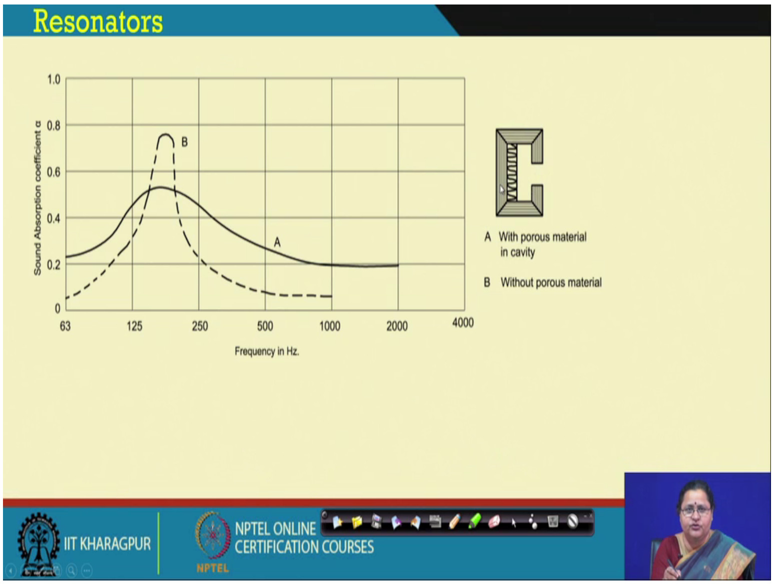

And you can create such multiple numbers in multiple numbers with wood maybe; you can get such kind of cavities into which the volume V is inside it. So, the sound enters to this and inside the cavity.

So, an array of such system can help now here you see 2 graphs are there the first one that is a when it is having a porous absorber inside it; it does not trap in much of the sound in the desired frequency that is 125 to 250, but without the porous material that is when you have increase the volume V of within this part; the frequency has gone high the lower frequency getting trapped in that is between 125 to 250 something around 175 is picking up. So; that means, this particular box the volume is made for that particular frequency around 175, which is getting trapped inside it which was not getting much trapped when the porous absorber was there.

So, volume V has increased and the frequency f has decreased and has targeted this 20 this 175 say the hertz has the frequency that was that is the target frequency. Whereas, it was behaving as a porous absorber more when it had this insulation we when it has this material inside it. So, the volume was reduced and the purpose of the principal was different.

So, case A is having more of a nature of a porous absorber where sound has entered into it reduce the volume of the space whereas, curve b is targeting a particular frequency of say around 175 hertz in this particular case, where the volume V has effectively increase just by removing it and in the market we get such kind of sound box units.

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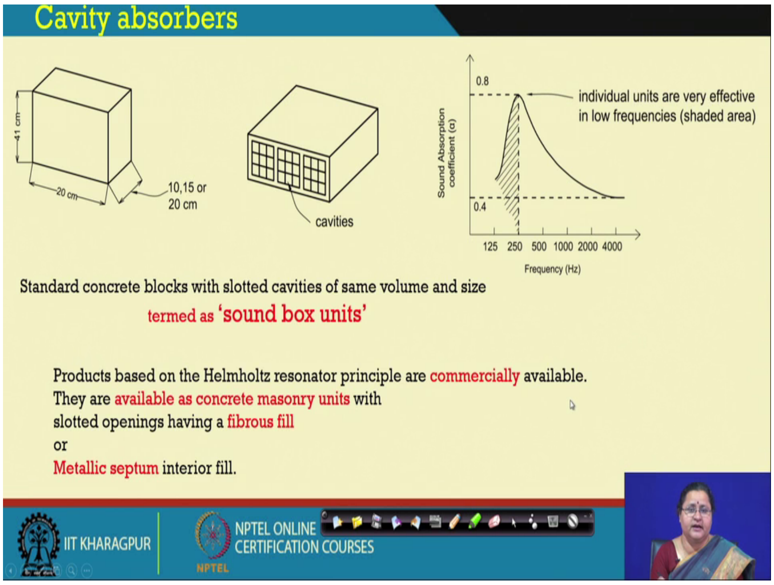

So, these are standard concrete blocks with slotted cavities of same volume and size. So, these are all same kind of volume, same kind of size which are pushing in air into this cavity and inside the by the process of resonance the sound energy which is the sound frequencies which are targeted are getting trapped inside.

