Architectural Acoustics
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Lecture – 31
Air Borne Sound Transmission

Good morning students. This is the 7th week of our Architectural Acoustics course on NPTEL online certification program. Welcome you all. Till the last week that is in the still the 6th week perhaps we have now have a kind of a foundation on various spaces which required the acoustical intervention, the architectural acoustics intervention. So, in this week, the 7th week we will going to discuss about some kind of other type of transmission other type of behavior of the sound in the indoor.

So, the 31st lecture today is on the air borne sound transmission one and we will have serious series of this airborne sound transmission lectures like the 1 2 and 3. So, I have separated the typical the fundamentals of the airborne sound transmission in 3 different the lecture models. So, in the first as we like to do is that; let us see that what are the learning objective of this lecture.

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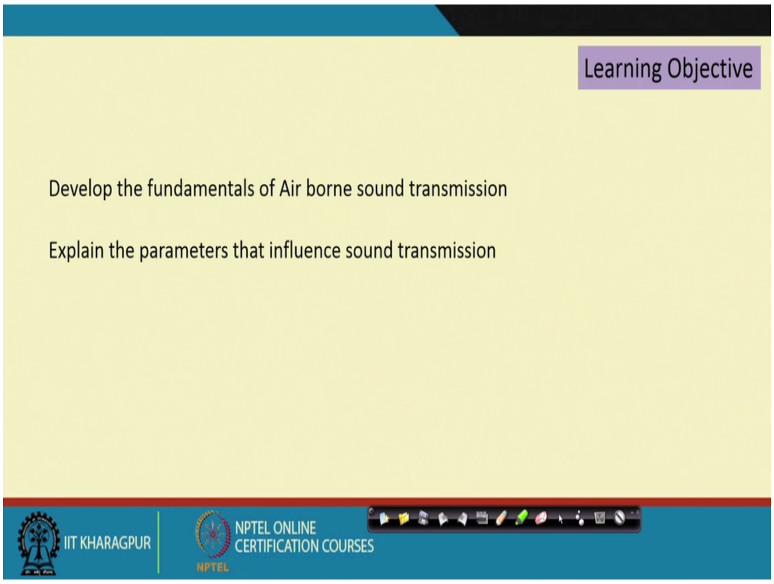

So, let us first developed some kind of the fundamental which are based on the air borne sound transmission, and we will explain the parameters that influence the transmission of the sound. If you remember in the very early lectures in the in the second week we talk about some, some of the various physical the phenomenon of the interior the acoustics in the interior. So, one of that is reflection, than other absorption, diffusions and the transmission

So, the transmission of the sound we will discuss today and transmission of the sound is having 2 typical types.

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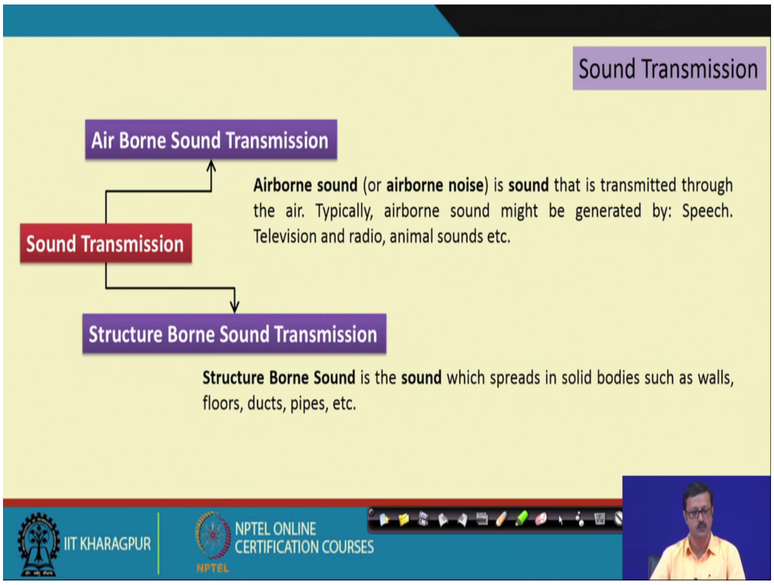

The first one is called the air born sound transmission, which is actually the propagation of the sound were born noise, which propagate from 1 place to other thought air. And that is something like a noise from some speech from one room to the other noise from the televisions, radio, music systems maybe some kind of the animal sound, some kind of the sound from the children in a classroom.

And the next room is suppose, there is library in some kind of a things of the transmission from one noisy space to the other space varying; I like to have a kind of a. The sensitivity of the sound is little bit more. The other type of sound transmission is called structure borne sound transmission. In that; the sound travels the study of the sound that travels not in the air, but through the some solid bodies has to be studied, such solid body is a wall, floor or may be the duct, pipe or any kind of metallic or nonmetallic surfaces that is actually enclosed some space.

So, in this week the last 2 lecture is dedicated for the structure borne sound transmission. And the first 3 the 31st, 32nd and 33rd lecture is based on the airborne sound transmission.

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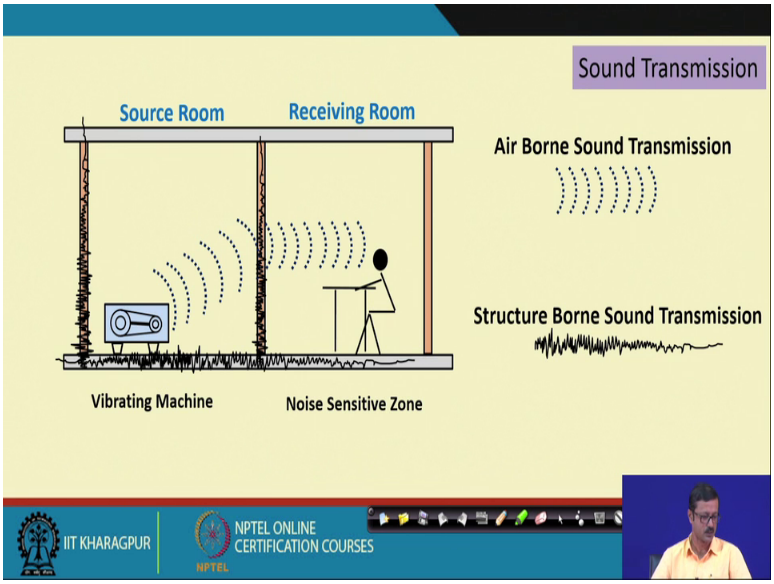

So, we will let us see with this small sketch that the problem. Let us first identify the problem, what happened is that? There is a source room; source room is that where the sound source is placed it may be a vibrating machine. It may be somebody speaking loudly or some noisy room.

