Architectural Acoustics

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Lecture – 13
Absorption in Spaces of Different Volumes

So, we were continuing with lecture 11 and lecture 12 where we elaborated on Acoustical Absorbers, but what I did not touch upon is where you are placing is also very important.

So, we have applications of these absorbers in different areas; it can be a big hall, it can be a small classroom, it can be a small very small recording room, it can be a very big auditorium, it may be medium sized lecture hall; we have given you some examples.

But which is more effective putting it on the ceiling, putting it on the wall we have seen the phenomena of reflection how reflection helps, to what extent it helps. We have seen that further is the point the sound travels and comes back takes creates delay and these long delays are to be trapped in. So, we have a back wall, we have a ceiling far, we have side walls ends where it is more effective where to put absorbers.

Obviously, we will put absorbers so that it does not disturb or disturb the quality of sound. So, we will have to put absorbers in the room after having an understanding whether ceilings are better, whether walls are better, whether 50 percent ceiling 50 percent wall is better, what is the volume of the room whether volume has an effect of it effect on it because all this things are all inbuilt in the equations which were taught by Professor Bhattacharya.

So, will see today and you will also calculate with what I present; so, that you can also make your own understanding.

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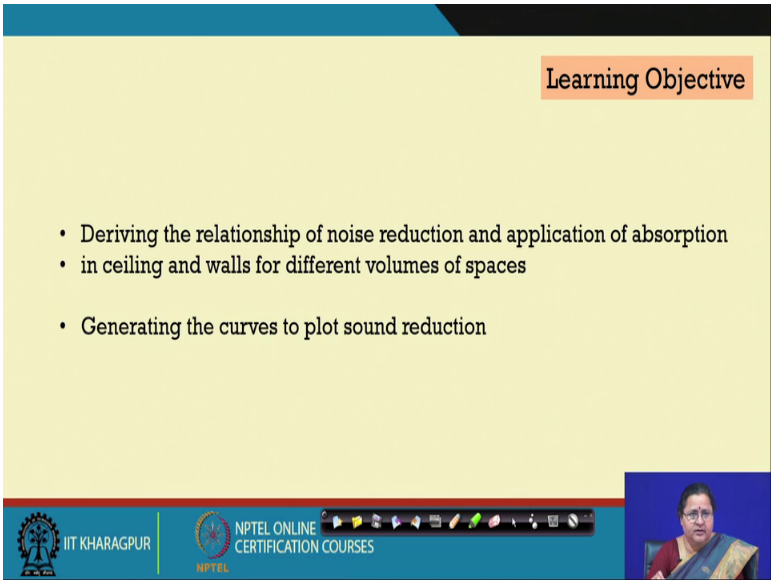

So, deriving the relationship of noise reduction and application of absorbers in ceiling versus wall for different volume of spaces is today's concern. So, we will try to generate the curves to plot sound reduction; how it reduces the sound in a enclosure. So, let us proceed.

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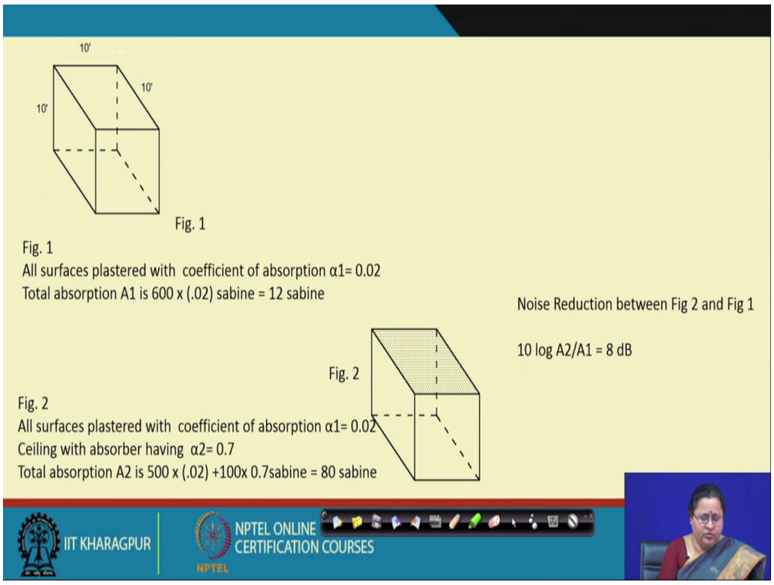

We consider we are going with a very simple thing, we are considering a 10 feet by 10 feet by 10 feet room; when all the surfaces are plastered with coefficient of absorption around 0.02. And hence the total absorption if we consider even the floor is 600 that is 10 into 10 each of the faces, there are 6 faces of this particular cube. And we get in 2.02 that much of sabine that is 12 sabines is getting absorbed.