So, these products are based on the Helmholtz resonator principle and are commercially available for us and these are usually made of concrete they may have fibrous infill; they may have metallic septums that is breaks in between to create the chambers and so, so, on and so, forth. So, commercialization of these items in which are working under the principle of resonators are available and we see the target frequency is mostly below 250 hertz.

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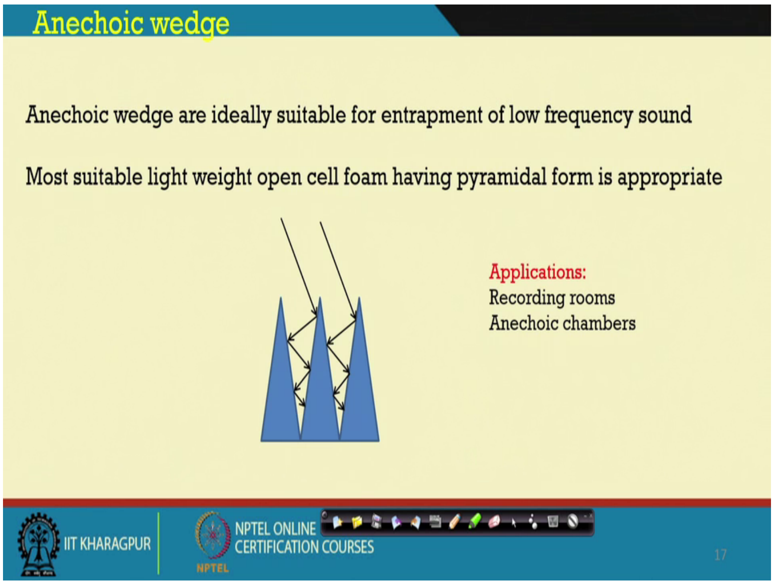

Now, we come to another very important item which is the anechoic wedge what happens here these are used to get almost no sound reflected back. So, these are triangular pyramidal wedges as I had shown you earlier in form of an egg crate you can see and egg crate in front of you which are having pyramidal surfaces to take care of those eggs. What happens here the sound gets reflected multiple number of times in between these wedges.

So, these wedges are actually trapping in sound closely at very rapid intervals and almost the entire sound gets absorbed. So, you can you all can have a look of this is the anechoic wedge which is used for particular purposes mostly in recording studios and anechoic chambers say in the hospital in where you have to do checks of your ear how good you are listening you have to have an environment where there is no noise no outside sound coming in. There you can see and the presence of anechoic chamber and it is more into more into other areas, we will come to those later I am not going into the details this is what is an anechoic wedge.

So, the sound gets every bit of the sound if it is lined inside the entire place; where you want to create an anechoic place. There will be no echo no rebound of sound you have to put pack in with dense such unit. So, this is what is anechoic wedge; so, this is how it works.

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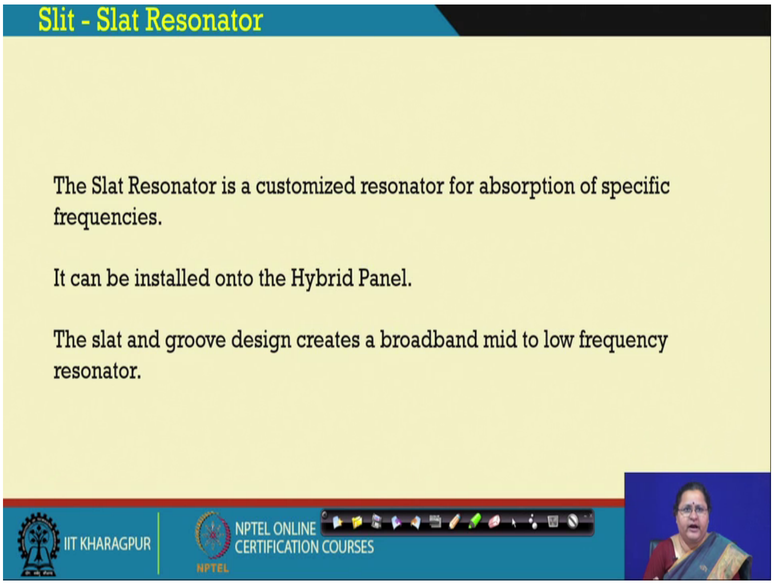