And then the next to that there is another room, which is noise sensitive zone and that is the receiving room. So, we have to see the how the sound is transmitted, and how this transmission is the reduced I mean; the amount of transmission has to be reduced that is the fundamental the question for any kind of a design. So, there is a noise transmission like that, which through the air from a vibrating machine to the next room. And due to the partition wall and due to the some property of the partition wall to be reduce, reduce the amount of sound or the level of sound will be reduced.

And there can be a kind of a vibration propagation of the sound or a structure borne sound also will propagate because machine is vibrating machine. So, suppose there is some people in the source room and creating some kind of a speech or any kind of a noise or any kind of a musical instrument playing, some musical instrument or so. There probably the structure bound sound is less, and the maximizing the airborne sound is the maximum in that particular level, if it is a vibrating machine; so both are probably the equal the level or the equal potential.

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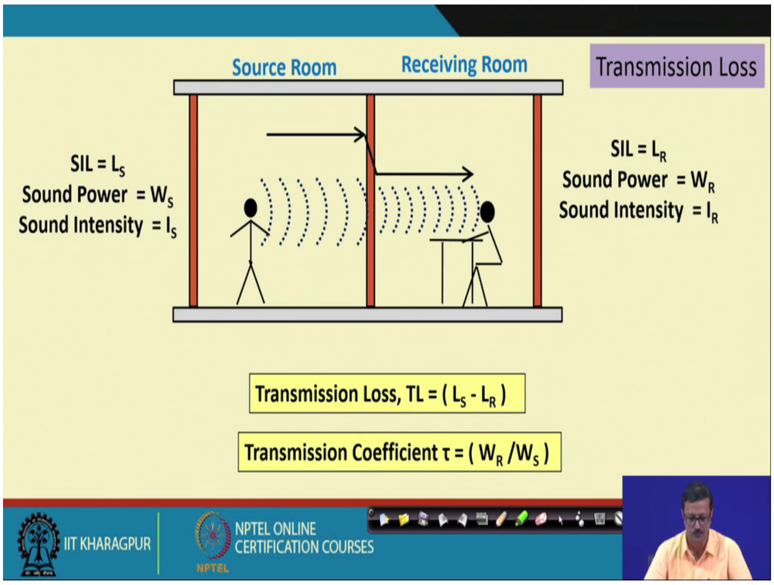

So, let us find out the physical property of a this partition wall, which is in the central line or central portion, which is dividing this receiving and the source room. Let us suppose in the S I L the sound intensity level in the source room is L S and which is actually comes from the sound intensity level I S or may be the sound power of W S. And that sound translated or the transmitted to the next room; receiving room and suppose in the receiving room the sound power is W R or the sound intensity is I R or the equivalent sound intensity level of is L R.

So, by virtue of the definition the transmission loss is a difference between the sound intensity level between the 2 room that is, the source minus the receiving room sound intensity level. And sound transmission coefficient is defined as the ratio between the sound power in the receiving room, divided by the sound power in the source room. So, this ratio will definitely be less than 1 and it will be very, very small if the partition wall is behaving very well, whereas, the transmission loss will be higher and that will be the most beneficial for our design designer case.

So, the difference between the level of sound in the source room and the receiving room has to be as high as possible.

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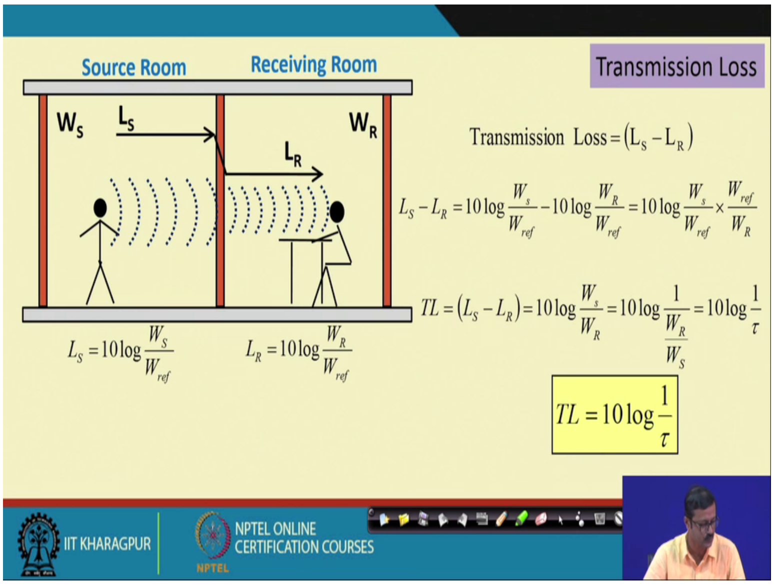

So, let us see what is the relation between these 2 this transmission loss and the transmission coefficient.

So, as we know the we can translate this L S that is, the sound intensity level in the source room as 10 log W S by W reference where W's are the wattage or the sound power in the source room. And similarly we can write say the same for the L R the S I L for the receiving room. And the transmission loss is L S minus L R. So, just put the values of L S and L R from this particular point L R and L S. So, finally, we come down to mathematically we can say; and if we just rearrange all those W S and W R. The transmission loss is 10 log 1 upon a tau the tau is your transmission coefficient or coefficient of the transmission, sound transmission.

So, this is a or one of the important equation, where T L the transmission loss and the transmission coefficient are when equating with a kind of a equation mathematical expression.

