NOISE CONTROL IN MECHANICAL SYSTEMS

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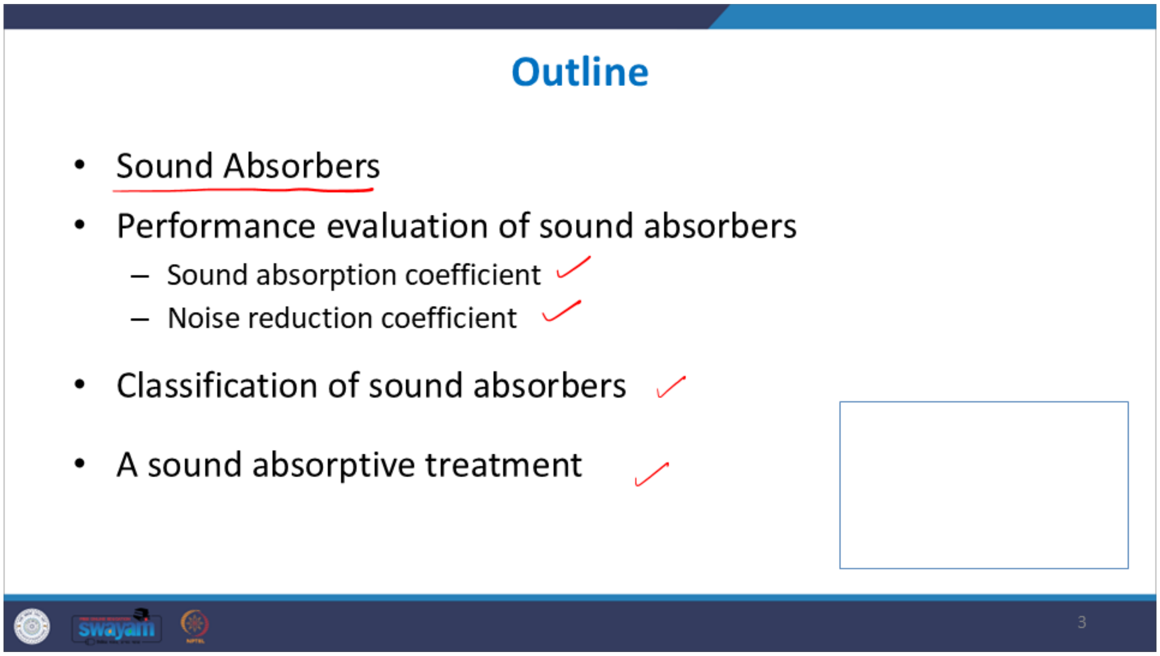
Week: 8

