Energy Efficiency, Acoustics & Daylighting in building
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Lecture – 35
Noise Outdoors (contd.)

So, we will continue with the external noise propagation that we are doing.

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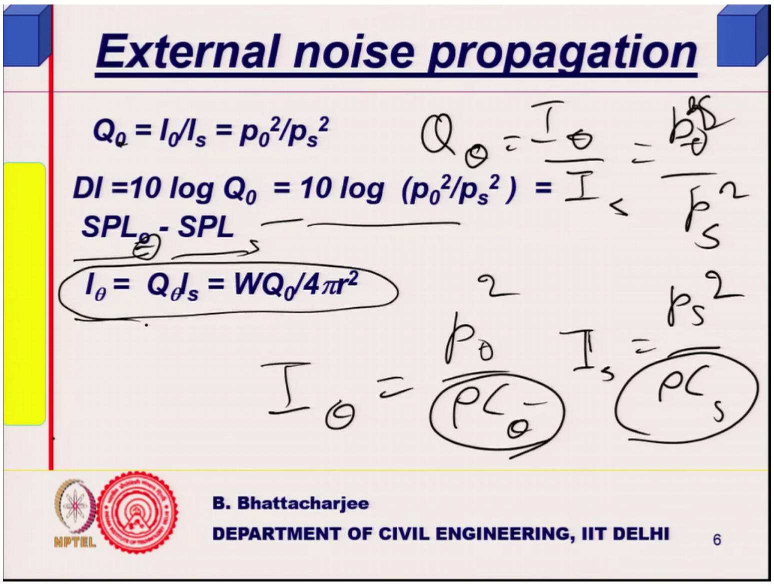

Last class remember we said something like this, at any direction Q theta, if I may call it if I may call it Q theta you know, if I may call it Q theta right Q theta actually if I may call it Q theta right. Q theta it can be written as Q theta can be written as I theta by I s that was directivity index we have to directivity factor and which can be written in terms of p 0 square divided by p theta square divided by p s, where p s stands for going equal in all direction.

Now, p theta stands for the measured pressure along pressure along given direction. So, this is square p square divided by. Now, there is one thing you see I theta is actually is equals to p all I am talking of r m s divided by rho c theta right. Similarly you know I s should be p s square divided by rho c s. Now, we are assuming that this will remain same you know there are small difference and neglecting the difference between the two otherwise this also should come into picture right.

So, we are saying that these are. So, this is this is the same that is your acoustic impedance in standard condition and in actual air ambient normally is not very different. So, therefore, you can neglect this. So, this is how we can write it SPL minus SPL theta, SPL theta minus SPL along all direction all right. So, general equation will be written in this manner, I theta is equals to, I theta is equals to, it will be written in this manner you know I theta is equals to I square, I theta is equals to I square I theta will be Q theta s divided by you know Q theta s into I s. That is how we will write it.

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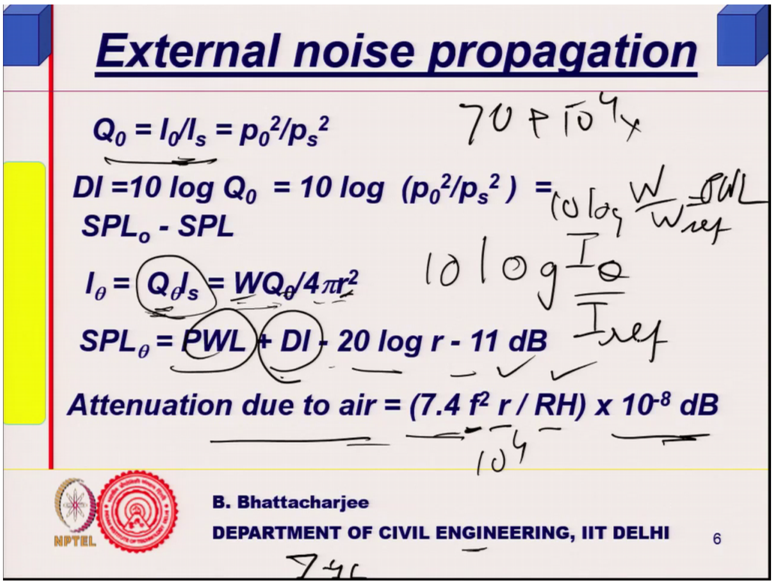

So, because Q theta is the directivity factor multiplied by I s by definition because we are defining it like this. So, is equals to this Q theta if we separate out Q theta then the directivity factor then it will be W divided by 4 pi r square equally in all direction and simply take log 10 log of both sides 10 log I theta by I reference and right hand side also you take W by W reference and take 10 log of this. This would be power level right 10 log W by W ref is p W l power level plus directivity index because 10 log of Q theta is directivity index by definition minus 20 log r because r square is here and this turns out to be eleven. So, that is what we have seen.