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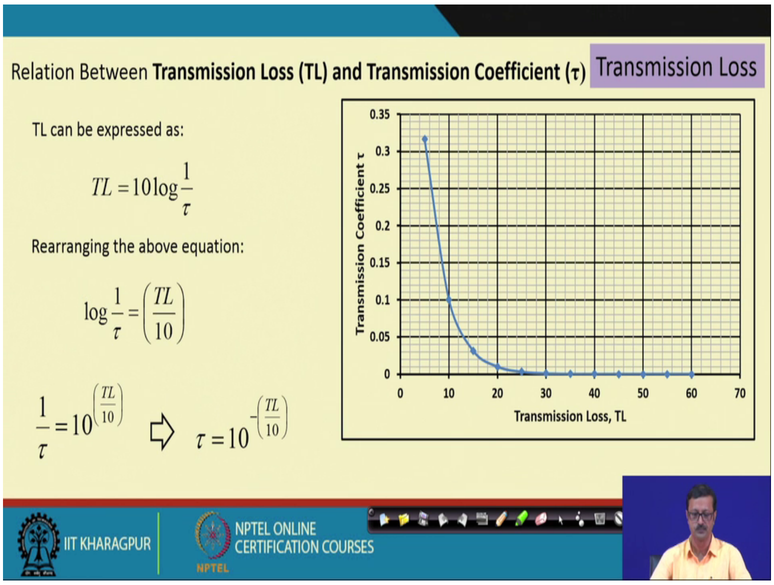

Where the relation between as I told you this T L and is equal to 10 log 1 upon tau. We can again re write and reverse this equation like. And finally, we can say that; the tau is nothing but the 10 to the power minus T L by 10. So, suppose you are getting a transmission loss of 20 dB, because the transmission loss having unit of dB, because it is the difference between sound level from 1 place to another.

So, if it is 20 dB so I can say the transmission coefficient is 10 to the power minus 2 because T L by 10 is 2 and 10 to the power minus 2. So, and this tau or the transmission coefficient is a unit less quantity. So, you can plot a graph. So, in x axis if I say the T L, and in y axis if it is the tau then we can say that the graph will be kind of exponentially decreasing kind of a graph. And the values of T L are actually very, very less if you attend some higher amount of T L. If you go to the right hand side to the x axis, the higher amount of T L gives you almost negligible amount of power it is a very the less in that the ratio is very, very less.

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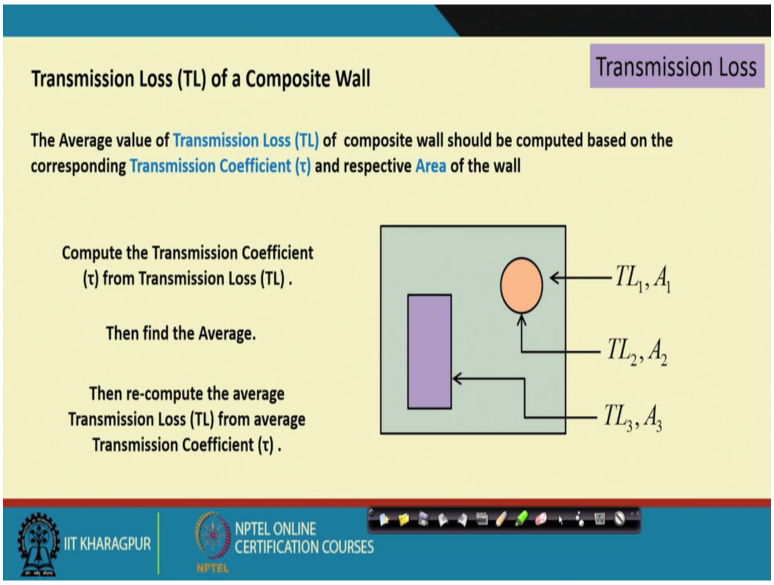

Now, how actually I will compute the a partition wall T L the composite, composite wall the partition wall is a composite wall. Suppose because any wall may not be of the uniform material and the uniform thickness and all those kind of a thing. So, it may be it may have a window, it may have a door, it may have some differential material of thickness and the density and the property.

So, if we actually want to find out the what is the average value of T L ; so it cannot actually directly get the average by T L plus T L T L 1 plus T L 2 by 2 or something like that. We have to convert T L into the tau that is, the transmission coefficient, why, because the T L expression is a dB expression or the decibel expression or the logarithmic expression. So, getting the average 2 logarithmic scale cannot be add together. So, to convert the T L to A, it is corresponding tau value and then the 2 ratios can be added together, because the ratios of power can be added together instead of the logarithmic of the values of the ratio.

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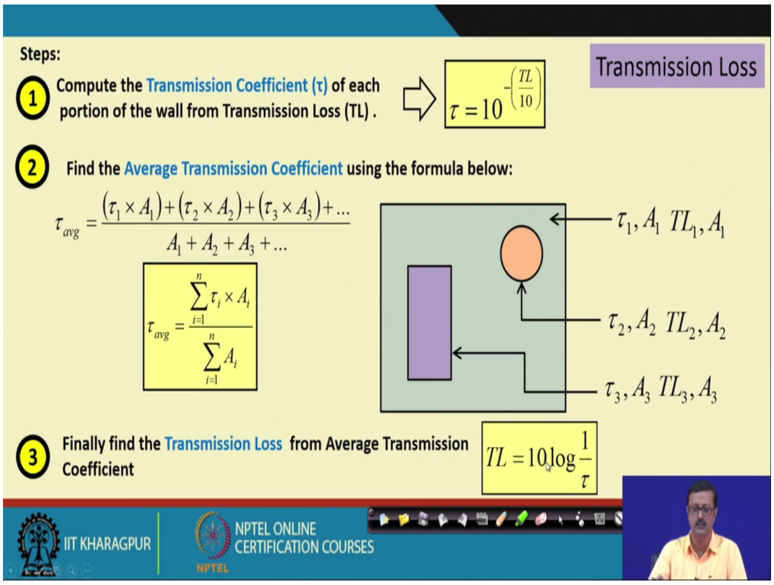

So, in the step one: we will actually find out transmission coefficient tau from the each proportion portion of that wall. Then suppose it has a suppose I have sketch a particular compound or the wall or composite wall, which is having a door and a window circular window of values of the door, the total, the actual partition wall is having the area a one and T L 1 is the transmission loss and some of the areas at A 2 and T L 2 A 3 T L 3 like that.

So, you convert that all what will be the corresponding value of tau 1 corresponding value of tau 1, for the corresponding value of tau 2 from the T L 2 using this equation; and then add all those tau values the transmission coefficient values with it is corresponding area. So, tau 1 will be multiplied with A 1, tau 2 will be multiplied with A 2 and added like that and divided by the whole area so this is the mathematical representation of that.