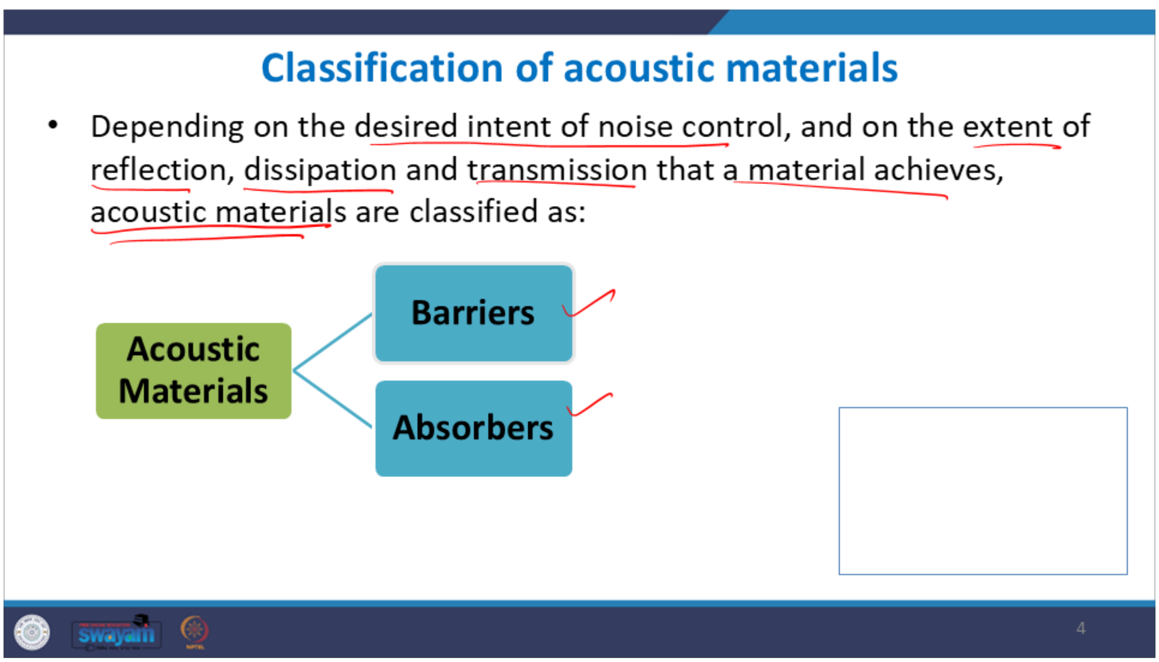
Lecture: 36

Lecture 36: Sound absorbers

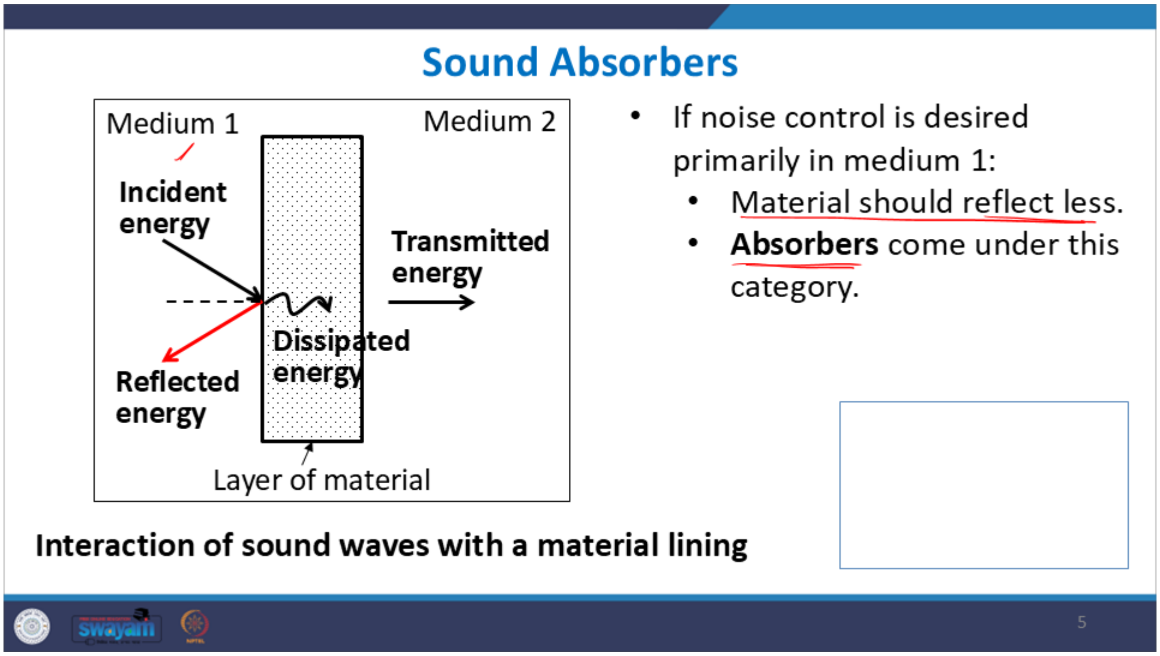
Hello and welcome to this course on noise control in mechanical systems with me Professor Sneha Singh from IIT Roorkee and we have been discussing about you know sound barriers. So, we started our discussion with you know passive noise control followed by you know the various kind of barriers what do you mean by that and what is acoustic enclosures and we also solved certain problems related to that. So, in this class we will begin our discussion on sound absorbers ok. and we'll see you know what are the things used for evaluating the performance of absorbers so we use sound absorption coefficient and noise reduction coefficient and how are these absorbers classified and what is a typical sound absorptive treatment,



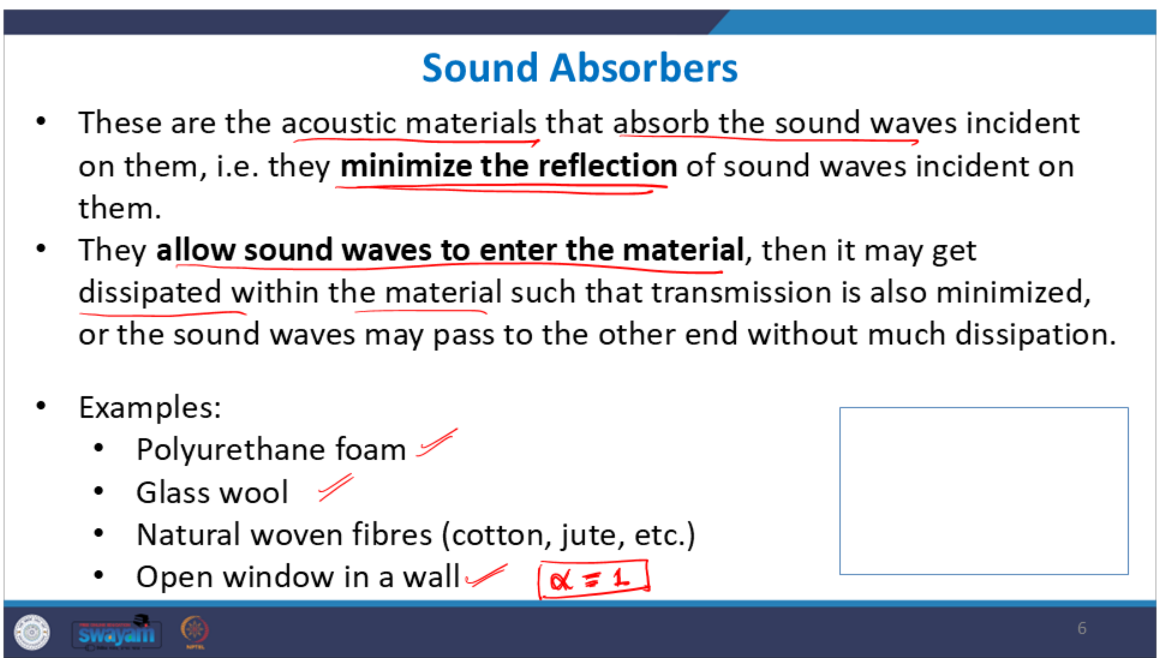
so for a quick recap you know based on what is your desired intent of noise control and what is the extent of reflection



dissipation and transmission that your material can achieve the various kind of acoustic materials they are classified as barriers and absorbers. So, what do you mean by absorbers? It is when you know suppose you want to achieve the noise control near the source itself in this particular place. okay so in that case whenever it's hitting the material it should not reflect back because it will just increase the noise source near the medium of

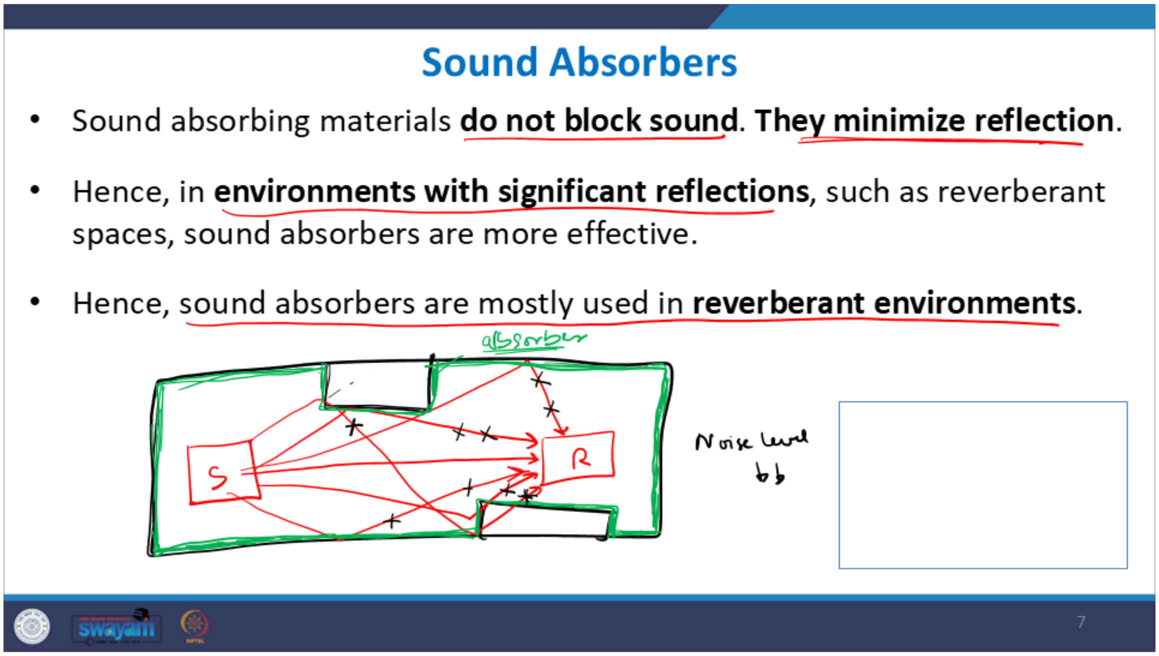


incidence or near the source so absorbers fall under that category where the materials they have to minimize the reflection okay so how do we define them these are the acoustic materials that absorb the sound waves whatever is incident on them that is they minimize the reflection of the sound waves So, how do they do this?



