Energy Efficiency, Acoustics & Daylighting in building

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Lecture – 40
Sound within Enclosure (contd.)

So, we will continue with the sound within enclosure. Now let us go back to noise a little bit, we will come to auditorium back, this is a principle which is applied to both.

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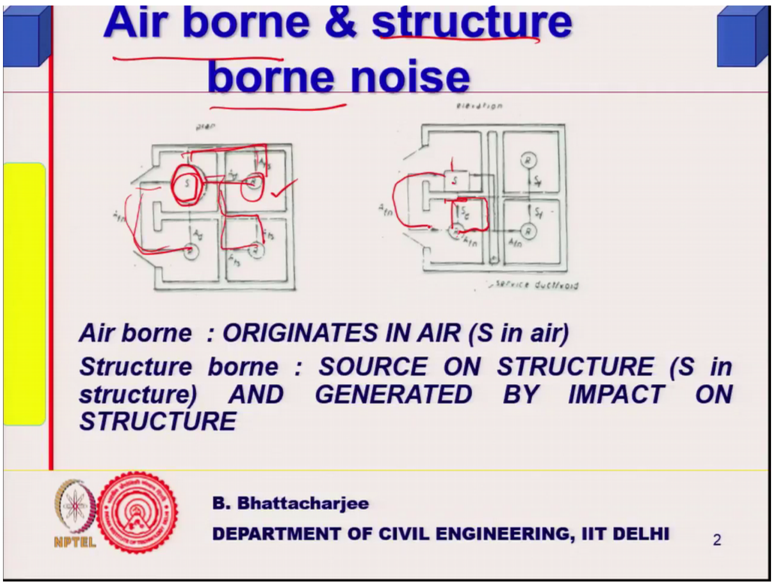

So, 2 types of sounds we actually distinguish. One we call as airborne, another is structure borne. Now I will write airborne and structure bone right.

Now, what is the airborne sound? My source is in the air, right? For example, I have a speaker, it is hanging somewhere. It is actually is a airborne sound, you know generated by vibration in the air itself. As opposed to this I am stamping on to the ground. The sound is generated because of the vibration of the structure itself. That is called a structurable noise right.

So, see this diagram, in this diagram you have a source here suspended, right. So, from this source it can pass through the wall and reach here. So, we call it airborne direct airborne stands for generation, where it has been generated, right. And then it can pass through the wall partition wall, it can pass through the partition wall. And directly reach to the next room, or next space this is the next space. So, we call it airborne direct. But it can also reach through the wall themselves, because velocity of sound in solids will be somewhat more, and it can go around the wall and reach there also, because you know like from diffraction on similar principle it can actually move down to that side.

So, this is called the airborne flanking, airborne flanking; flanking through also if I have a window open it can come here again, airborne flanking through the air. This is airborne flanking to the structure. This is airborne flanking through the structure, airborne flanking through the air because windows are open. So, you keep all the windows of yours, classroom open and next classroom is also open, there will be disturbances from this room to the other and right.

So, this is how it is and it can even go like this flanking structure borne or flanking structure borne. So, this noise paths one can visualize, if want to do some noise control, you know you find the noise is high then you got to do the control. So, you can visualize you have to visualize this path. So, airborne sound is one generated in that air; whereas structure borne sound is something like this. The machine is kept on to the flow. And it is causing vibration of the flow.

So, it will generate both air borne noise as well as structural borne noise. Airborne noise will come because the after all machine will cause vibration of the air in the surrounding. And structural borne noise because it will cause vibration of the structure, and then structure borne flanking can be their structure borne direct because you know borne in the structure. The one vibration of the structure itself and that goes directly; to the receiver.

So, that structure borne right, structure borne direct structure borne flanking also can be their vibration of the structure to the next you know the vertical wall and then to the right. Then this is airborne flanking. Because it will have airborne noise also a machine if I keep it on the floor on the first flow let us say, this is in elevation this earlier one is in plan, this is in elevation. So, if I keep a machine on the first floor, it will cause vibration of the structure.

So, therefore, it will have some airborne noise generated right. And this airborne noise can transmit through the structure itself wall and go to the next room below that is air just structured borne flanking through the structure. And it can also have structure borne you know air borne noise also. So, you will have all air borne noise flanking also, or airborne direct you know all combinations are possible.

So, structure borne noises are by the sources which are placed on the structure. Airborne noises are those were sources place in the air, right. And you go to identify the path in order to do a noise control, in order to do a noise control right. So, this is what the definition is important, originates in air, sources in air, sources in structure and generated by impact on the structure itself. So, you want to control both of them do it in a different manner.

Principle of controlling noise control now we talked of sources outside earlier. And then that comes to you know maintain distance, directivity direction and all that trees whatever we talked about barriers. But now you have the source within the space, and you do not want it to go to the other space, or within the space itself you want a specific sound other sound you do not want.