And after you get the tau average, then your work is still not completed you have to go for the third step and you use the reverse equation; and find out this what will be the T L average just putting the value of tau average over here and get the value of T L average.

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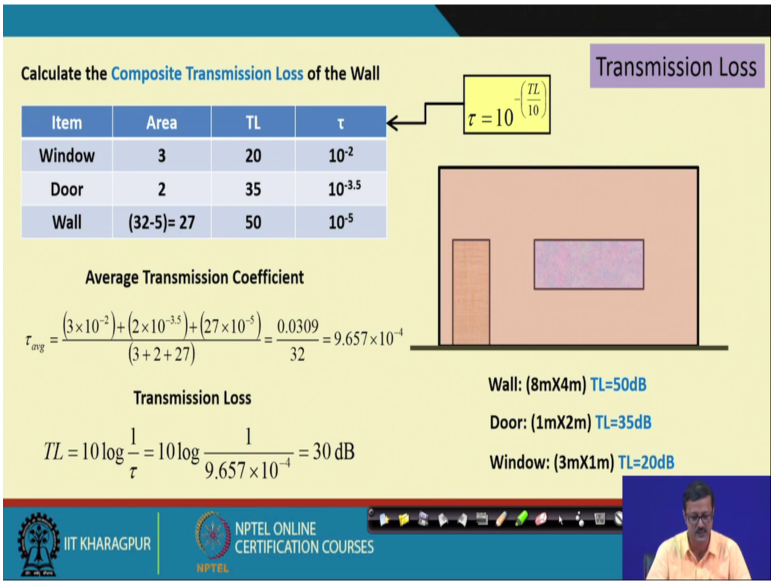

So, we will take a small small very small problem. So, I have partition wall having one window one door the dimensions and corresponding T L values are given over here this 32, 35 dB T L is for the door, 20 dB is for the window and wall is having a wonderful transmission loss value that is 50 db. All the dimensions are given this 8 meter by 4 meter is overall dimension of this wall and those are the individual dimensions of the window.

So, what have to do is; if you remember the last power point slide, the first step, what I did is that; I calculate the individual areas. I have those T L value and I convert those T L value to the tau value with this equation. And then I have to multiply this with this, corresponding tau value with the corresponding area value. And divided by the total area that is your 32 and then I got the tau average as 9.67 657 10 to the power minus 4 it is very small very, very small value.

And then I got the transmission loss value by reciprocating that with that equation of T L equal to 10 log 1 upon tau. So, this tau is now average tau which is this, so this is 30 degree. So, I just cannot multiply this 20 and 3 35 and 2 and 50 and 27 then get the average, because the logarithmic cases this cannot be the arithmetic sum cannot be functional in that mathematically that cannot actually happening. So, you have to transfer that with tau.

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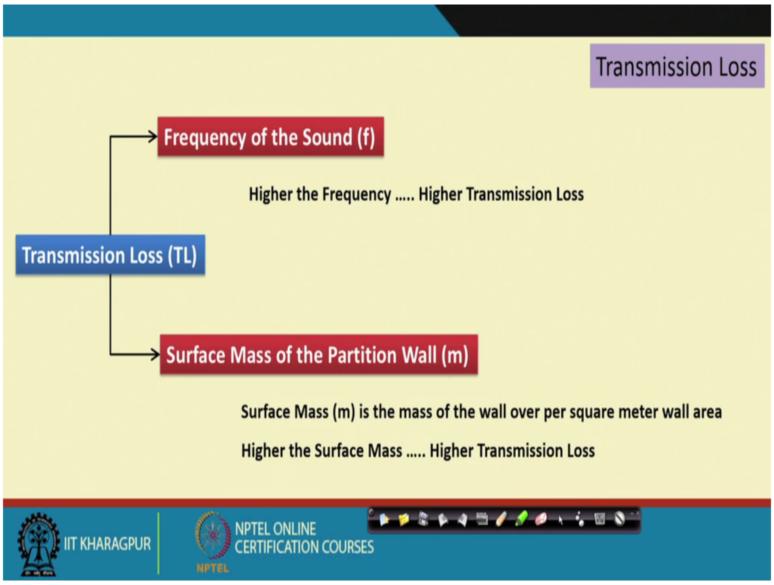

Now, let us see that we have discussed that tau and all those T Ls. And all the what are the different the property of a partition wall, and the how the T L is influenced by some physical parameter there are many physical parameters and out of that many physical parameters 2 or more important, 2 or a really going to have a play vital role to find I mean for that the T L value, the transmission loss value of any partition wall. The 1 is the frequency of the sound if the sound frequency is higher, transmission loss is also higher it is a kind of a proportionality, in nature proportional in nature.

Another one important thing is that the surface mass of the partition wall, what is surface mass of the partition wall? It is a per square meter of the area of the wall, what is the mass of the particular wall. So, if you can find out the density of material and if you just multiply with thickness of the wall you can find out the surface mass of the wall, why surface mass of the wall is important, because the transmission loss is actually going to occur because of the loss of sound energy by vibrating the partition wall.

So, if the surface mass per square meter of the surface the mass is increased, it will require to higher amount of energy to vibrate and then pass through and to transmit to the next room. So, it is very common or if it is very general that; if the surface mass is increased higher the surface mass is the transmission loss also will be higher.

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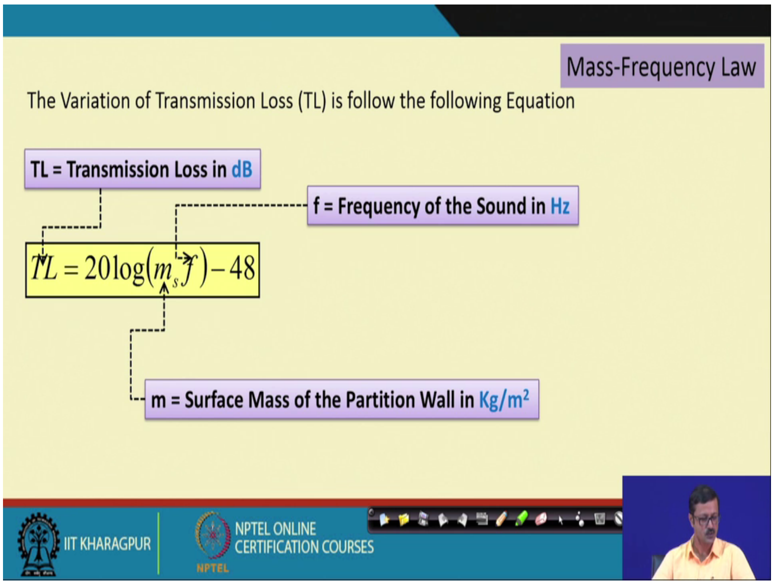

So, there is a kind of equation there is a kind of a the relation between this the surface mass and the frequency of the sound and the T L; has stated as T L is the transmission loss in dB is equal to 20 log m s f minus 48, where m s is the m s is the surface mass of the partition wall in kg per meter square, and f is the frequency of the sound in hertz. And this is equation comes from lot of scientific testing and all so it is a empirical kind of equation.