How do you minimize the reflection? So, whenever the sound wave is hitting a material, you minimize it because you do not want it to reflect back. So, basically you would like it to pass through. So, these materials allow the sound waves which are incident to enter inside it. And once they enter inside it, it's up to you know the it's up to the case by case you know the material can either dissipate the sound energy within itself while passing and in that case not just the reflection is minimized but even the transmission to the other end gets reduced and otherwise they can just allow the material to pass through sorry the sound waves to pass through the material without any dissipation and even that could be called as absorption. So typical kind of absorbers, we have these, you know, various kind of porous materials like foam, glass wool, even the natural woven fibers. And even like, for example, we have an open window in a closed room. So, you know, whatever I'm speaking, it's like a medium continuity. When the sound waves, they propagate and they reach the open window, they don't reflect back because, you know, the impedance of the medium

left side of the window and the right side of the window is the same so the sound wave simply pass through as if because it's a continuity in the acoustic medium so there also absorption is there and the because the entire waves get absorbed there is no reflection there because it's the same medium continuing the absorption coefficient for this case becomes 1 and then i took the example of some of these fibers for example the kind of clothes you wear if you see your clothes and everything there they have so many pores and holes and spaces in between them that the sound waves can pass through it okay so now you know that these materials they do not block the sound they simply minimize the reflection okay so they are more effective so suppose suppose in any field we had the source suppose it was a free field environment okay and the source was directly reaching the receiver through a direct path without any significant reflected paths then use of absorber is not going to be very effective in that case because Here you know it is supposed to minimize the reflection but if you consider an open field environment there already there are almost no reflections.



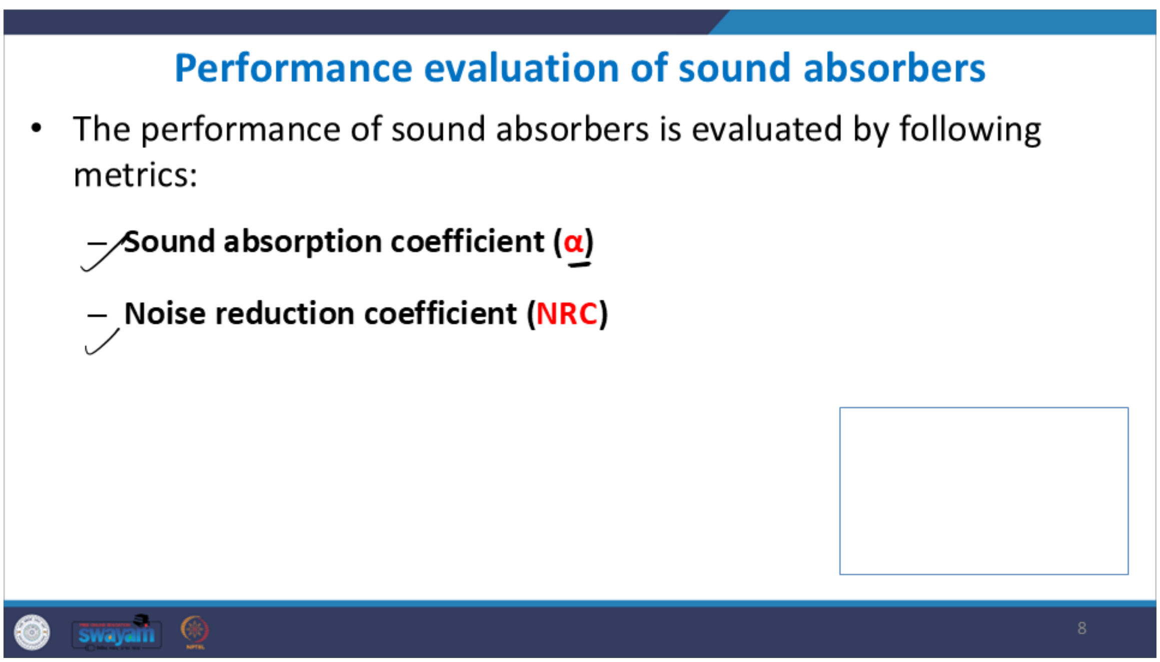
So the use of absorber is ineffective there you know it is not contributing anything there. So basically when you have environments with a lot of reflections there on these reflecting surfaces if you have sound absorbers then what it will do is it will minimize it is going to reduce these various reflections and it will turn out to be more effective for noise control. So, that is why absorbers they are mostly used in the reverberant environments. So, here from a schematic you can see suppose we have some machinery or some mechanical system which is our source and these are the receivers.

Okay In the very first case, you know there is an open field environment and there are no reflections and the sound waves are just emitting like this. Even if you have an absorbing material which absorbs whatever is hit on it, how is it going to effect the sound level? There are no reflections at all. But if suppose it was a reflective environment, we enclose it within a room.