All other sound produced in this particular space that is 10 cross 10 cross 10; apart from 12 sabine is reflected back, this is our test condition that is our reference. And then that all surfaces remain plastered that is that 10 cross 10 cross 10 room. So, the walls are and the floor all are free and only the ceiling is having absorber and with 0.7 as its coefficient that is the NRC value that is the alpha is 0.7 for this figure 2, it is written as alpha 2.

So, that total absorption A 2 is 500 into that is one of the faces that in the ceiling is left out and all other 5 faces are reflecting are absorbing 500 into that 0.02 units. And the ceiling is observing quite a lot that is 100 into that is 10 cross 10 that is the ceiling area into 0.7; the unit is sabine. So, it is absorbing 70 sabine the ceiling where as the all other 5 walls are absorbing 80 sabine 10 sabine.

So, it is total into 80 sabine and what is the comparison between these 2 rooms, what will be the noise reduction once you are producing a sound here and producing a sound here what will be the reduction of the sound intensity between the 2 rooms? It is given by the formula 10 log total absorption of A 2 divided by the total absorption of a one these has been discussed at link in earlier classes.

So, it is 10 log A 2 is 80 divided by 12 you can calculate it out it will be 0; 6.66 something and log of that will be around 0.8 8 and in 10 times of it will be 8 decimal. So, the noise reduction whatever sound is produced here and whatever sound is produced in this figure 2, with this is as our reference the first figure as our reference I 0 that is intensity at 0 that is figure 1 and figure 2 we get a reduction of sound by 8 decibels in case of figure 2.

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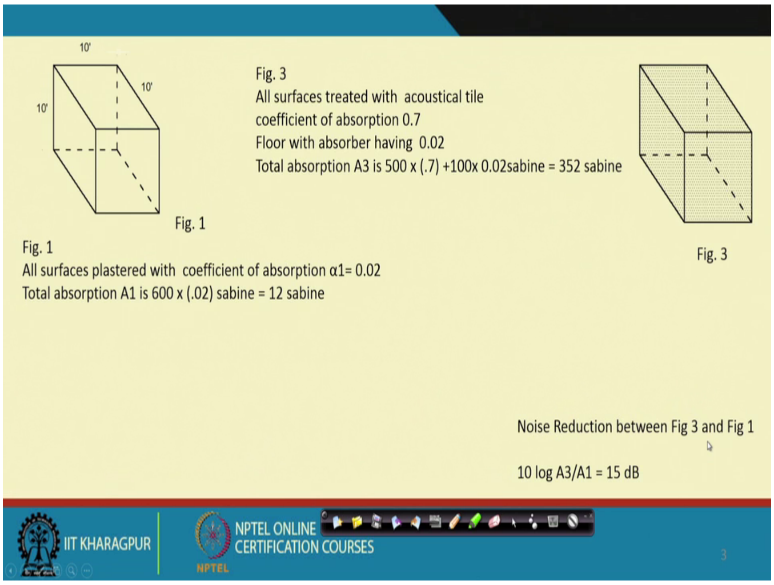

Now, we will put in another case when all surfaces are treated with acoustical tiles of coefficient of absorptions say 0.7 and floor is only having a absorption of 0.02. So, after leaving out the floor we have covered all the walls along with the ceiling with absorbers.

And we see here A 3 that is the total unit of absorption which is 500 that is the area into 0.7 and the floor is left free that is point that is 100 that is 10 cross 10 into 0.02 that comes out to be 352 sabines. And again we compare it with our reference here the noise reduction between figure 3 and figure 1 is 10 log A 3 by A 1 that is that will come out to be 15 decimals.

So, if you consider the previous case figure 2; by covering the ceiling only you had a reduction of 8 decibels, when you are covering all sides; all walls leaving only the floor you are getting a reduction of 15 dB; so, where ah; so 4 of the walls together could make a difference of 7 dB.

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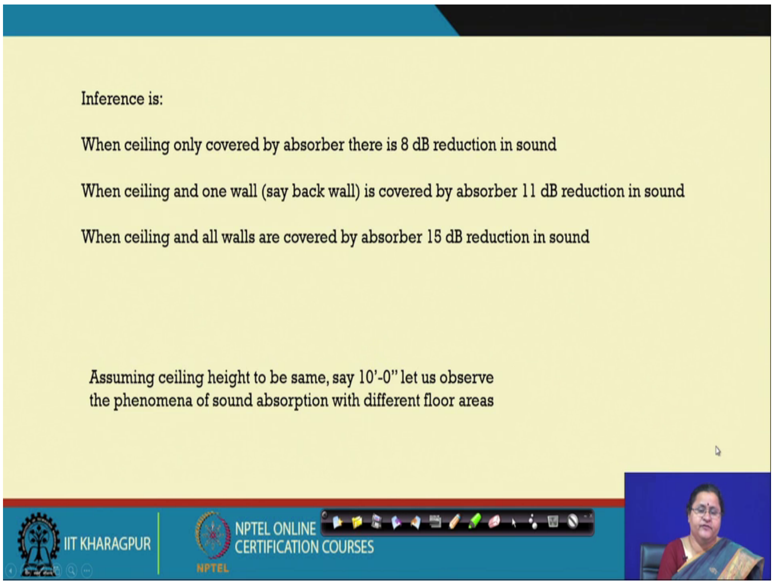

So, the inference is when the ceiling only covered by absorber there is 80 dB reduction, when the ceiling and one wall say the back wall is covered by absorber if you again workout another step, another case it is only one wall that is ceiling and the back wall is covered by absorber; you will see 11 dB reduction with the test case. When ceiling and all walls are absorbers are covered by a absorbers leaving the floor only, you will see it is a 15 dB reduction.