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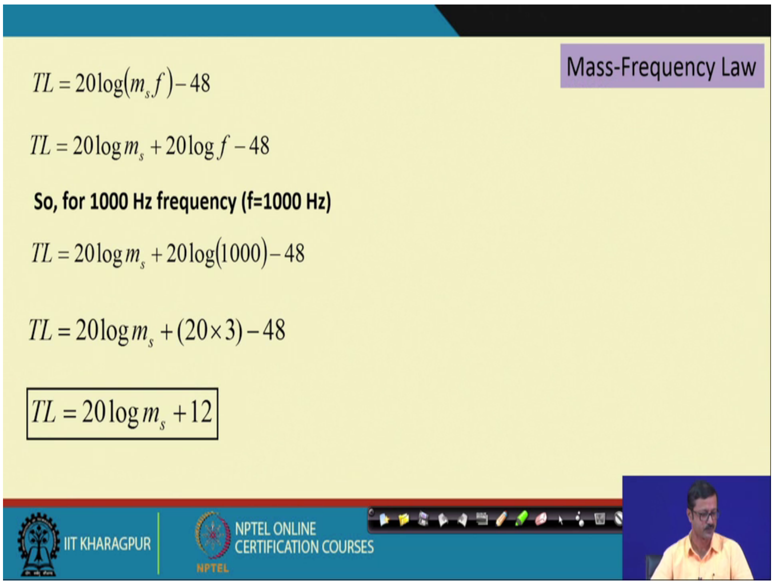

And with this equation holds good holds goods for the middle band of frequency.

So now let us suppose, if we have a the frequency is suppose I fix the frequency as 1000 hertz then, I will re write this equation; and I found the equation is like this, if you just follow the steps and like I find I can say that; this equation. And this f is replaced by 1000 and then I will get the T L equal to 20 log m s plus 12, where this equation can be hold or used to see the variation of the T L based on the surface mass of course, the frequency is tentatively in the middle zone of 1000 hertz, 1000 hertz is tentatively taken as a kind of a the average frequency for any kind of a testing or so.

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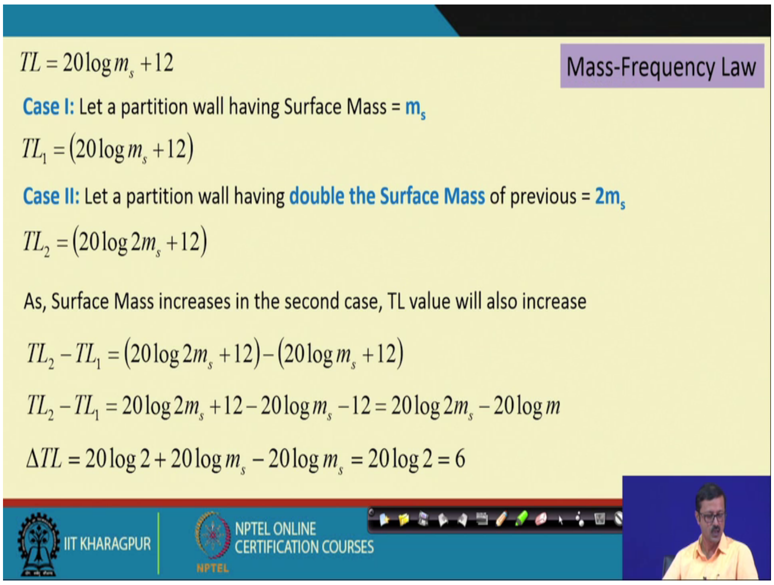

So, let us take a case 1 and case 2, let us see the how this can be interpreted this particular equation. So, if in the case 1, I have I may having partition wall; whose surface mass is ms. So, this is the in that case, the T L wall for the case one this will be my total transmission loss.Iin case 2 what I did is that I double the surface mass.

So, I will stick another similar kind of the partition wall and stitched together glued together and then the total surface mass is just doubled and by virtue of that my equation T L 2 that is, the transmission loss for the case 2 will be 20 log twice of m s plus 12. Now definitely this T L 2 will be higher than T L 1, because this is double of the mass. You required more energy to require to be penetrate or transmit from one source room to the receiving room.

So, let us see what how much is the difference between this 2. So, T L 2 minus T L 1 is this minus this 2. So, if you just open it up and then if you just find out what how the logarithmic operations all the logarithmic operations then finally, we found out is the delta T L the change in transmission level is nothing but, 20 log 2 or 6 or 6 db. So, by doubling of the mass you can increase the transmission loss by only 6 dB only 6 dB.