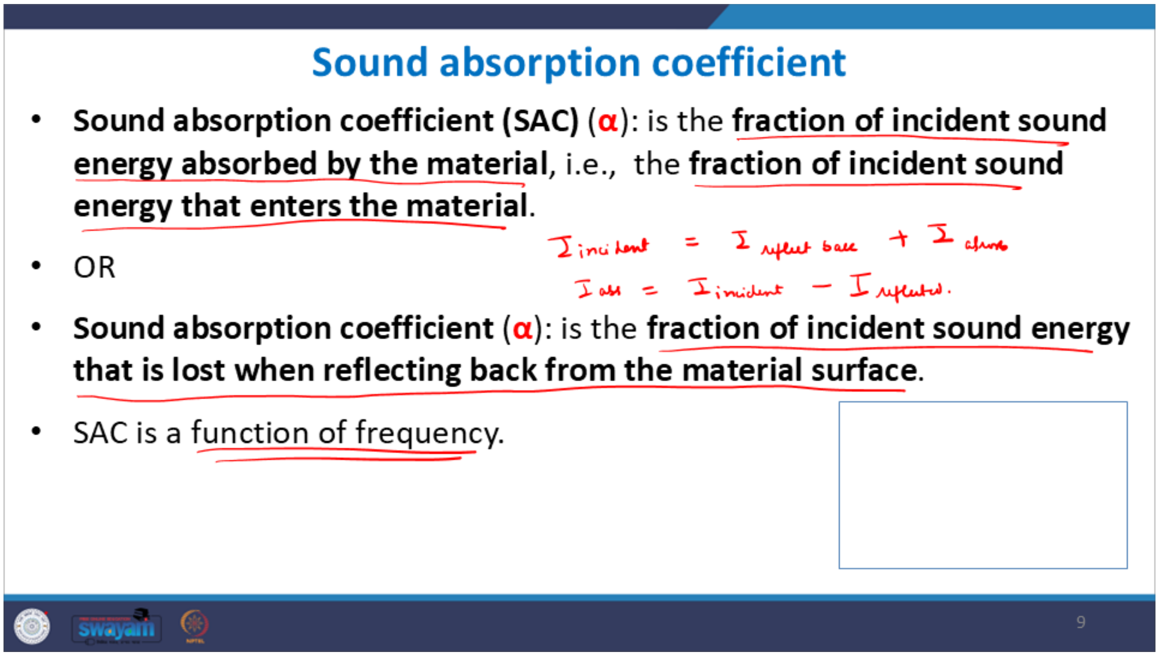
highly reflective room hard walls and also there are so many structures within the room that are also reflective in nature let us say so now in this case the sound is reaching the receiver via the direct path then also via some indirect paths okay some other kind of indirect paths you know Let us say many such kind of indirect paths are there and the sound is simply multiplying. Okay So, now if you use the absorbers and you have the absorber linings on all these reflective surfaces, this is the absorber lined on the reflective surfaces. okay and all around this wall.

okay so in that case what happens now whatever sound is incident on these reflecting surfaces it's not reflecting back so this path has been cancelled because it's getting absorbed into the material so the reflection has stopped in the same way here also it absorbs and this reflection stops here also this stops here also this stops okay and various other reflecting paths so now all of these things they have cancelled out all of these things and rather we just have the direct field coming in. So, because they were significant reflections which were increasing the overall noise level and with the use of the absorbers we have cancelled out and removed these you know various alternate pathways that the sound was taking. So, now the noise level will go down. So, the more reflective the environment there is the more you have reflections.

The better the performance will be when an absorber is used, but if it is a free-field environment and the reflection at the beginning itself is very low, then the use of an absorber is not going to be effective, okay. So, how do you know how to evaluate the performance of sound absorbers? So, there are two measures: sound absorption coefficient and noise reduction coefficient. Alpha is the symbol used for the sound absorption coefficient.

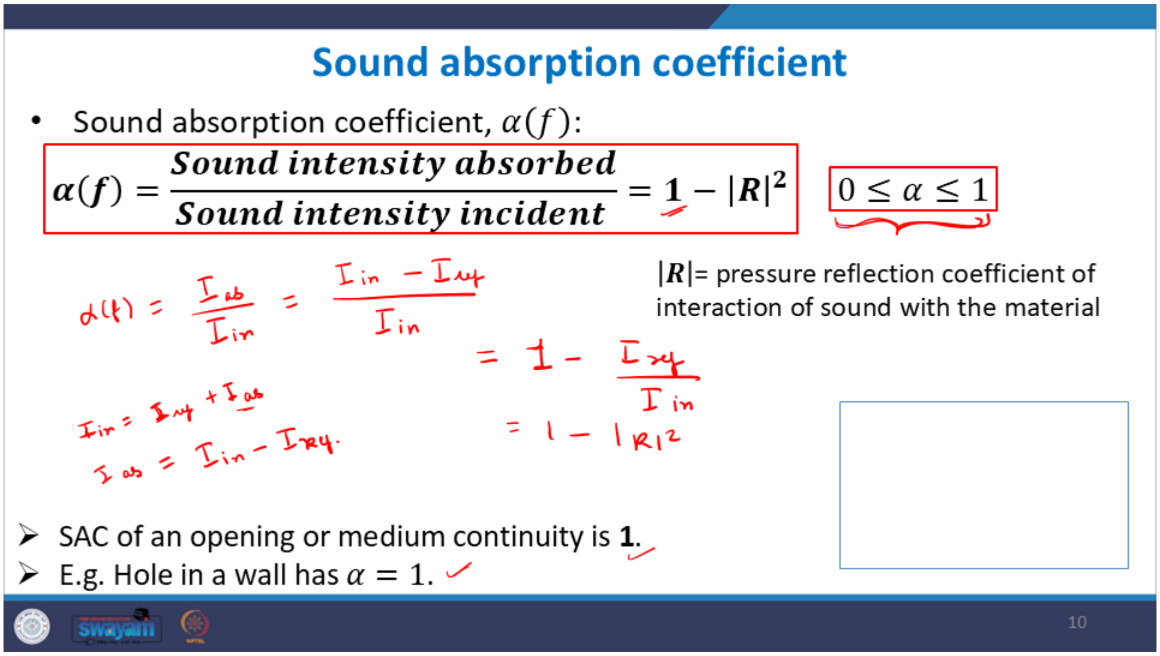


We already defined the sound absorption coefficient when we were discussing the acoustic fundamentals, and that was defined as 1 minus mod r whole square. So, now in the context of an acoustic material, what do you call it as a SAC or the sound absorption coefficient?



It is the fraction. So, if you see here, this is the fraction of the incident sound energy absorbed by the material, i.e. the fraction of incident sound energy that is entering inside the material, okay. So, what is so if, suppose, a 1 pascal sound wave is incident—intensity of 1 of sound wave is incident—how much of it is actually going into the material without reflection? So, the fraction of incident energy that is getting absorbed or entering the material.

Another way to put this is that you know that whatever energy is incident, okay, it will either reflect back from the material or it will get absorbed and pass into the material, okay. So, whatever this is, it will become I incident. Okay, so in that way, you can say that it is the fraction of the incident sound energy that is being lost when reflecting back from the material surface, and SAC is a function of frequency, just like all the other measures such as transmission loss, insertion loss, and so on.