So, with distance attenuation of air of course, we said in 7.4 f square function of frequency and relative humidity 10 to power minus 8. So, at low frequency this is very little effect at higher frequency it will have some effect you know this because at low frequency supposing it is something like 100 hertz. So, 100 square would mean actually

100 square would mean actually 10 to power 4 and this 10 to power minus 8. So, if you are adding this is attenuation of air in dB, this is in dB. So, say 70 dB plus 70 dB plus 10 to power minus 4 dB multiplied by some factor really does not make any difference. Only if it is 10 k or so, this will some this is the distance this is the relative humidity this will have some effect that is what we have seen right, that is what you have seen in the last class.

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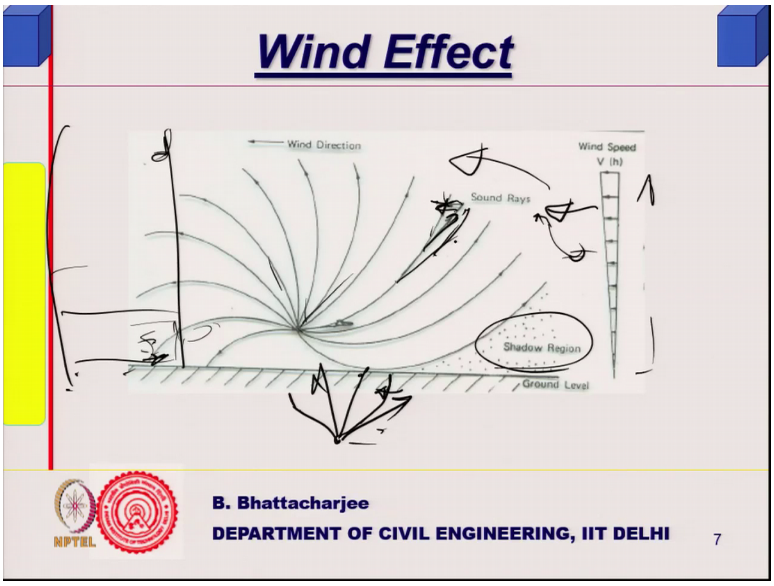

Then we said that there will be some effect due to wind. So, if there is any wind velocity of wind it will have a tendency to you know sort of distort the, distort the spherical wave front because the wave will propagate along this direction I mean the sound rays will propagate along this direction. So, these are the rays. Now, since the velocity at top is higher than velocity at bottom. So, this will tend to this push it more compared to this you know compared to this, you will have a net effect is a vector this vector and this vector together it will try to bend it. So, as a result you will get a shadow region in the windward direction of the source and somewhat amplified or more sound on the leeward side of the source.

So, if you are building is somewhere there, building is somewhere there you might find that there noise level here is higher than noise level there for a tall building force you know depends upon the height because if it is not very tall then this effect will be not very significant. So, that is what it is. So, this is one effect this is one effect. But these effects are either the absorption or these are not more than 5 percent or so, so we really do not quantify, but sometimes we can take into account or keep this in mind that this place is possibly would require slightly higher insulation then this, but as I am saying the dB level would not change significantly here.

Student: (Refer Time: 06:15).

1 is the velocity relative difference in velocity, so this is what it is. And sound velocity of sound along this direction you know the wave, so naturally this will tend to distort this and this will have this sort of a thing and this otherwise it would have gone like this from point source you two have gone equally in all direction. Now, you have a higher velocity along this direction compared to somewhere at the bottom, at the bottom.

So, this would effectively bent it. A point by point if I look at it, it will tend to bent it you know bend this with spherical wavefront distort it, it is no longer as you mean spherical rather it will take two bent it along this direction. So, that is what I am saying right. So, this is one effect.