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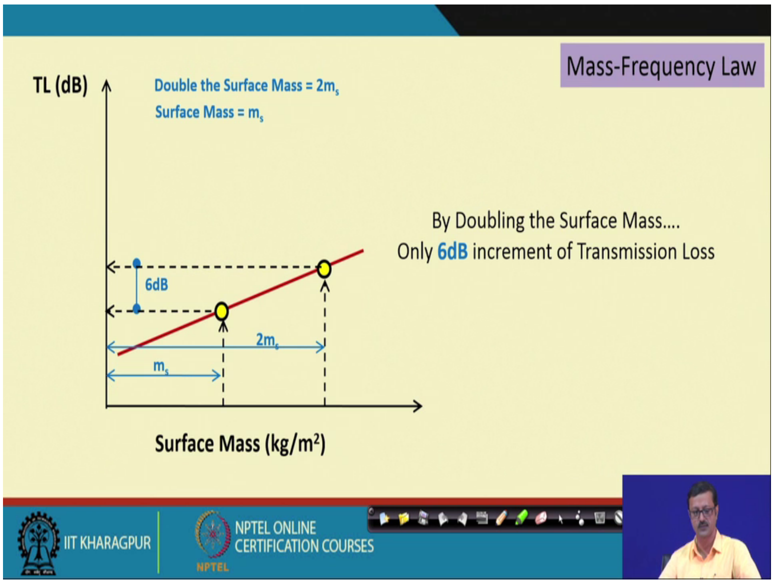

So this is sum transmission loss for the surface mass equal to m s it is doubled. So, it is increased by 6 db. So, it will follow a kind of a straight manner equation like that of course, this is a logarithmic kind of equation surface mass logarithmic of the T L values or so.

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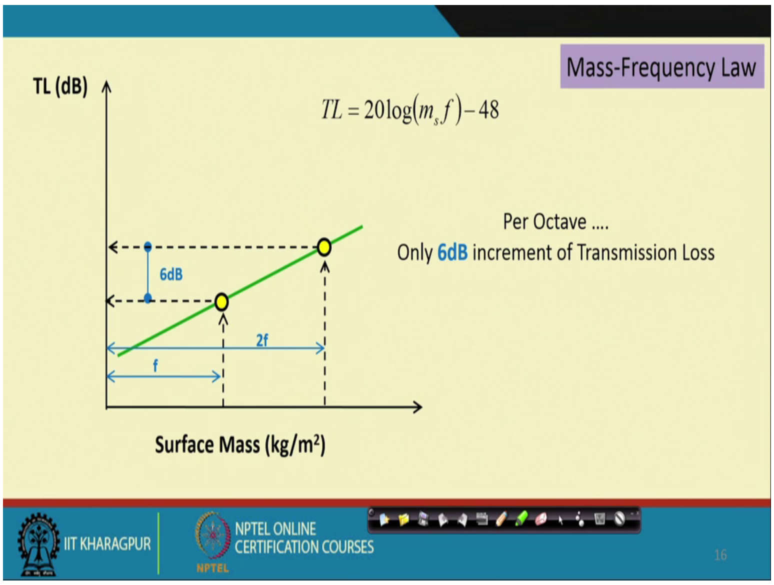

Very similarly, with this equation I can say because the nature of equation is very similar logarithmic is very similar. And if I constant I can make the surface mass constant, there is no change in the thickness of the partition wall. And I increase the frequency by double. So, it is octave kind of a thing so, f and there is a 2 f. And very similarly I can say it is also going to be a raise of 6 dB of sound, transmission sound loss if we increase the frequency from one to the double. So, the octave per octave it is 6 dB higher and increment of the transmission loss.

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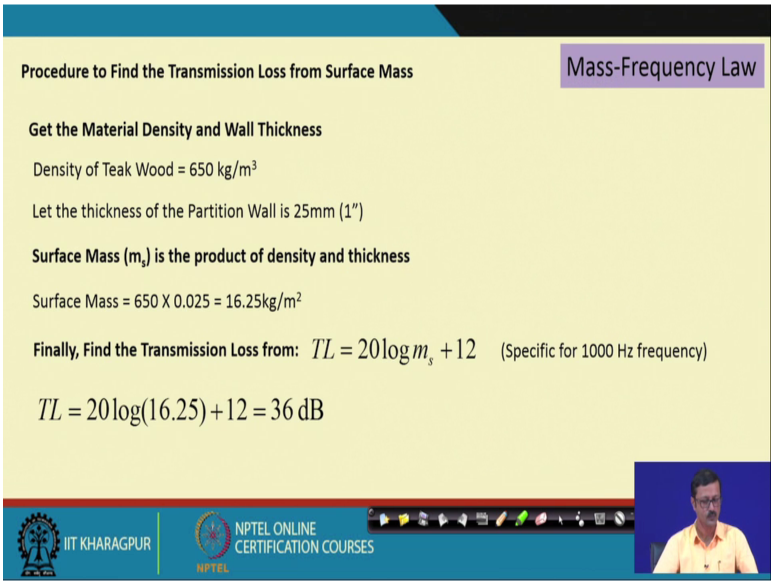

So, let us find out a kind of with a small intervention or small problem that, how this particular transmission loss can be calculate. So, let suppose a teakwood, there is a teakwood wall and the density of teakwood as I know it is 650 k g per meter cube almost, and let us thickness of the partition it is almost about 1 inch that is 25 mm. So, if I multiply this density and this particular mm in of course, in the meter scale meter unit.

Then I will find I can say that this particular 1-inch teak teakwood partition wall is having a surface mass of 16.25 kg per meter square. And if I assume that it is for 100 sorry 1000 frequency sound, then I can use this equation which I have told before, and I replace the ms by 16.25 and by calculation of this 10, 20 log 16.25 plus 12 is 36 dB

So, at the end I may say that a 1-inch-thick partition wall of teakwood can shield or can protect almost about 36 dB sound

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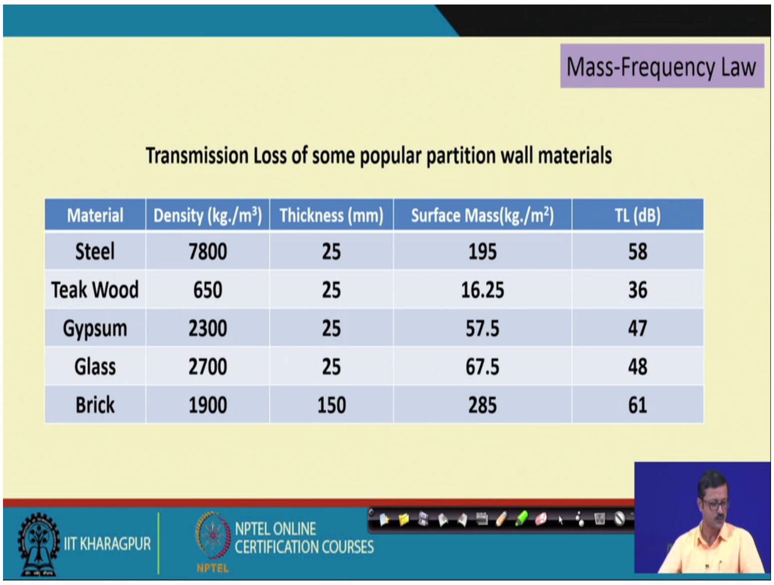

Material	Density (kg./m³)	Thickness (mm)	Surface Mass(kg./m²)	TL (dB)
Steel	7800	25	195	58
Teak Wood	650	25	16.25	36
Gypsum	2300	25	57.5	47
Glass	2700	25	67.5	48
Brick	1900	150	285	61

So, there are some typical density chart, some for this some material is usually used for some partition wall steel, partition wall or the Teak Wood, Gypsum and all. And I have kept the thickness of the first 4 as 25 mm 1 inch.