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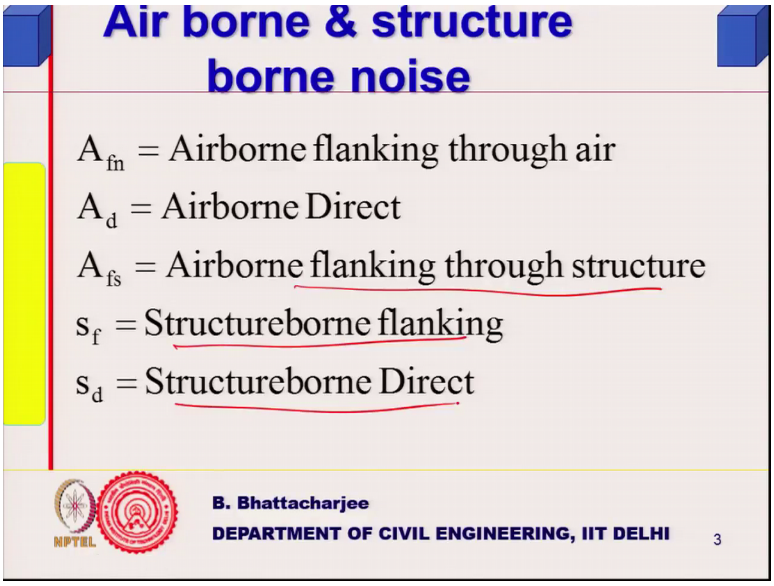

So, such kind of situations we are looking at. So, A fn is airborne flanking in this diagram, airborne direct airborne flanking through structure borne flanking structure borne direct etcetera, etcetera that was then the diagram I explained already, right.

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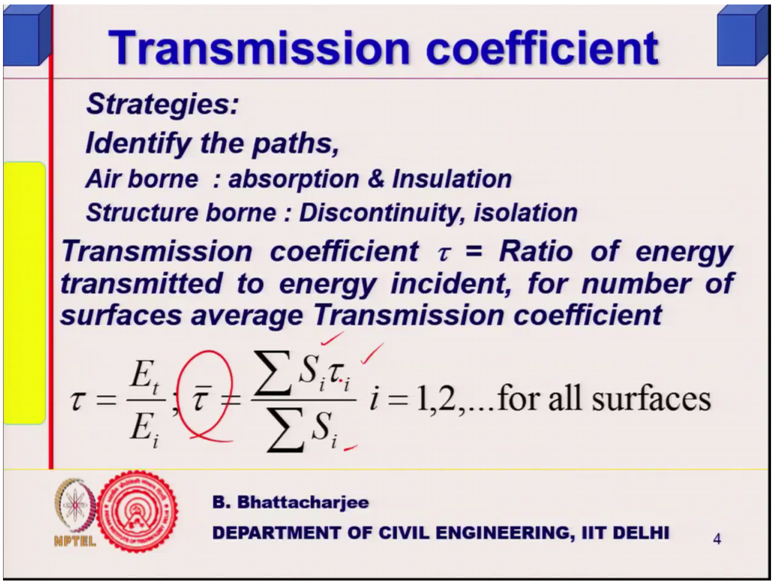

So, you have to identify the path, airborne how will you control? First you have to identify the path of course, you know the source. If the noise is airborne, then you control through absorption, and if you do not want it to go to the next room then provide insulation between the 2, I mean I am talking in qualitative terms now we will quantify them, right. Insulation related relates 2 transmissions from one room to another room, is room is insulated.

So, something from outside is not able to come. Absorption generated within an absorbed, absorption by the wall generated the source is inside the room, and I make it to get absorbed in all the walls, I am ceiling and all that. So, if I want to control the noise generated within this space that I do not want you know for example, is the machine is vibrating. And I do not want some other person might be working somewhere you know some work space is there. I do not want this noise to be too large, then I provide a lot of absorptions.

So, that reflected sound does not come back, and reinforce the direct sound, right. Reinforce the direct sound. So, I was talking to you about anechoic chamber, you remember that will only have direct sound. So, I must have a lot of absorption it should not come back all should get observed, right. Now insulation means, it should not come from the other room. So, I insulate this room it shouldn’t come from the other room. Then structure borne noise how do you do it? Structure borne noise is generated by vibration of the structure itself. So, is a essentially vibration isolation. Put the between the source and structure you put some sort of isolator mounting, and that will ensure that you do not transmit the sound.

Fortunately, the sources that we cause a structure borne noise are usually machines, right. And their frequencies are known by and large, I mean dominant frequencies will be known they are not random frequencies like, many other cases one might come across. So, these are structure borne noise. So, generally we provide either discontinued the structure cut you know separate some sort of construction joint that we ensure that noise from this side will not go to the outside right; obviously, construction joints are not provided for noise, but if required you can do that or you can put a resilient material in between which will ensure that your noise is not transmitted to the other side vibration is not transmitted isolation is the other one as I saying mounting.

So, we define in this context something called transmission coefficient. When I am talking of insulation, we talk in terms of something called transmission coefficient. You know, this is like absorption this is ratio of energy transmitted to energy incident. You know absorption was the ratio of energy absorbed divided by ratio of energy, I mean, you know ratio of energy absorbed by energy incident here we are saying ratio energy transmitted by energy incident. For number of surfaces again you can define average absorption coefficient.

So, it will be given by you know tau bar S i. So, tau bar will be given like this weighted, average surface area weighted average, like we did for absorption ok. So, it is similar and tau bar so, tau bar is the average absorption coefficient and right.