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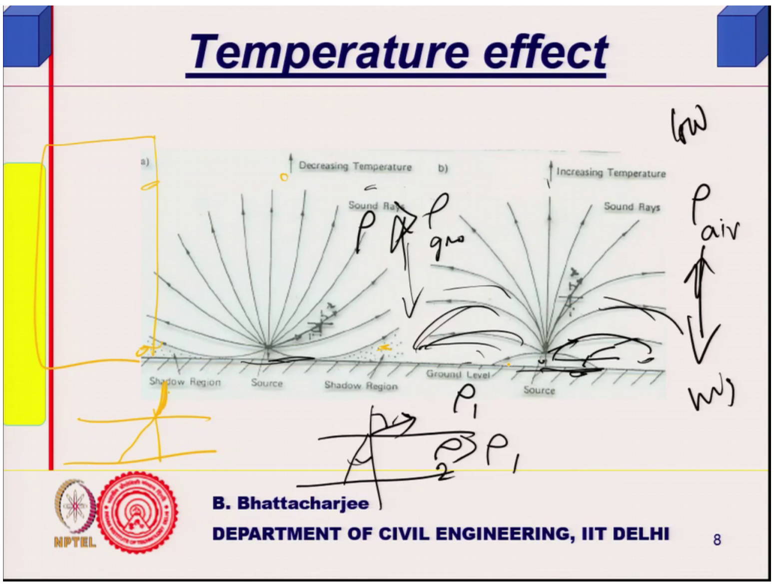

The other effect is get that that due to layer of airs with temperature change. So, temperature change results in different densities of the air layer. So, if you are increasing temperature rho air right will be lower it will be increasing along this direction low to high right and when sound travels from a denser medium to a rarer medium it bends outward for example, from a denser medium to it. So, this is denser medium greater rho here is higher than rho here rho 1 and this is rho 2 is greater than rho 1. So, what will happen? The sound traveling like this will travel like this right incident angle and this is the incidence. So, it bent outward you know refraction. So, what does happening here? It will have a tendency to bend outward. So, you will have one and the you know from one layer to another layer it will bend like this and go further. So, it will have a tendency to actually bent here.

So, you will have more sound at the ground level and lesser sound at the because it will have a tendency to again distort the spherical wave front in this manner it will you know in this shape it will tend to bent it along this direction and this is when the temperature is increasing along this direction; that means, this temperature is lower. So, you have a source somewhere there ground level source not very far off from the ground level and temperature is increasing there which means that you know ground temperature is lower than the air temperature.

Now, this will happen actually in somewhat in the night because ground would have radiated because or you know like no you know night or later for early in the morning or something of that kind. And while the when ground get heated at the end of the day then this is temperature here is higher. So, if my density is density actually will be decreasing temperature. So, density will be increasing. So, rho will be increasing along this direction rho is greater than no near ground.

So, rho at the top is. So, this would have other effect the opposite effect; that means, you will have something like you know the composite effect means you are going from now, rarer medium to denser medium. So, sound will bend inward in this direction and if you continuously if it bends. So, it will have a tendency to may have sound shadow at the ground level because it will have tendency to bent all over and have some relatively more sound at the top level.

So, again you have a building somewhere here you know you do not see it over a small range of the thickness of air layer, it has to be somewhat tall building then this variation you will see temperature variation will be significant. So, you might find that less sound in the day peak of the day evening know when ground has become hot and possibly more sound somewhere up there similarly it will be other around in this situation. So, these are, but these effects are not very high, but one can keep that in mind supposing you come across you know some sometime in the day time when you are analyzing diagnosing the cause of noise or something like that there is a noise source. So, one may keep that into mind and then basically you know take care of this.

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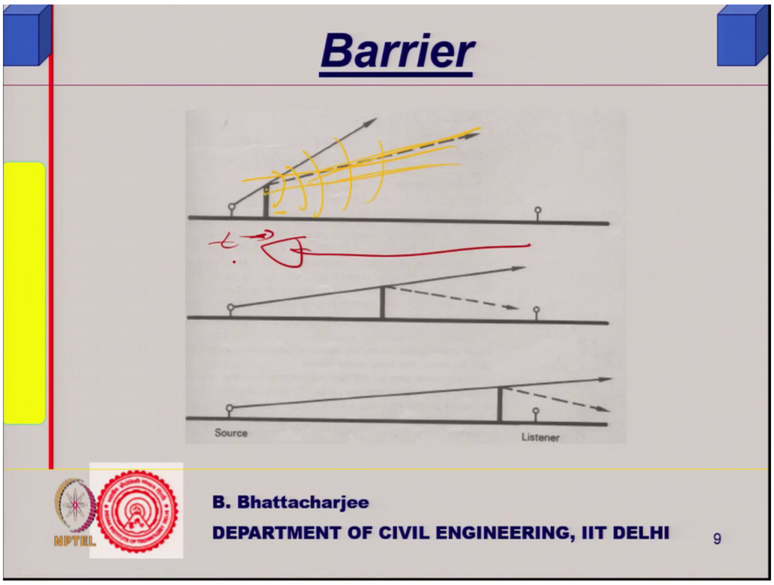

Barrier I was talking about and I just explained this in the last class to you that barrier should be either close to this receiver or close to the source because sound will deflect every point on the path of the wave can be treated as a source again it tends to go the wave we actually tends to if there is an obstacle. So, therefore, it will this point itself again sound would travel in this manner and this is the diffracted sound.