And for the brick wall it is not possible to construct to be Brick wall of 1 inch. So, I have kept 10 inch or sorry 5 inch, 6 inch actually 150 mm is 6 inch. So, correspondingly surface mass has been calculated and with that logarithmic formula this T L values are calculated from that. Of course, this T L values are calculated for using the that formula and having keeping the frequency is one thousand hertz.

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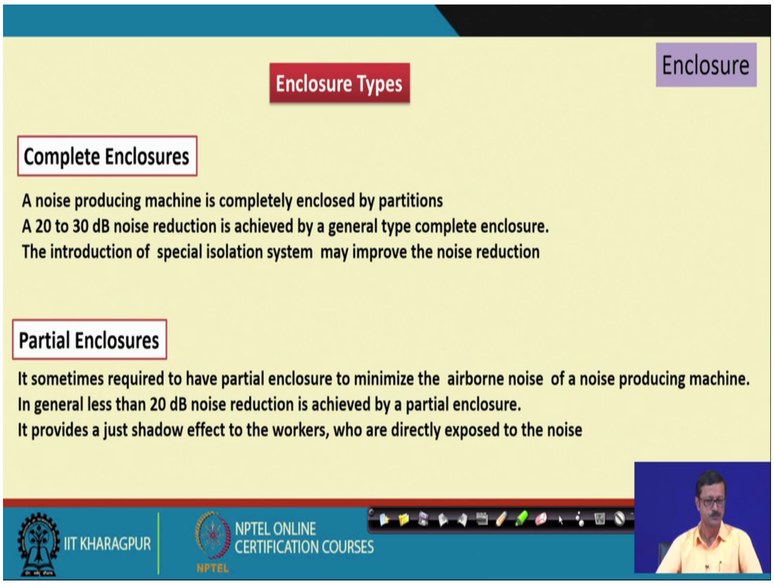

So now there are enclosure, we will definitely create some kind of the enclosure where those enclosures are giving me kind of a reduction of the sound level or so. So there are 2 type of enclosure, one called the complete enclosure where the particularly some noisy area or may be some kind of a noisy machine is completely enclosed all the 6 or the if you say, it is a cubicle kind cuboid kind of a thing.

So, all the 6 the surfaces while some kind of the partitioning wall or the material some kind of wall material. And due to this complete kind of a enclosure it is the noise reduction or those kind of the transmission loss will be tentatively will be around 20 to 30 dB, depending upon the what type of material and what type of enclosure you are going to provide. And this kind of some kind of special isolation system of some advance material some absorptive material also enhance the noise reduction level or this particular transmission loss little more.

There are some cases the partial enclosure are also used, some of the machines may you may not actually fully enclose. There may be some the surfaces or some 1 or 2 surfaces are open because of some kind of operations because of some kind of a piping or those kind of a some attachments and all. So, of course, in that case the in general the noise reduction level or the transmission loss level will be nearly less than the 20 dB or so.

And sometimes it is required because sometime is by the function of the particular machine may not allow you to enclosed completely. Sometimes the temperature may increase or some other phenomena can be decides the phenomena for that. So, we can provide some kind of the partial enclosure to create kind of a sound shadow or kind of a sound shadow where actual the worker are actually exposed to the (Refer Time: 25:16) that particular sound.

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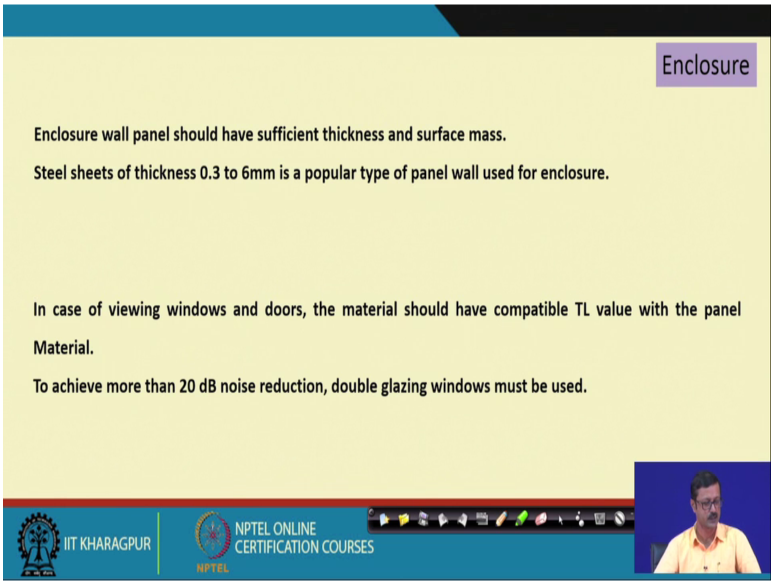

So, let us discuss some kind of enclosure, and what are the typical property of the enclosure we are looking for; of course, there are some points over here we will discuss in the next lecture. One of that the enclosure will have a that wall panel should have a sufficient thickness of the surface mass, because that will actually the boost or increase your the T L value.

Steel sheet of thickness point 3 mm to 6 mm is a popular type of panel for in used for the enclosure. In case of the any kind of viewing window or any kind of a door, which is a additional material or some other material actually placed in a particular partition wall; should have a T L value with very comparable to that particular actual the partition wall, then only we will achieve tentatively average value is very good.

The achieve if you want to achieve more than the 20 dB of the reduction level, sometimes in case of any kind of the window we provide. So, double glazing window has to be provided.