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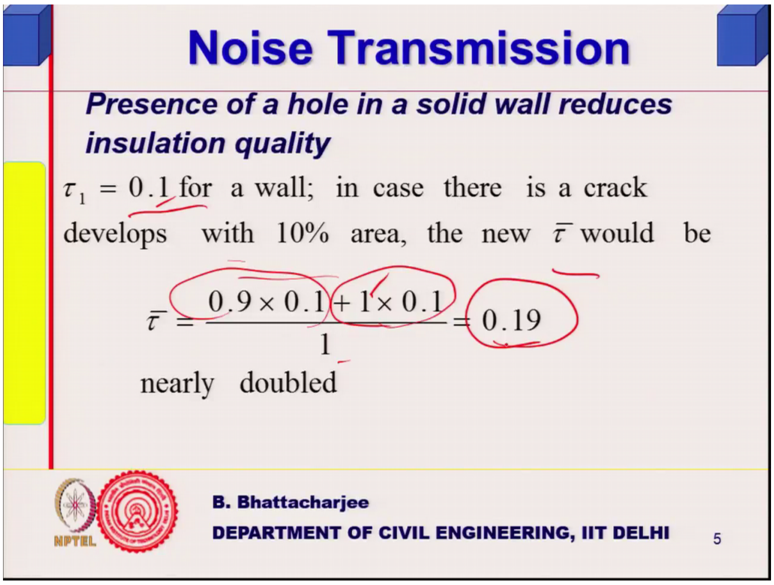

So, then just as an example if we follow this and if I have a whole what will be this transmission tau value? If I have a hole.

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Yeah it will be wall. So, you see it can disturb the whole presence of a hole in a solid wall, it can reduce the insulation quality significantly.

So, leakages should be avoided. If you are doing it insulation leakages should be avoided as much as possible; say tau 1 otherwise this 0.1 let us say, for a wall, right. And in case there is a crack developed with 10 percent area. Tau bar will be what? It was 0.1 because it was all solid. Now a crack has developed, and the area of the crack is let say 10 percent of the idea. I mean crack or hole or whatever it is some integrity loss has been there. So, it will become 0.91 into one, because 90 percent will have 0.1 steel, and 10 percent will have 1.

So, if I get 0.1 and you know it is actually, transmission has doubled. Transmission is nearly doubled. So, you know, that is what that is what I saying, same in case of barrier if you provide a gap, that would actually reduce down the delta value, dB reduction value reduce similarly here in an insulated in an wall, if you are joints are not proper, and you have left holes or there is a crack or something of that kind that can increase the transmission significantly right. So, here it was nearly doubled I took an accelerated scenario. So, this is what it is noise transmission if I look at it now.

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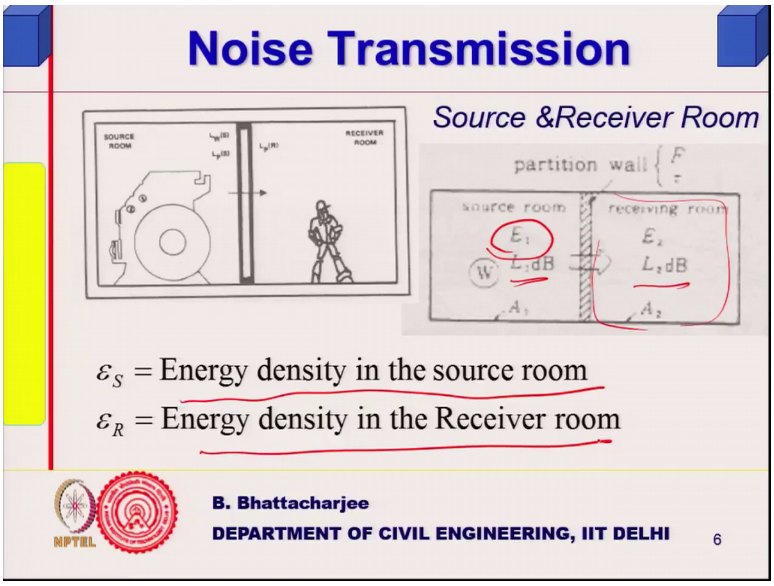

This is a source machine, this is the smart gentleman there you know, he is in the receiver room.

So, sound from here will be transmitted partition wall which should have a good insulation. So, this is you know it will be transmitted in this manner. So, we talk in terms of ok, now it is a continuous source, right and generating noise at the same level. That would be typically the case, when I am dealing with insulation. Random sound will look at slightly differently. Let us look at kind of you know fixed sound. So, machines etcetera generate fixed sound right.

So, this is a machine who generates noise, and I can assume the field here is diffused field, by and large is a diffused field, right. And here also it results in a diffused field. So, let me call this, I think I am calling it Lp Source room, or you know you can call it E 1; the energy source is L 1, this is L 2, and room area is A 1, this area is receiving room area is A 2, and I have a wall whose you know transmission value is known and area is also known to me.

So, E S let us say, let me define E S is the energy density in the source room. Energy density in the receiver room, when they are all diffused I am talking off. We are diffused, because I have you know diffuse scenario, but direct sound will also pass through. Because it will pass through directly let us separate. So, what I otherwise reverberant field is diffused by enlarge. So, that is what I can assume.