So, after having all these understanding we will find plenty of application of slit slat resonators which is also working in the principle of resonates. You will see mostly now, on you please try to be aware wherever you go you try to see your surrounding whether there is any treatment. If you happen to go for a theatre in a in a hall you try to see what is there you will see plenty of application of slit slat resonator. These slats and the grooves designed creates a trap for the low frequency resonator let us try to see how it is doing so.

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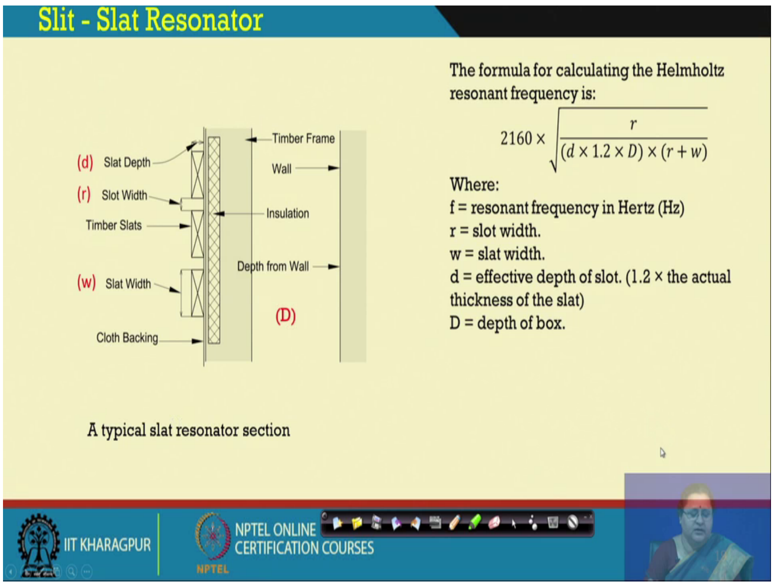

So you see it is similar to the system we have a big formula over here and we see that we have the slat which is which is nothing, but which is nothing, but a wooden member fixed on top of a system; the gap that is the slot with that is denoted as r you can see that is the width that is the spacing of those bars; the wooden bars of width w are placed at a distance r. And the these slats are having a depth of d the small d and the entire subsystem is put in front of a structural wall at a distance d that is big d.

So, if I can define all these things you can understand it is what you see in front of you is an array of wooden members of a specific width and of a specific depth placed at a distance interval r against a hard surface. So, in this way what is happening small slots?

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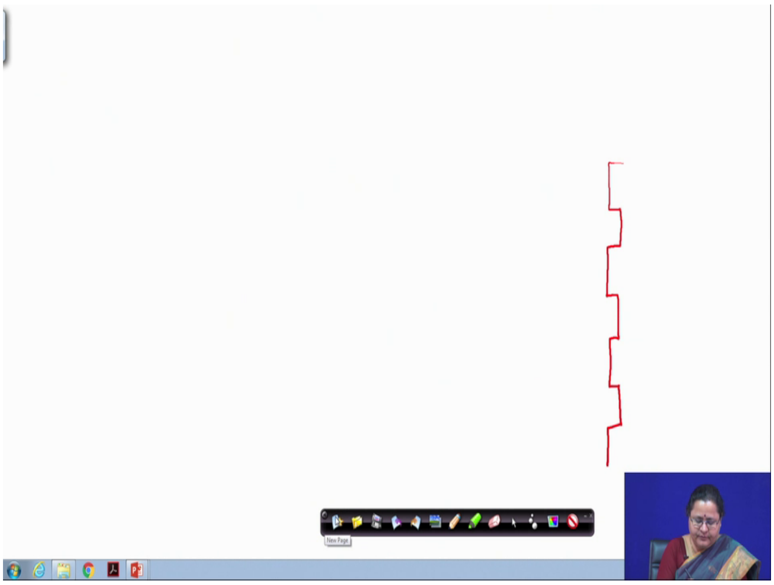