So, diffracted sound also significant diffracted sound will go along this direction all right and if you put in a center the diffracted sound can reach that receiver again, but if it is away then it will also go over that you know head level of that receiver. So, best ways to put a barrier is either close to the source or close to the receiver whichever is in your control.

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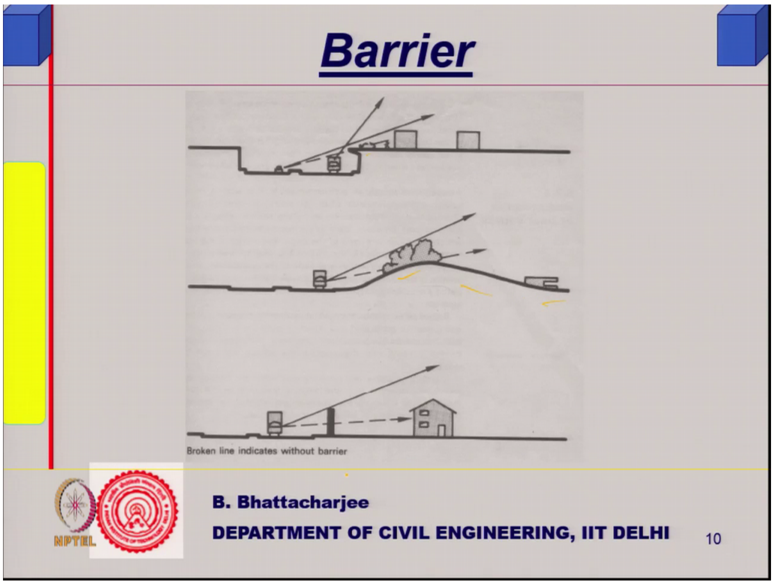

So, that is what is done in case of noise apartment in town planning. You might put the you know if trench if you have highway my very traffic, might put some sort of a trench and there are your buildings. So, might be something like you know sort of this there may be a tree, there may be a tree or a hump, literally ensure that the sound does not go if you have nothing then put a barrier, right.

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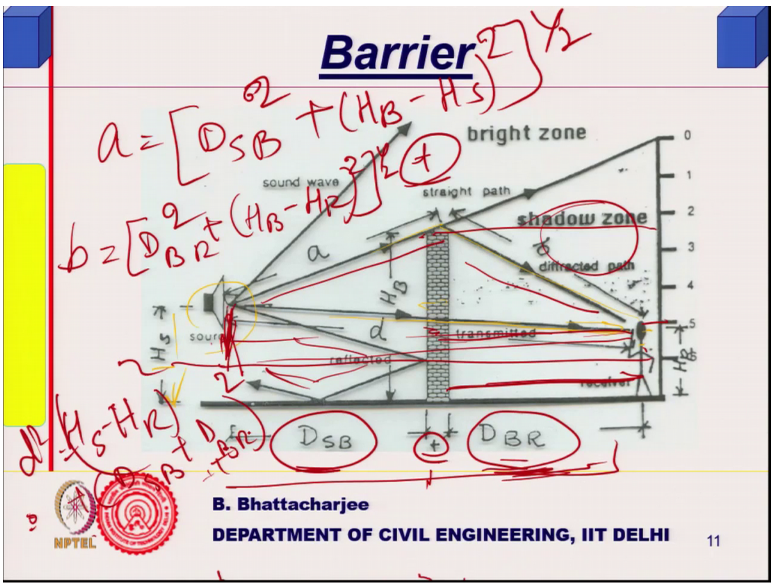

So, we can now find out roughly what should be the parameters of the barrier actually if you are designing a barrier. So, this, if you look at this, this is your source and this is the receiver, this is the source and this is receiver and let me call height of the sources H S from the ground. And this is a height of the receiver right height of the receiver H R I may call it is something like this H S and H R, so this, the height of the receiver. If there are no barrier it will gone straight like this, even if there is a barrier it will also direct sound do linear paths because their beats it can be transmitted through this.