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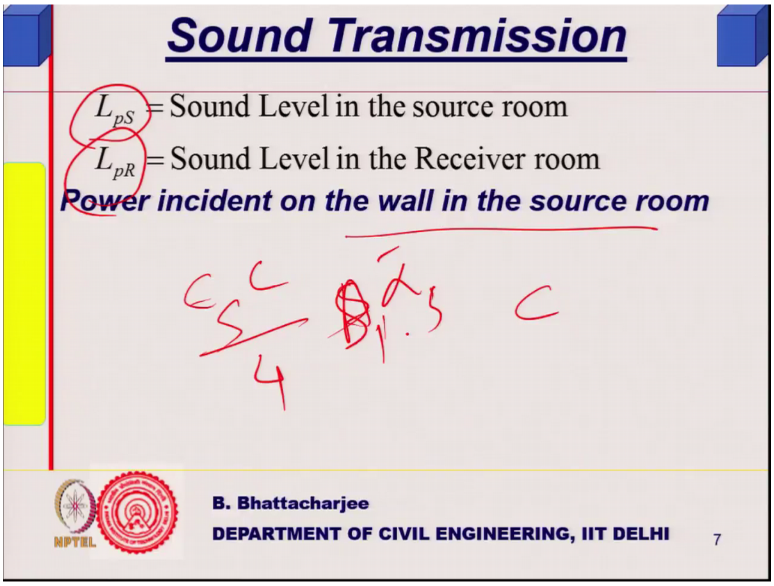

And then sound level in the source room let me call it as L pS and sound level in receiver room is L pR and say steady state scenario because my machine is not stopping, I am keeping it on.

So, you know noise level within this room and that room will remain, same they will not vary they will not vary they will remain with time invariant under that condition I am considering. If I put it off anyway everything is gone. So, it is good, but if it is on there is a situation I should see it. So, power incident onto the wall of the source room, we have already derived that earlier if you remember in terms of epsilon. That will be epsilon, source room how what is the notation you are using S r. We are calling it epsilon S epsilon s, the source room not S r. So, epsilon S is a source room power into c divided by 4 into S right.

So, this will be the amount of energy incident, power incident the wall of the source room will be given by this, right. Similarly, for the source room and receiver room this will be. So, S is now A 1 or S 1 whatever I am calling, it S is the notation I have used for. And that will be for the for the second room it will be epsilon r c by 4 into area of that room internal area of that room, because that is what we have taken and we are calling it alpha bar remember. We are calling that also as alpha bar of the source room and alpha bar of the receiving room, right?

So, this I can find out. So, power incident I can find out. Power incident I can find out for the time being let us find it out, that only power incident wall of the source room.

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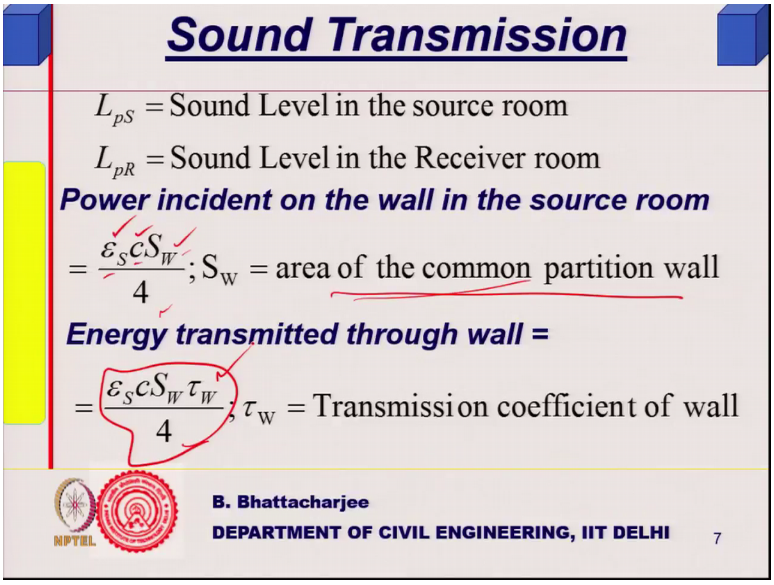

So, in the source room epsilon S c by 4 S w is an area of the on the common partition wall this is energy coming. So, common partition wall this is the energy that will be coming, right. And this will go to the next room multiplied by tau. This is incident upon that wall multiplied by tau that will go to the receiving room. But receiving room also whatever comes in a part of it will be absorbed.

So, this is coming into the receiving room. And it contributes to the receiving room level plus something is absorbed. So, in a steady situation actually I can equate. So, energy transmitted through the wall is simply this that is what we understand very easily because epsilon S c S w by 4 into tau is what will be transmitted. That is how we define tau energy transmitted divided by energy incident so, multiplied by tau that fraction. So, that is a transmission coefficient to the wall that will be transmitted and in steady condition energy entering into the receiving room must be absorbed in the all surfaces, right.