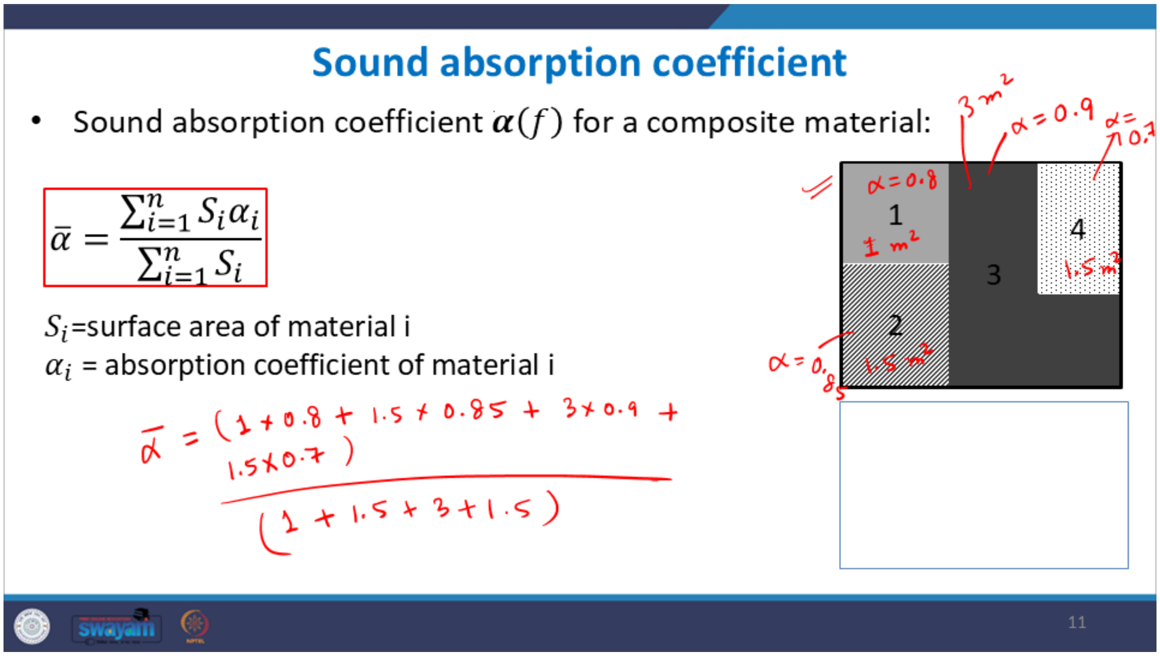


Okay. So, the sound absorption coefficient is a function of frequency. It is defined as the sound intensity that is absorbed by the material divided by the sound intensity that was incident on it, and it is 1 minus mod r whole square, okay.

So, obviously you know whatever energy that is falling on the material ok. The maximum absorption that you can get is the entire energy gets absorbed ok. and the minimum would be you know that none of the energy is getting absorbed so the alpha value is always going to lie between 0 to 1 it cannot be greater than 1 because suddenly the energy is not going to add it up we don't have an external source of energy in this material then whatever is incident the entire thing the maximum that can pass through is the entire thing that is passing through without an increase in the energy so by the conservation of energy The value of alpha has to be between 0 to 1. Okay.

So, how it is derived? We have done it in the acoustic fundamentals module as well. So, alpha is the intensity that is absorbed by intensity that is incident and we know that if something is incident on it, it will either be reflected back or it is going to be absorbed. These are the two things that can happen. So,

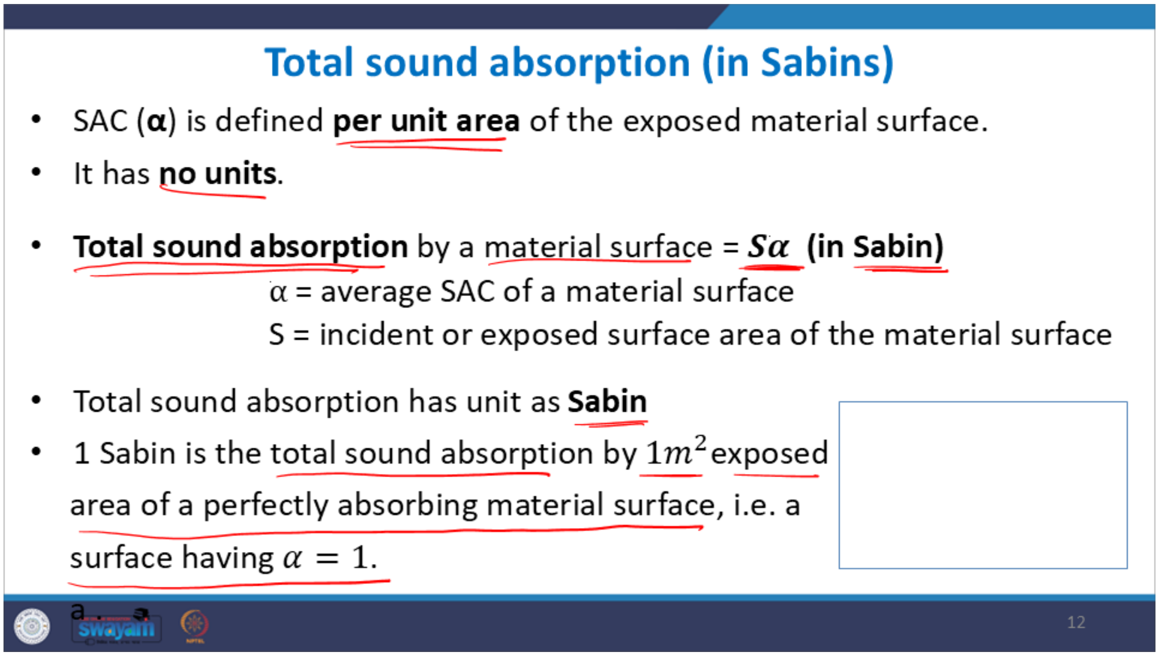
I absorbed would be I incident minus I reflected. Okay So, if you do this thing here it will be 1 minus I reflected by I incident which is simply 1 minus mod R whole square.



okay so whenever there is a medium continuity then SAC becomes one so for example you have got a hole in the wall so for that hole the alpha will become one because whatever is incident on the hole it's simply passing through the hole is not going to reflect back okay so, the sound absorption coefficient suppose you know so sound absorption coefficient is something which is defined as per unit area term okay so here we assume that we have the material surface of uniform composition that is having the same alpha throughout and that for that material surface you define what is the net absorption SAC per unit area.