Small slots are created and within those actually the sound gets lost; apart from the vibration and all what is happening, whatever material is capturing, whatever absorption is being happening; particular frequencies are getting trapped in to those particular slots. So, and you can calculate out what is the frequency. So, we see a big formula which is not much big when you put into put values to it and we will see how it varies.

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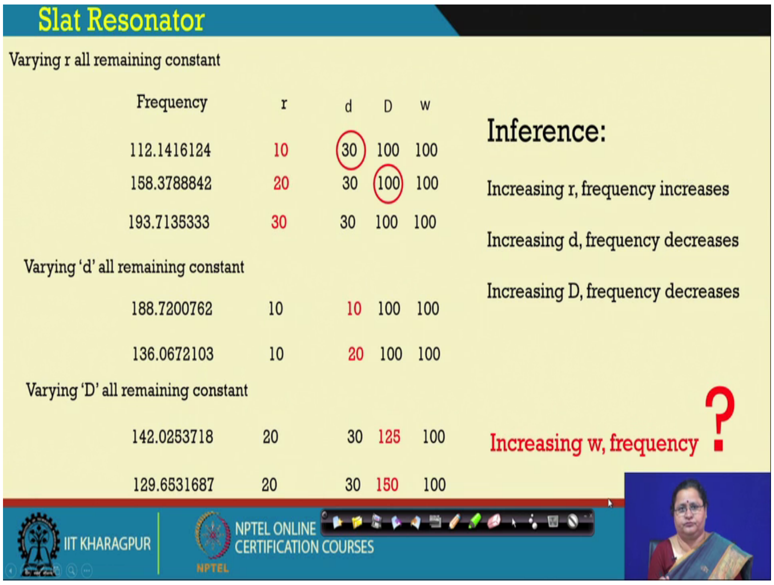

Now, varying r that is the gap; keeping everything unchanged what do we see? If we calculate the frequency with r is equal to 10 that is the gap is 10 and these are constant that is d that is the d that is the slat depth, w that is the slat width and d that is the distance from the wall. You see with r we get the target frequency is 112 hertz. You change it to 20 that is you change the gap, see the target frequency becomes 158.

So, other things remaining constant if you move the, that is if you space them your target frequency is getting higher. And if we see the other one the next one that is the gap is 30 units; 30 millimeter, here we get it 193. So, it is increasing one from 160; it has gone to 190 more than 190. So, every gap there is a jump of around 30 hertz of frequency. So, if it a good idea to control let us see what happens with other parameters; so, varying d all other remaining constant.

So, we keep r as 10 because we are targeting lower frequency. So, 112 was when r was 10 and d was 30, but we see when r was 10 others remaining constant and d has gone down to 10; we see the target frequency is 188 then with d has 20 that is the thickness d is the thickness; the target frequency has gone down to 136 and with d as 30; we have that as 112. So, if you have very thick thick thick things then our target frequency gets lower and lower are you getting it?

So, target frequency gets lower and lower if that the yeah the depth is more and more. So, that is the cavity is deeper and deeper; so if you have a deeper cavity the target frequency will be lower, but we cannot do afford big things because we have we have to work with space let us see what happens when d varies that is the structural depth varies.