But deflected sound path will be something like this right and this, this could be the thickness of the thickness of the wall that or barrier that I have put in, thickness of the barrier that I have put in let us say it is t you know, I call it t, barrier thickness is t then a is this path b is this path or if I put it a you know I can include the thickness, but usually t is relatively small unless is very heavy very thick.

So, usually t is small, this t is small compared to a b and you know this one itself what we call D BR plus D SB. What is D SB? Distance of the.

Student: (Refer Time: 13:28).

Distance of the source from the barrier, distance from the receiver from the barrier so, otherwise you should we will have to take half t half t both the places, but usually they are small. So, this a is a plus b and this distance I have to find out the height of the barrier let us say is H B, height of the barrier is H B. So, this is the direct path some rays will be reflected back that is not my concern, but this generally is normally direct sound shadow zone. So, nothing will reach there, but still diffracted path will be there and this path difference between these two if it is some multiple of the wavelength then intensity will increase intensity will increase right. So, then diffracted sound would be disturbing this or reducing down my noise.

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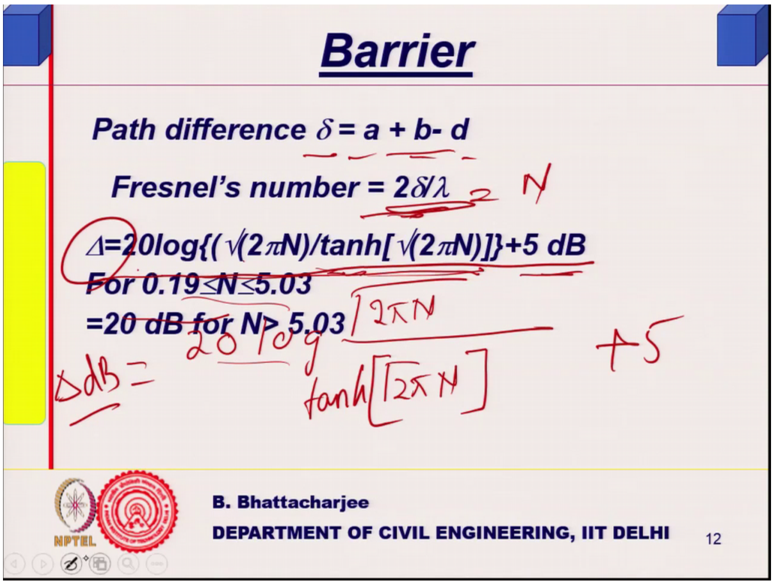

So, this can be related to what is called Fresnel number. Path difference is a plus b minus d and Fresnel number is 2 delta which is a path difference divided by lambda, because you remember that was equals to N lambda I said that 2 you know delta should be equals to multiple of, multiple of lambda. So, it is Fresnel number is given by 2 delta by lambda and empirically decibel level reduction is given by 20 log root 2 pi N this is one of the formally there are some other is semi empirical. We understand that it is related to Fresnel number N all right.

So, it is related to 20 log under root 2 pi N divided by tan hyperbolic the whole thing is divided by this, this part you know. So, this is together and this is 20 log of all this plus 5 dB. So, under root 2 pi N divided by. So, it is actually 20 log right you can write it like this 100 2 pi n, and 2 pi N right tan hyperbolic something like this 2 pi N divided by tan hyperbolic under root 2 pi N and this is under root again plus 5 dB, plus 5 dB.

Student: (Refer Time: 15:51).

Sorry, this is delta dB, reduction, attenuation, this is the reduction and small delta is.

Student: Path difference.

Path difference which is related to N so, that is how we can calculate out. So, this is, this is what is given right, this is what is given. So, this is equals to delta d b delta dB. So, that is what it is. For a situation for some condition because this is not semi empirical equation as I am saying it is valid for certain condition and that condition is for N should be greater than 0.19 and should be less than 5.03 all right, 5.03 and when the path difference will be small if the height of the barrier is quite small, height of the barrier is quite small or no barrier let us say.

So, 20 dB for N greater than 5.03. So, there will be hardly any delta if you have less than 0.19 you know effect would not be practically, would not be there because your height is so less the path difference is practically not there. So, this is between this is valid and this is greater than this you take flatly 20 dB. So, greater than, greater than, 5.03 N equals 2 you take 20 dB this is related to what difference is related to path difference; and obviously, the wavelength or frequency of that sound that is it.