But what if that particular material itself was composed of different you know materials each having their own sound absorption. Then for that particular composite material What you do is the average absorption you can calculate which is the summation of you know the surface area of that particular material multiplied by the alpha of that material and so on divided by the total surface area. So, let us say you know this particular material had an alpha of 0.8, this had an alpha of 0.9. this had an alpha of 0.85 and this had an alpha of 0.7 and let us say you know the area was you know this was if we consider this as 1 meter square this was let's say 1.5 meter square this was let us say you know 3 meter square and this was again 1.5 meter square let us say

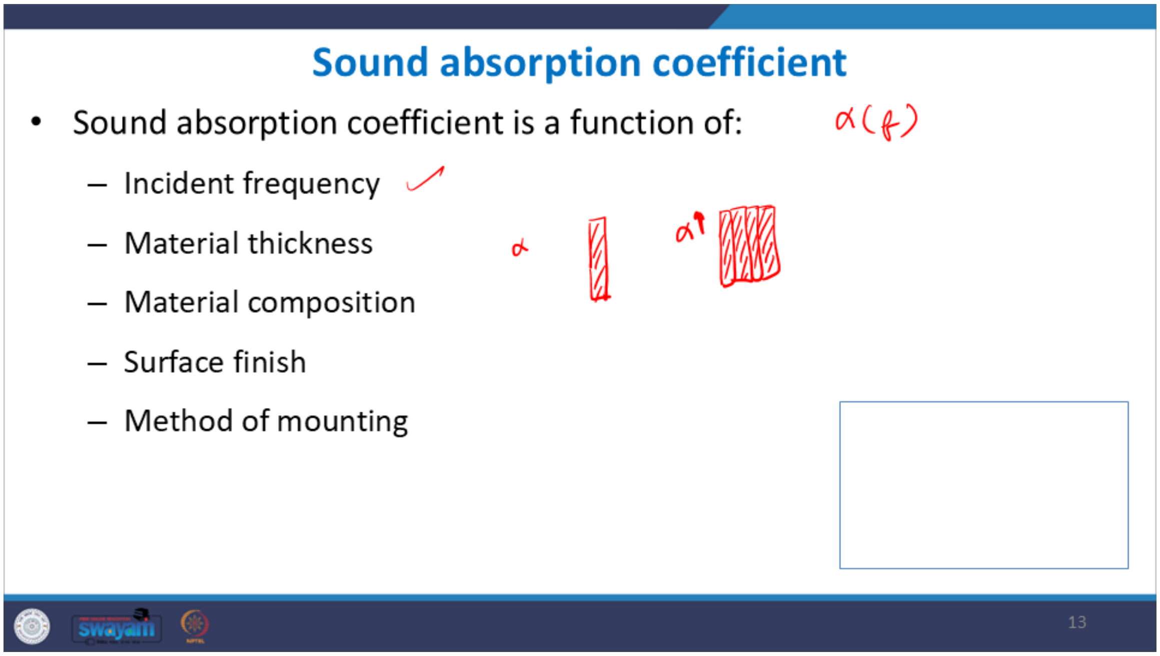
Then alpha bar for this particular wall is going to be you will multiply the surface area with their corresponding alpha ok. So, we have done this. divided by the total surface area which is okay this is what should give you the total average absorption for this complete wall okay.



Fine so now that we know that see alpha is defined as per unit area okay it is a fractional quantity and you know for a material with uniform composition you can find out per unit area absorption in the same way if it is a material made of different things there also you can find out an average value which is the fraction of the energy that is getting absorbed so it is a per unit area quantity it has no units. But suppose you know if you have a material of you know suppose a certain alpha and you keep increasing its surface area then the net sound absorption would be you know whatever is the per unit area absorption multiplied by the surface area.

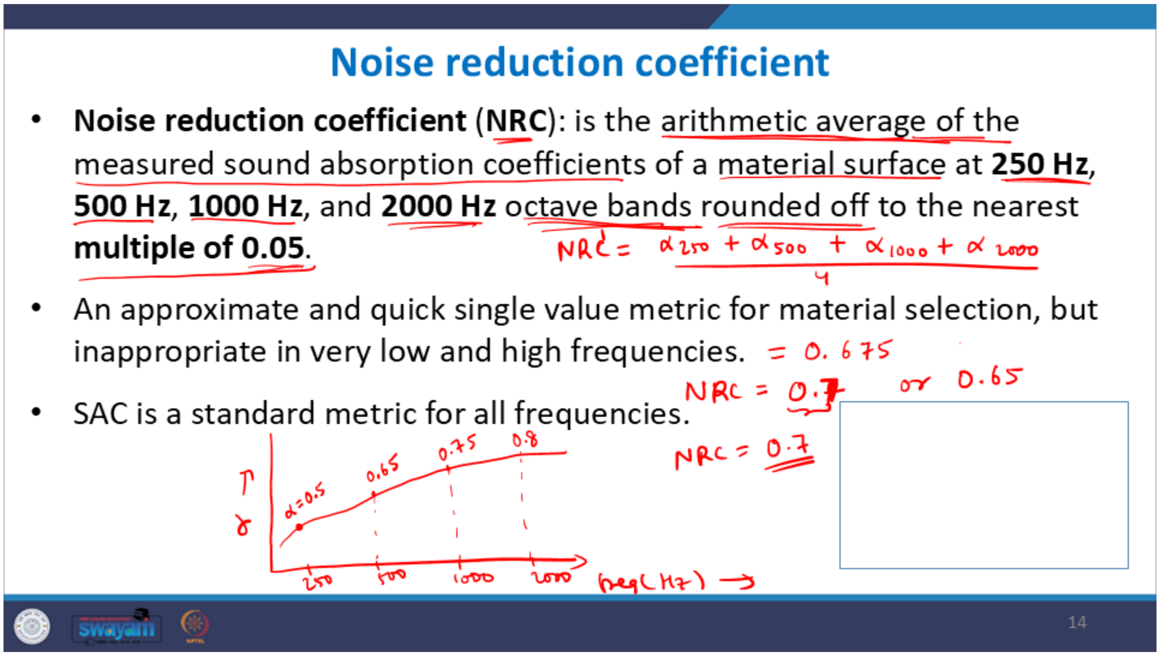
So, that quantity we call it as the total sound absorption and it is simply S into alpha bar and the units that we assign to it is Sabin. It is after the scientist who you know formulated this. So, you simply say that okay this is the per unit area alpha of a particular wall or a particular surface and the S is the total surface area then the total surface area multiplied by the absorption per unit surface area will give you the total sound absorption ok. So, how do you define this unit Sabin as it would be the total sound absorption by a 1 meter square.