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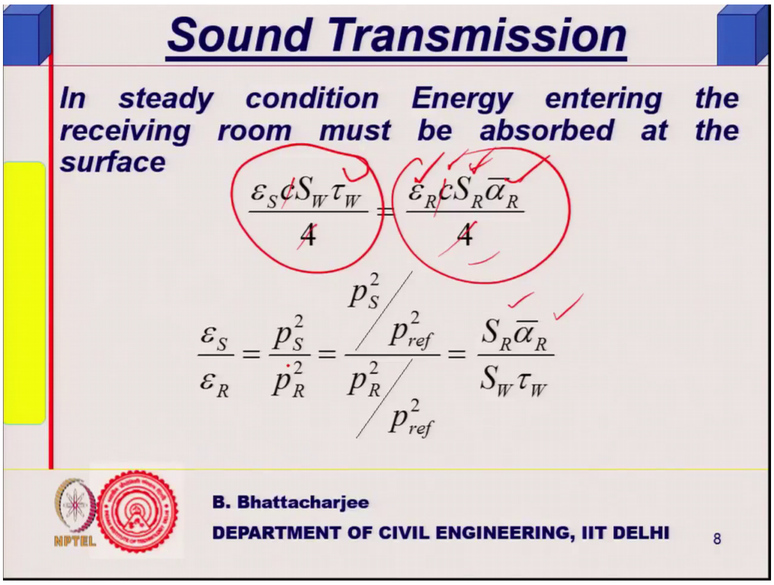

Because whatever is entering because the condition is steady. So, we know how much is the energy absorbed in the surfaces that is actually the receiving room energy, if density if it is there c is the velocity. S r stands for surface area of all the surfaces in the receiving room. Because absorption will occur through all the surfaces including the partition; including the partition, right. And average absorption coefficients of you know receiver room by 4, right. This is this fine.

This; whatever it is transmitted, and that is lost through all the surface part of it actually also get absorbed on the wall which means that it might come back to this room also. So, if I do this, then I can get ratio of S e by e r; which will be you know I can write S S r by alpha r rest all will cancel out, this will cancel out this will cancel out this will cancel out this will cancel out. So, E S by E R will be S bar alpha bar by 4. And this I can write, because we said that energy density is a function of p a square I c by 4.

So, rest all things remaining. So, it should be p rms of course, I am talking of p r square. So, you divide by p reference square, take 10 log of both sides, then you will get the decimal level change. So, 10 log of both sides you get something like this. And you get you know, this is nothing but what is this 10 log of this minus 10 log of you know.

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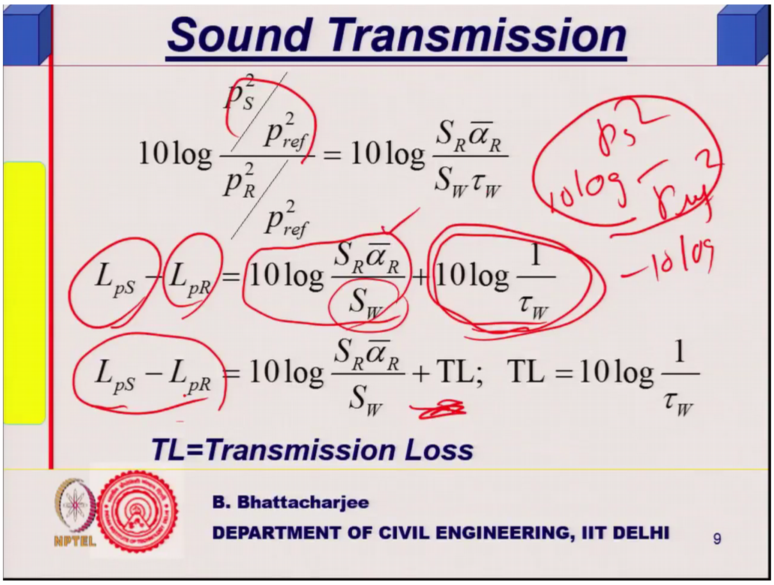

This can be written as 10 log of p S square divided by p reference square, minus 10 log of p r square divided by. So, what is this actually? This is nothing but level in the source room, minus the level in the receiving room. And this one I can do 2 things I can simply separate this out, 10 log 1 by tau this part I have separated out. And this part is very much there 10 log, surface area of the receiving room all surfaces. Multiplied by average absorption coefficient of the receiving room; divided by the area of the wall separating the 2 rooms, right. And this is 10 log.

Now, this we define as transmission loss of the wall. 10 log 1 by tau of any wall we call it transmission loss. So, we call it transmission loss, did I define it earlier? I did not define, perhaps transmission loss TL transmission loss I think somewhere I might have defined it TL is transmission loss. So, transmission loss is 10 log 1 by tau for anyone. Transmission log is 10 log 1 by tau for any wall. And then L pS though rather delta dB reduction in the dB from the source room to the adjacent room is given by 10 log S r surfaces of the receiving room and absorption, coefficient of the receiving room average absorption.

In other words, total absorption of the receiving room, divided by the area of the wall plus transmission loss. So, transmission higher the transmission loss; obviously, this will be more, but also receiving room absorption should be as low as possible. I mean as you know as high as possible sorry as high as possible so that it can absorb good lot of it. So, you know adjacent room noise you can control right. So, this is how I can control.