So, we have one case at the top where the d was 100 that is that is 100 millimeter where we see r as 10 and d as 30; we have the frequency 112. So, just we increase 1 inch that is 125 millimeters ahead the entire system mounting. So, we see the frequency changes from 112 to 142 when r has changed to one from 158 has reduced to 142; when r has changed to when d has changed to 125. And further we see that when d has changed to 150 we see that the frequency has gone further down. So, what does this implicate? That higher the gap you will get a lower and lower of frequency, but that is against the space which have already told. So, we have to work out how much we can give.

So, it is not one particular solution to one particular problem to general problem; you have to look into how much you can afford space wise, how much you can afford towards the depth though market available things are there then in that case you can just change the mounting distance and play. If you are making your own thing, you can change the depth, you can change the gaps, you can change the slot widths slat widths and you can carry on.

So, increasing r frequency increases, increasing d frequency decreases, increasing big D that is the distance between the wall and the thing frequency decreases, but what happens when we increase w? That is your task we may continue we may explain it in the next lecture, but I would request all of you to go through this lecture and try to solve out solve here what is happening? So, this slat width w; when it is changing how much changes happening to the result? That is our target frequency. So, hope you understood all this points here you see d is the effective depth of the slot which is considered as 1.2 times the actual thickness of the slat.

So, whatever thickness you have you add you multiply it with 1.2 that 1.2 is for that channelization; what I told in resonators you have air getting channeled into it. So, you consider that 1.2 as the depth as the multiple of multiplier of the depth to consider that it is channelizing from a little ahead. So, you are taking care of that through this 1.2.

So, hope you understood it and I expect that he will report what happens when w changes is there any effective change or no change, whether it is increasing, whether it is decreasing and that remains as a task for you. So, I leave you with this task and I would request all of you to bring calculators when you sit for the next lecture that is lecture 13 and you should have a pen and paper with you. So, that you can work out and you can just see whether you are getting the same results which I am going to present it to you. So, that will help you to get into with us.

So, that will actually make it more interactive; so, I also want intended to show you that how increasing w, what is the effect and that maybe we can do it if we get some time; almost at the closing part of this particular module.

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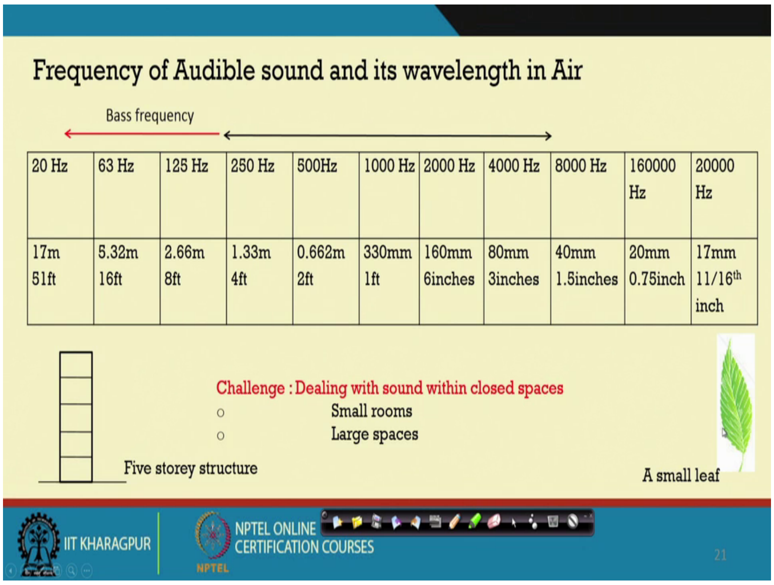

So, what we what we understood that by use of absorbers if you can recall this slide by use of absorbers porous absorbers help in taming the 250 to 4000 hertz area whereas, the bass frequency that is from 250 and below; we can tame it by the use of resonators and panel absorbers.

So, with it it is our challenge to deal with sound to the extent; it does not affect the compromises with our sitting space our comforts etcetera, but creating a bad sound inside a space is also very annoying. So, I expect that you will be continuing with lecture 13 with computer with calculators pen and pencil and paper.