Exposed area of a completely absorbing material surface such that it has an alpha of 1. So, S. So, one Sabin would be what S into S is equal to 1, alpha is equal to 1, you will get one Sabin like that, OK.



So, the sound absorption coefficient, the measure first of all, is a per unit area measure without any units. And it is a function of, you know, what frequency is being incident, as I told you that alpha is a function of frequency, OK. It also depends on the material thickness because this is a per unit area quantity.

So, suppose this is the cross-section of some material, and per unit area it is having some alpha, then suppose you keep on, you know, increasing the width of the material like this. So, for this material, the per unit absorption is going to go up, OK, so it depends on the material thickness, OK, and it depends on the material's composition. You know, different materials have different absorption capability. It also depends on the surface finish and the method of mounting, and when we do a discussion on the individual sound absorbers, we'll see how this variation happens.



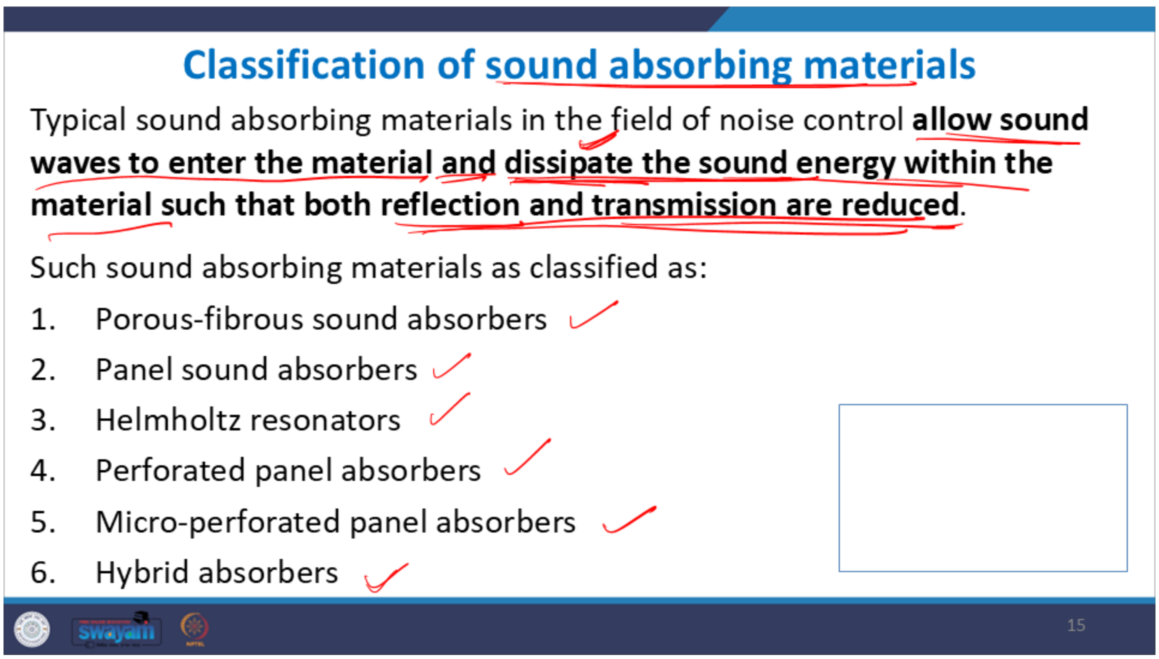
OK, so let us now see the second measure used for evaluating the sound absorption by a material. So here, the first measure was SAC, but SAC is not a single-value measure, OK? You see, it is a variation with respect to frequency, but as a noise control engineer or any engineer, we are always fascinated with having some single-value measure just for a very quick analysis and estimate. So, that single-value measure here becomes, you know, the noise reduction coefficient, OK. So, what is it?

It is a single-value measure. So, how do you obtain this? Suppose you already have the alpha versus the frequency. You do the arithmetic average of the measured sound absorption coefficients of the material surface at 250, 500, 1000, and 2000 hertz octave bands, OK. And then you round it off to the nearest multiple of 0.05.

So, a way to show this is that, let us say, you know, we have some material like this. Okay, sorry. Alpha versus frequency—I want to see. Okay, this is 250 Hertz, this is 500 Hertz, this is 1000. Let me draw a larger picture. Okay, so this is the frequency. In the octave bands, this is your alpha value, and suppose we have some curve here like this. We find that at this value, your alpha is coming out to be 0.5; here, it is 0.6. Okay, then your NRC would be—what would it be? We will do the arithmetic average first to find out NRC dash, let us say. So, here you do the arithmetic average. You know, it is linear: 0.5, 0.6, 0.7, 0.8.

So, it will come out to be 0.65. Now, you will see whether it is a multiple of 0.05. So, let me, you know, here take a case where it is not a multiple of 0.05, so we can do that like this point. Okay, so if you do this, what you will get is 0.65, and one more thing—so it will become 0.1 by 4, likely. So, then here, this is not a multiple of 0.05.