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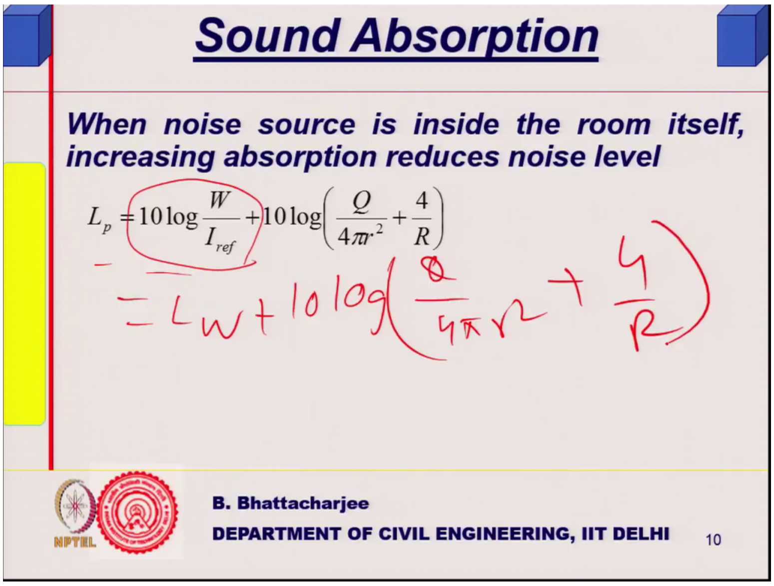

So, when noise source is inside the room itself, increase the absorption. If it is in the next room, increase the transmission loss between the 2 right. So, we come back to this right. So, the basically transmission loss between 2 walls separating or partition wall separating 2 adjacent room, if it is high you will have noise control. Same thing goes into a periphery boundary also. It is you know envelop. So, if you have outside noise, even do not want it to come put insulation put insulation.

So, that transmission loss you know, of the periphery ceiling etcetera will be low, right. And how it how in what properties of the wall transmission loss depends we look into that later on right. So, this is what it is. When noise sources inside the room itself at so far, I talked of noise source in the next room. And if the noise source is inside the room, itself then let us see how it goes, right. You see L p is equals to 10 log you remember this L w plus 10 log of q by 4 pi r square, plus 4 by r.

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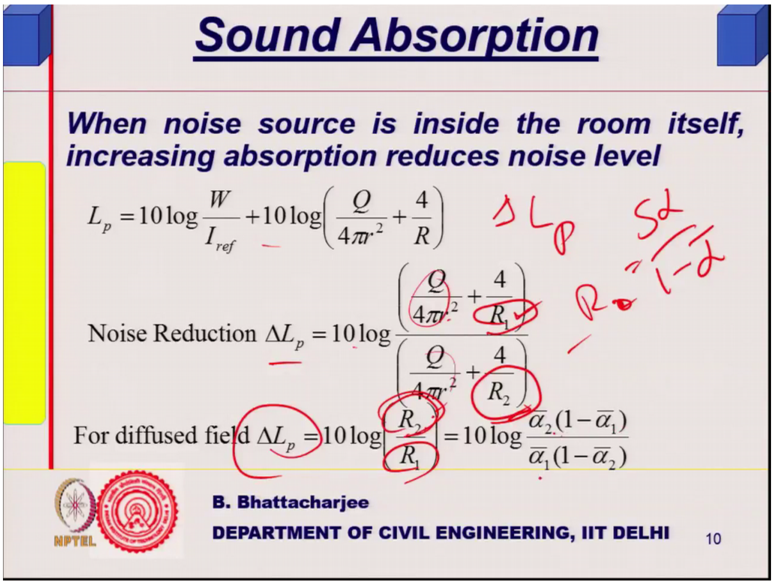

And if I just forget about the direct sound, you know that is what it is delta p delta L p will be this term, and you will go out only remaining will be this.

So, delta L p for 2 cases room absorptions let us say is R 1, other one is R 2 at any distance is same, then this will be given by this formula, right. Because this minus R 1 minus R 2. So, this will be delta L p. In other words, it is this factor which will control the noise level. Because this you cannot do much your distances are fixed directivity is fixed. So, this will control the noise level if the sources within you have a machine in some corner and some workstation or something some working place somewhere. In the end and you do not want too much of a noise to be there. Like earlier good old days typewriting machine.

So, they generate noise, and you do not want that noise to be disturbing the others. So, you got to put a lot of absorbers in the room accordingly of course. So, R 1 by R 2 has got a role there. And for diffused field fully diffused field 10 log you know this term I just omit I will get R 2 by R 1. So, if you increase R 2 delta L p will increase with R 2 by R 1. And what was R 2? Room constant or R, R was S alpha bar by 1 minus alpha bar right. So, if R 1 by R 2 ratios will be simply alpha 2 1 minus alpha bar alpha 1 bar alpha 1 right. So, this is what it is.

So, you know following from following from the same formula. So, that is how it is. That is how it is. You know this direct sound no q divided by 4 pi r square. So, distance from the source. So, for the same distance it is you know and if we take only diffused field which is far away from the source, then this will be the scenario it is. I should obviously, plan it to keep the source away from my wherever I am working.

So, R i can reduce it down, and R i can increase sorry R i can increase, and in the diffused area where the field is diffused beyond the room radius, beyond the room radius, increase absorption will always ensure that the sound is less, sound is less you know finally, you know diffuse sound field will be less. So, that is the point. So, you can actually in design you can use this.

Now, we can have specific absorbers, because frequency of the source will be known in such situation also. Frequencies of you know for example, I said typewriter. So, we know their frequency or some other source machine or similar sort of thing, whose frequency will be known to me. So, in my frequency is known, then I can have absorbers which has got a absorption capacity corresponding to those frequencies themselves, right? Because absorption is also a function of frequency, absorption is also a function of frequency, right.