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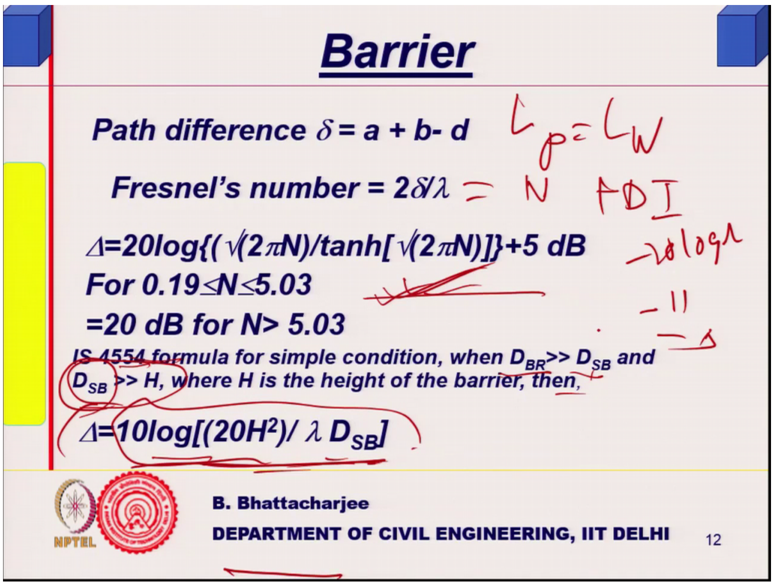

So, if you look at another formula which is given in IS 4554, Indian Standard 4554 which is actually the code for noise abutment in you do not know as a abutment generally in outside why did you know D BR. So, let us see what is this a plus b plus d, let us get an expression for a plus b plus d first. What is a? A, you know one can calculate out a from here, a is nothing but D SB plus you know D SB plus H B minus H S square of both oh no. So, what would be a? a is equals to d, you know a is equals to D SB square plus H B minus.

Student: H S.

H S square right. So, a is this. What is b? b is b is DB you know this will be now D BR if I neglect the t thickness is being neglected plus now H B minus H R receiver square to the power half, all right. So, this is this to the power half. So, b is like that I can geometrically calculate out this square plus this minus this you know basically this I am trying to calculate out. So, this minus this square under root of that that is b, that is b.

Student: So, small t is.

Small t is the thickness of the barrier which we are neglecting. Otherwise you take t by two everywhere right, but it is small this will be large in 50-60 meters this will be in you know millimeter, centimeter. So, that is why this, this is large in meters and this is actually small in millimeters, but if it is sufficiently thick then you have to take that into account otherwise you can neglect this right.

So, what about, what about direct path that is my that is my you know like what we are calling is a plus b minus, a plus b minus d, d is the direct path is not it; I am calling it a plus b my d, d is the direct path. So, d is the direct path, direct path is nothing, but this much H S plus, H S minus H R square plus all this you know. So, this height is nothing but H S minus you know this, this height H S minus H R that is squared up right plus this distance which is D SB plus D BR square and that is equals to d square. So, that is equal to d, that is equals to d square you know d square is equals to all this..

So, you can calculate out a plus b minus d which is geometrically simple and if you want to take t you do can take t here also there will be small value of t there. So, you add here t to this part of the thing and square it up, but that is usually to be small that is why we are saying we do not take it to account. So, that will give you a plus b minus d which will be equals to delta and then calculate to delta by lambda for every wavelength and you can find out. So, that is how we can calculate out the barrier height. You can design the barrier for this, design the barrier right.

Remember this has to be solid, if not we will see what happens, we will see it sometime later on. Because it can, supposing there is a hole here, this can cause some diffraction.