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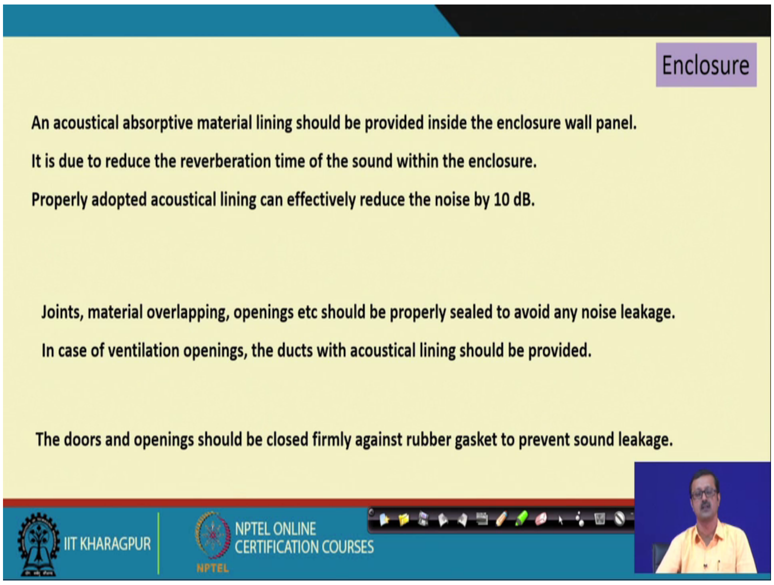

The acoustical absorptive material lining should provided in the because there are sometimes there are some kind of a loss of or the kind of a leakage of the sound happening in those kind of the junction areas or so, so a lining is required.

Sometimes a reverberation inside because it is a enclosure kind of a thing there is a sound and it is actually a small area, and there is a reverberation of the sound will happened. And that that may again further because there is a sound stay back the old sound stay back and there is a new sound. And so, total amount of sound level in the source room sometimes it is increases.

So, it can be properly acoustically treated, and this enclosure can be acoustically treated to reduce down this reverberation and to reduce by the total sound level in the source room. Any joint any material overlapping those are usual phenomenon in the partition wall should be properly sealed with for the noise leakage. In case of any kind of a ventilation opening, duct etcetera should be again lined. Ventilation opening ducts etcetera is required to any case of the enclosure in machine enclosure. The door opening and the other openings like, window openings and should have rubber gasket to again prevent the sound leakage or so.

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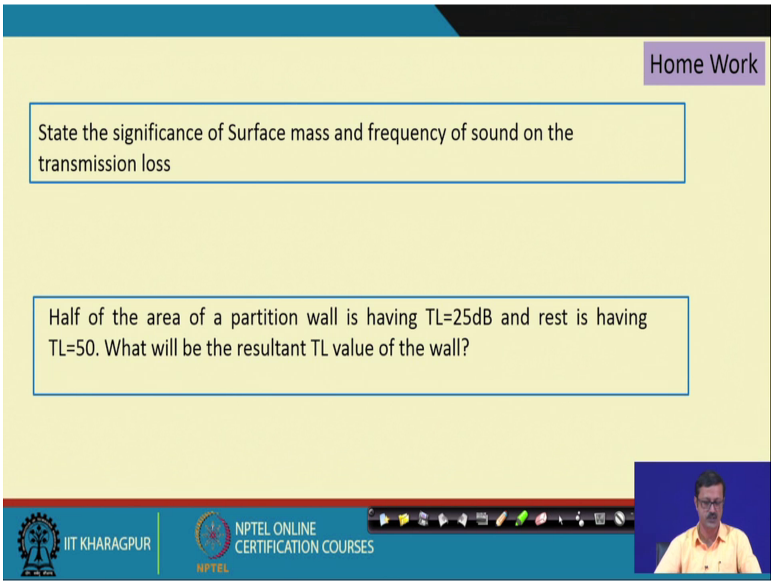

So, that is end my lecture of 31st lecture on the airborne sound transmission 1. As usual we have I have some home work for you. And the first one you think and write maybe the significance of the surface mass and the frequency on the transmission loss, what is the significance of that, because we will carry forward the frequency part of the significant part of them the transmission loss in the next the future lecture.

And another one suppose a wall is having T L some 2 different material made of by 2 different material, the 50 percent of the wall is made of a material which is having a T L of 25 dB, so there is a there is a transmission loss of 25 db. And the other part other half other 50 percent is of T L of 50 dB just doubled. So, find out what is the total T L of the wall, what is the resultant T L of wall. And it is it the just averaging of 25 and 30, 50 that is 37.5 or so, or it is towards 25, or it is towards 50. So, you can see after you solve it and then you decide that what is the nature of the averaging of that, and what will be significance of that when you design for any kind of a sound proof partition wall or so.

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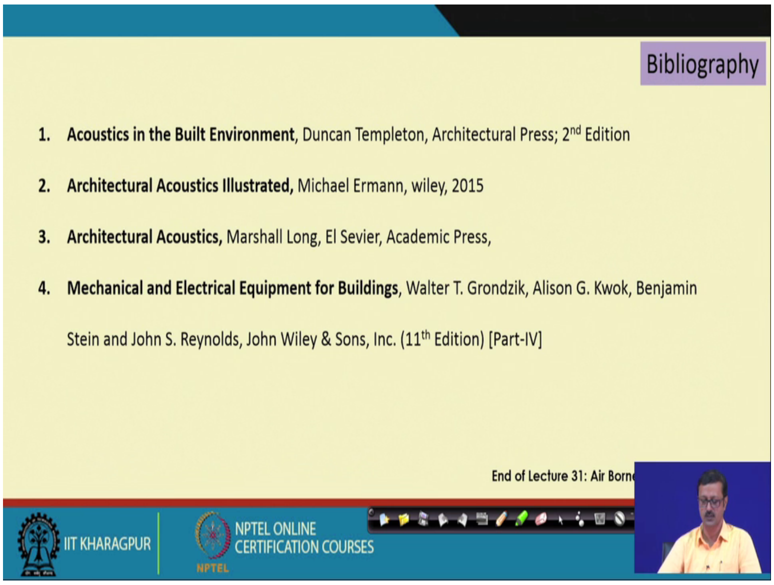

So, that is all for this lecture and these are the some of the books that I have referred during my this lecture preparation or so.

Thank you very much.