After all the types of absorbers if you see, they are either as I said if I have a porous material, porous materials their pores, then you know there are frictional losses, and the sound reflected sound will be less. It cannot come back. You know, if you are a poly surface it will reflect high. Porous surface is will not reflects. So, absorption right and, but it will also depend upon frequency. Size of the pores related to frequency and things like that will depend upon frequency. At all frequencies they do not show similar absorption capability.

So, it is a function of frequency, and we shall see this characteristic. So, I can select accordingly type of absorber, I recur depending upon my source if I am doing it. So, there are 3 4 types of absorber, there are 3 4 types of absorber, right.

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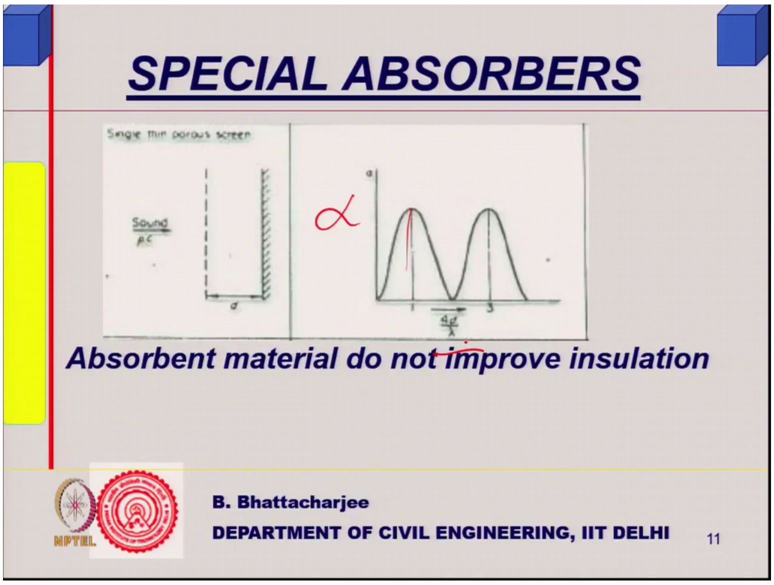

For example, screen, just a screen. This is the backing there is a gap put a screen. Put a screen with some holes, then you get this sort of absorption where this is alpha value this frequency, right. And at certain frequencies, you will have peak absorption; certain other frequencies. So, mechanism is either by vibration, you know it vibrates. So, some energy is lost or through the pores there are frictional loss heat generated. This is a kind of mechanism, and sometimes in within the holes, there can be resonant. Size of the hole is such that it corresponds to the you know the resonance within the hole itself, in such cases sound will not come back again.

So, there are 3 4 types of absorbers. Like, there are something called a porous screen. I will just do it again I will come back to this in the next class as well, right. And remember that they do not have improved the not necessarily improve the insulation quality. You must distinguish between insulation and absorption, now one good absorber not necessarily a good insulator. Insulation will depend upon the whole wall. Backing and everything put together. While absorption is a largely surface type of property, right? Supposing I have brickwork and is very polished. It will have low absorption, but when it comes to transmission, well it will be as good as not so polished surface.

So, there you must distinguish between the 2. So, absorbent do not improve insulation not necessarily they do. This I will come back again.

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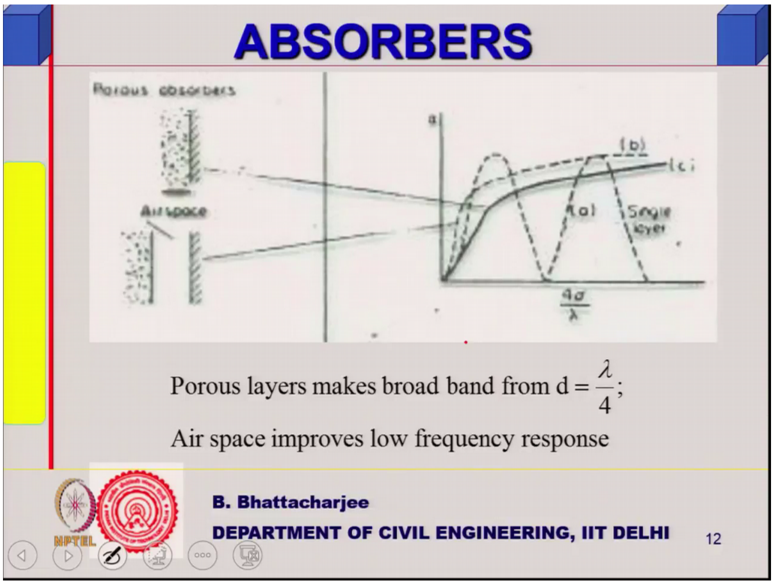

And there are other came out of absorber something like you put a porous material onto the backing without gap or with gap. The characteristics absorption characteristics with frequency start changing, right. We will see that again in that as I said in the next class.