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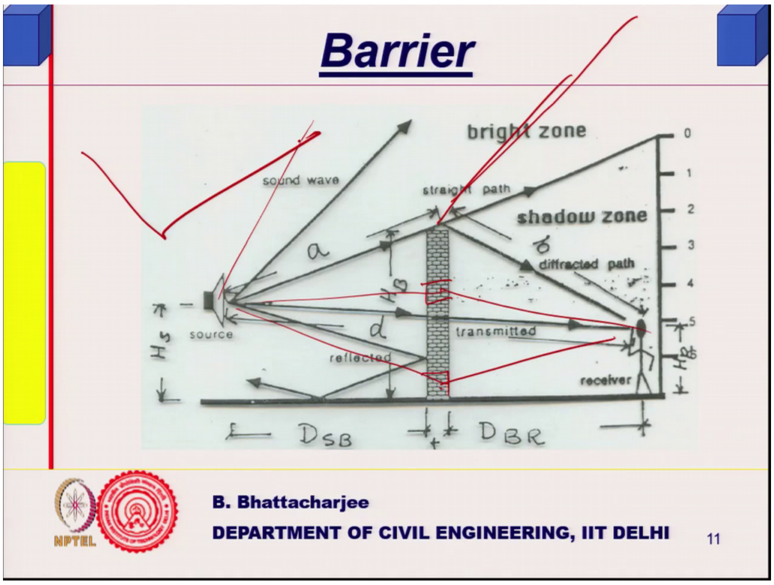

If there are some hole there this can cause some deflection not only that if depending upon your source it is a point source, so it is fine. If is a line source then this length also has to be sufficiently large otherwise in plan it can again deflect in this manner. So, the you know the path difference largest path difference you should be taking because greater than 5.03 anyway reduction is you know then the diffractors have known reach actually right, at least sound sorry you should be taking the least path difference which will be your conservative design, least path difference will give you conservatively.

Largest park difference will actually increase the delta, you want to take the least delta. So, that is how we can do the barrier design, we can do the barrier design in this manner. Now, as I said that is code gives you an empirical formula assuming D BR is very very large compared to D SB which means what which means this kind of a situation which means this kind of a situation you know, which means this situation. This is very large compared to source to barrier is small barrier to the receiver is large.

So, in such cases you know formula becomes somewhat empirical formula you can use, one can use the empirical formula which may be the case in many cases and it also assume you know the this is much greater than source to the barrier and this is much larger than the height of the barrier height of the barrier. And these are empirical equations therefore, it gives you delta is equal to 10 log 20 H square by lambda D SB simple, 20 H square you know lambda D SB.

You perhaps cannot derive that out of from the previous curve it is not, it is not, but it is a separate one you know neglect of those may be some idea you get the delta now you know it will be different actually. So, so for large this large once you know in this is because the diffracted path will actually move away. So, this is, this will be in our previous case will be 20 dB, previous case possibly it will go to 20 dB we know if we calculate out the path difference because I mean basically this is for case that case that we talked about.

So, but you this is generally one can use this quite there is more general you have sort of curves plotted actually and from the derive this equation. So, one can actually derive barrier design we one can do using this. That means, first you will calculate out how much is that how much is you know d r; you know L P you will calculate out in terms of L W plus D I minus 20 log r, minus 11. Now, you put a barrier there will be a additional. So, subtract it from delta that will be the actual L P that will be the actual length we write, that do the actual L P, that will be that gel L P. So, that is how one can calculate.

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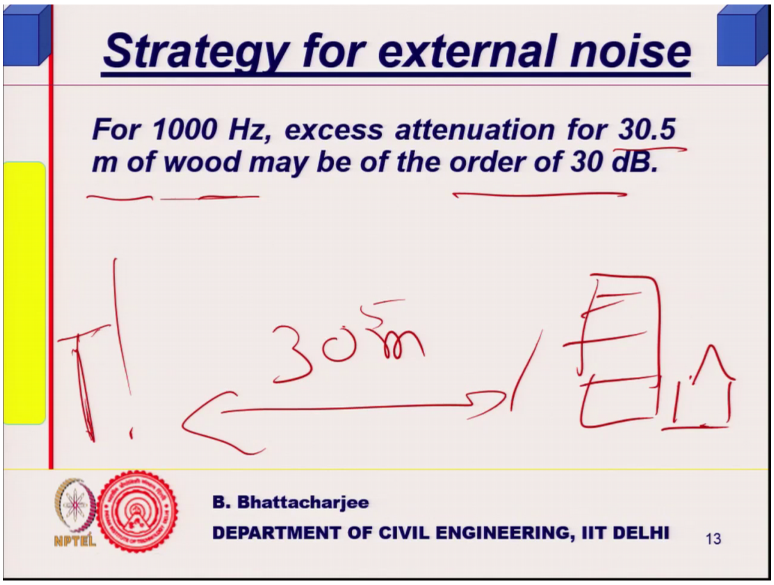

That means this is additional reduction over and above what you would have got otherwise there is no reduction mode all right. So, if you have trees, if you have trees, if you have trees then 30.5 dB, 30.5 meter of dense wood dense wood, but it has to be can reduce order of 30 degrees.