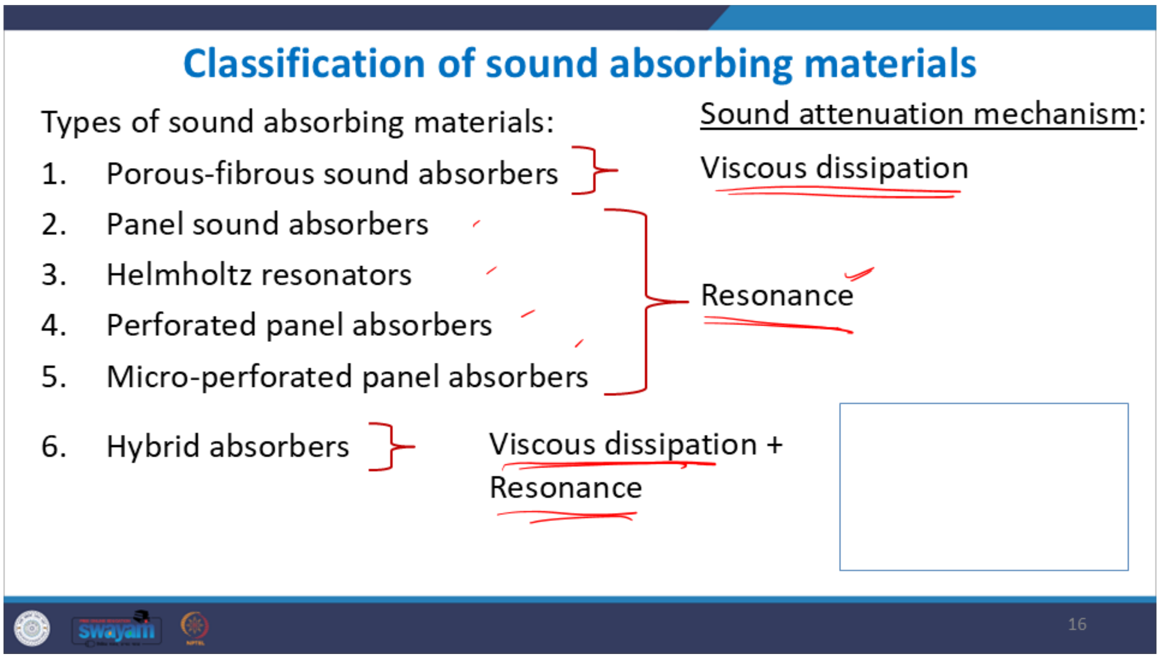
So, your NRC will then become—suppose you have found the arithmetic average is this—then your NRC will become the nearest multiple of 0.05, which can either be 0.7 in this case or it can be 0.65. So, usually, the engineers choose the upper value, and they give, you know, if both are near to it, they give the upper value. Okay, and like this, they calculate it.



Now, how are the sound-absorbing materials classified? You know, we have various kinds of classifications based on how they work, you know, and what is the mechanism involved. Porous fibrous sound absorbers, panel sound absorbers, Helmholtz resonators, perforated panel absorbers, micro-perforated panel absorbers, and hybrid resonators—each of them has its own working principle, okay. So, if I have to give a summary on what is, you know, what is there inside the material which is causing the dissipation of the sound waves.

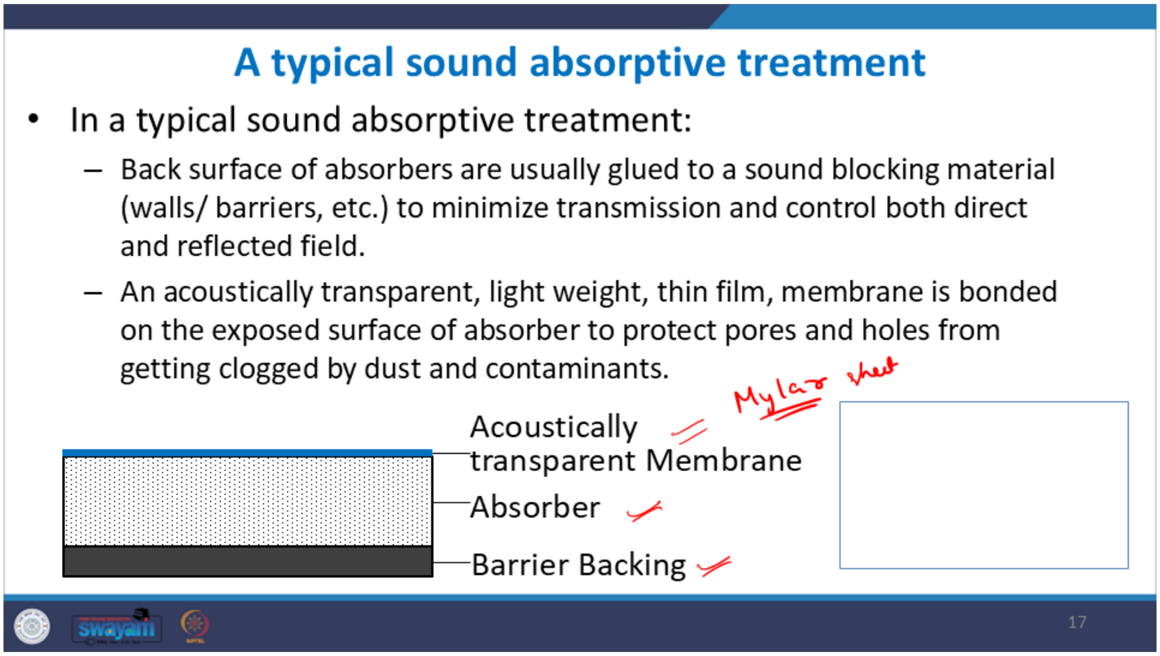
So, this is the typical sound attenuation that is happening. So, here I would like to insist that even when the sound wave is entering a hole or an open window, it can be called absorbing. But when we talk about passive noise control and sound-absorbing materials, we typically talk about materials that allow the sound waves to enter and, at the same time, some dissipation happens within the material so that both reflection and transmission are reduced. Okay, So, it is not just allowing the sound wave to pass through the material as it is, but it allows the sound waves to enter inside.

get dissipated due to some mechanism, and what is dissipation? It is the conversion of sound energy into heat and hence getting lost. Okay, so when sound energy gets lost as heat, that becomes dissipation. So, these materials allow the sound waves to enter inside, get dissipated, and lost within the material, so both reflection and transmission are reduced. And in these materials, let us see what dissipation mechanism is happening.



So, for porous fibrous sound absorbers, we have viscous dissipation that happens. For these other absorbers—panel, Helmholtz, perforated panel, and micro-perforated panel—the resonance phenomenon leads to sound attenuation.

And for hybrid absorbers, which are usually a combination of porous materials with a resonance material, both phenomena operate together to achieve sound attenuation.



Okay, so this is a typical sound absorptive treatment that we do because we want to use these absorbers. We want to stick them to various surfaces because absorbers can't be standing or suspended in the air in most cases, so usually they are placed with some material backing so that and because they have to allow the sound waves to enter inside, usually they have some pores. Most porous materials have pores, etc., so these pores have to be protected from dust and other particles because the material's performance depends on that. So, an acoustically transparent membrane, such as a Mylar sheet, can be used. So, it will protect the material from particulates in the air but will allow all sound waves to enter.

So, this kind of treatment can be done on the surface. And then you have the absorber material, and then you have some barrier backing, typically because whatever sound is emitted outside, we want to control that as well. So, we have a barrier installed. So, this provides better sound absorption treatment. So, with this, I would like to conclude this lecture.

Thank you for listening.

Thank You