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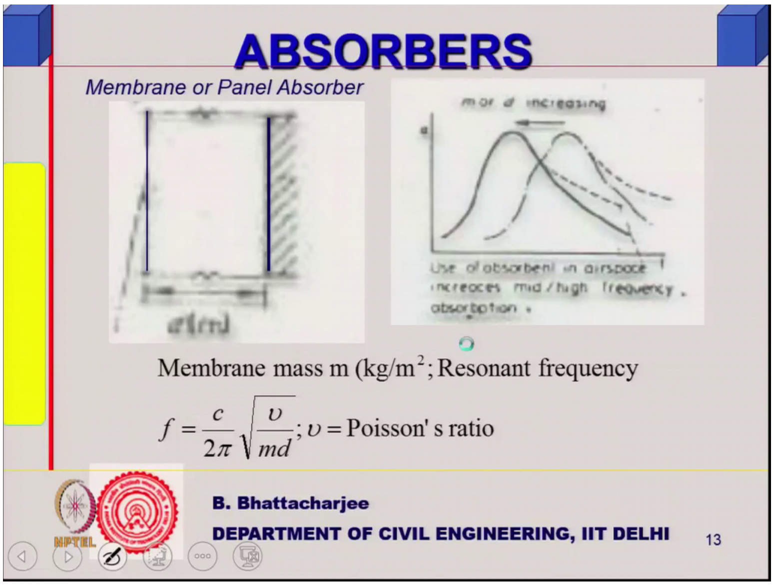

Then there is something called a membrane absorber. So, this was first was a screen, porous screen, and then porous absorber on a backing. Then you have got membrane absorber just put a plate membrane, a plywood sheet or something of that kind.

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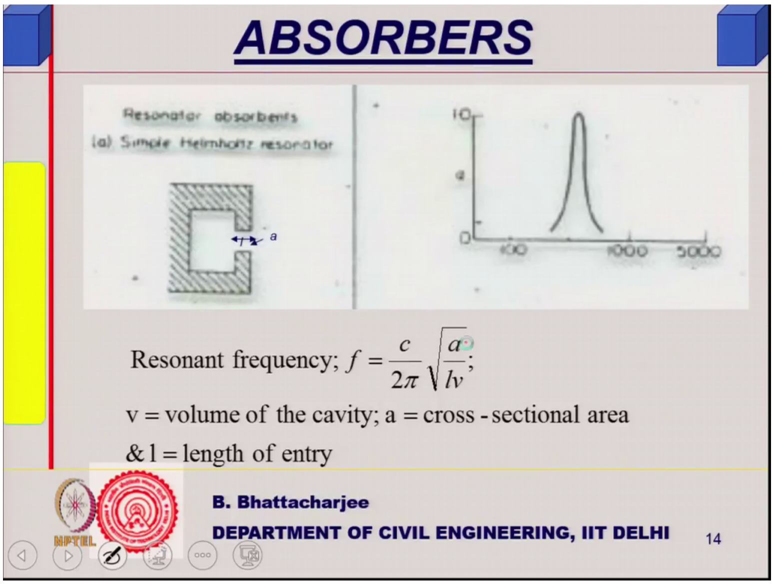

And then you can have something called a Helmholtz resonator, cavity resonator, cavity resonator. And you know modification of this we will have something like this where I have got perforated holes, it is like medieval.

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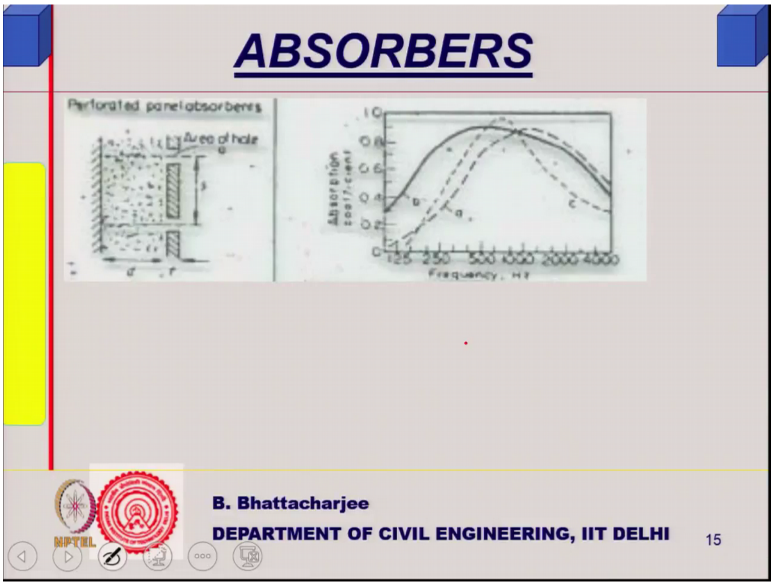

So, they are you know absorption kept characteristics changes with the frequency. So, if I was source machine or something, and I know that frequency characteristic, frequency of the frequency of the source, I can choose the absorber accordingly. Normally you know people just put it anything they like in, you know like it is it is not the science is not that much used in some or other in building it is not that much used actually. But industrial situation or such office situation if you know the principle you can choose accordingly. You can choose accordingly just put any absorber is not the best thing to do, better thing would be to do it accordingly.

So, we look into this in the next class. I think will break here. So, we are look into this absorbers the frequency at which they actually absorb maximum, will not go into details you can have mathematical modeling of this one we are not going to do that.

So, that part is not there, but overall purpose this itself will be good enough. So, any more question?