So, this is this from practice understandable understand, you know thick forests thick wood would reduce down the noise level thick not really sparse, not so dense. So, about 30 meter width. So, here 30 meter width we have provided 30 meter width you know 30 point around this order it you know and this is your traffic source and all that these are your residences these are your residences I mean you know building etcetera, then you will get it provided is a dense forests if it is dense forest otherwise 30 dB even good. So, this is approximate there are some other books will give you some other values. Many places you might get effect.

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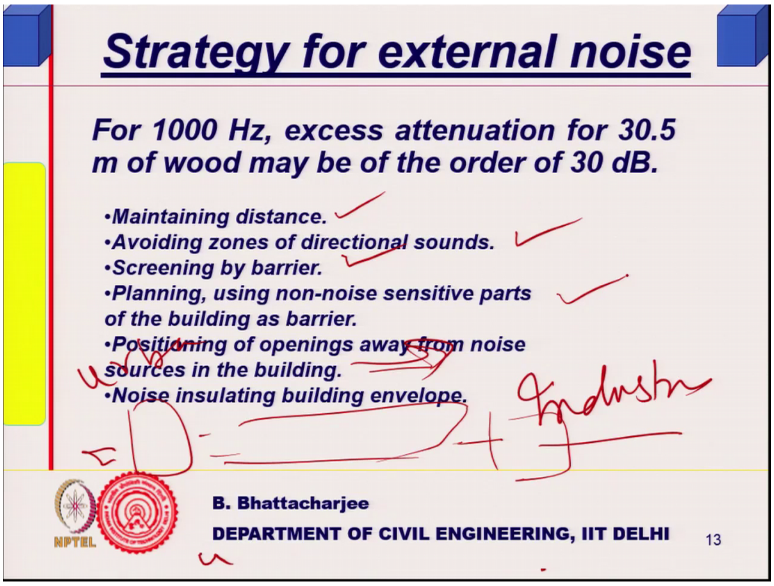

So, what is my strategy then? First strategy is I would like to maintain large distance between source and.

Student: Receiver.

Receiver, that itself will reduce down the noise. Then there is another concept is that about the source of directional sound. For example, if you have industries here know and you know the windward direction also then residences should be somewhere here if the direction of wind is like this. So, this is industry and if the wind prevailing wind direction is this direction industry should be there rather than this place.

So, this is your urban area, urban area should be here right, it is not rather around. So, that direction or if you have, if you can put some buffer in between for example, you may have trees here green areas, if it is industry of course, there is segregation of zoning, zoning is done in urban planning it is done for various purpose noise, fire, etcetera, etcetera. So, in case of noise keep the source away from the receiver that is the fundamental. If you cannot or you do it as much as possible in urban planning you can definitely do it, but you might put a buffer in between to enhance. For example trees will act as a buffer trees will act like buffers. So, you can put in buffers right, buffer which will actually absorb the noise.

Now, even within a building you can do that kind of thing the noise sensitive for example, a classroom do not keep it close to the workshop right and if you want to keep it say a canteen which is noisy and classroom which is also can generate noise for other classroom. So, between two classroom there should be either insulation or something right.

Now, if you know the direction of the sound you can keep that side away for example, you keep it in such a manner say this the back side of the classroom might be facing that where the noisy it will be blocking the noise facing some noisy area, you know if the directional noise is there something is generating some laboratory which is actually you know generating noise. So, you may have to, you may have to keep this, you may have to keep this in that manner I know. So, this is one thing. So, that is what we mean by avoiding direction of directional source of that.

Do not keep too many windows along the highway direction all right. Well if you do it you have to have a barrier I mean you have all options possible. So, this is another option, screening by barrier.

Planning using non noise sensitive parts that is what I said keep them non noise sensitive parts because some spaces are not noise sensitive right some noise spaces are not noise sensitive, you do not bother. For example you know like your things like washroom etcetera, these are not noise sensitive and do not some of them even do not generate noise and not noise sensitive they are very good buffers because they are not sensitive to noise all right. So, you can put in those ones which are not noise sensitive, but also do not generate noise their best. So, that is what it is. So, you can do that kind of planning both inside the building as well as outside of the building as a barrier.

Positioning opening away from noise sources in the building. So, do not keep your windows towards the traffic side noise then of course, you can do the insulation. Make the walls such that it does not allow noise to come in. How we do it we will sit later. So, I think that is essentially related to external noise protection, external noise protection all right. More of it will come back again, well after looking at, after looking at the internal noise part of it.