So, is it that simple? That only ceiling is effective only ceiling and one wall is also is little more effective and covering all will be further effective and we will keep on trying iterating. We also did not consider the volume; here it is 10 cross 10 cross 10 and if we think that it increases or it decreases, the volume also changes and the surface areas also changes. So, we cannot confine ourselves within a 10 cross 10 cross 10; we have to think beyond it.

So, this was the starting and the if we assume that the ceiling height in all our cases is 10 and absorbers which are applied all are having 0.7 as their coefficient, we will try to generate the craft how ceiling and the wall absorption behaves in different volumes of room. And what is the ratio between the wall area and the ceiling area considering that also we can make our understanding so, that we can make our choices.

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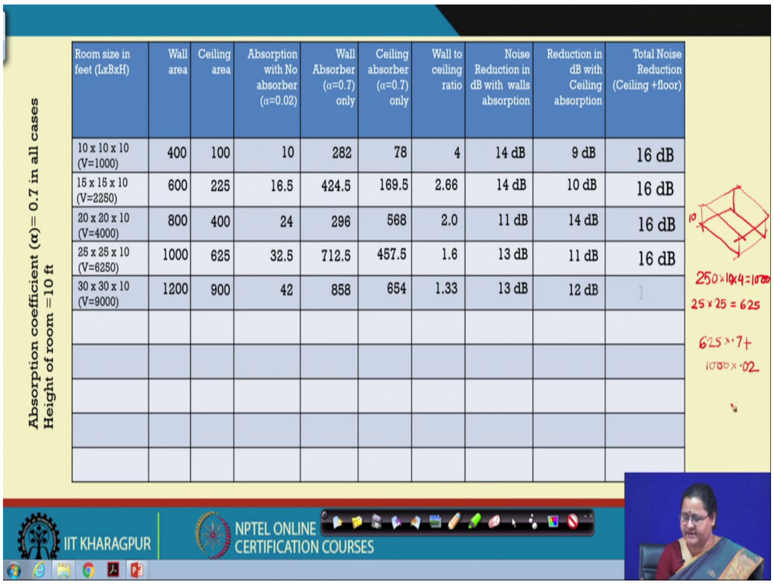

Room size in feet (LxBxH)	Wall area	Ceiling area	Absorption with No absorber (α=0.02)	Wall Absorber (α=0.7) only	Ceiling absorber (α=0.7) only	Wall to ceiling ratio	Noise Reduction in dB with walls absorption	Reduction in dB with Ceiling absorption	Total Noise Reduction (Ceiling +floor)
10 x 10 x 10 (V=1000)	400	100	10	282	78	4	14 dB	9 dB	16 dB
15 x 15 x 10 (V=2250)	600	225	16.5	424.5	169.5	2.66	14 dB	10 dB	16 dB
20 x 20 x 10 (V=4000)	800	400	24	296	568	2.0	11 dB	14 dB	16 dB
25 x 25 x 10 (V=6250)	1000	625	32.5	712.5	457.5	1.6	13 dB	11 dB	16 dB
30 x 30 x 10 (V=9000)	1200	900	42	858	654	1.33	13 dB	12 dB	

So, you can actually write down this table for your purpose and we will be filling it up with your help; maybe you are virtually connected to us, but you just check whether you are doing the right whether your calculation is right maybe I can also put in some wrong data you can inform, you that the system is that friendly.

So, we have on the first column the room size in feet length, breadth and height we are reporting. The wall area that is the summation of the all the walls we are not considering the floor that is the base in our case in this calculation. So, we have 4 walls we have one ceiling we have absorption reported with no absorber that was that is our reference that is alpha is 0.02; that is very minimal which is our start or our reference level.

And wall absorbers when walls having absorbers when alpha is 0.7; ceiling with absorbers when alpha is 0.7 same, we have the wall to ceiling ratio. Then the noise reduction in decimals with only wall absorption; next column is on reduction in decibels with ceiling absorbers and then total noise reduction that is considering ceiling as well as the noise.

So, if you cover all the ceiling all the all the wall then what is the where do we stand for different volumes. So, we start with the first we have 10 cross 10 cross 10; as we had already shown the wall area without the floor area is 400. So, 10 into 10 into 4 walls height of the entire calculation height is constant as 10 feet. So, the absorption with no absorbers it is 50 into 0.02 that is 10 10 sabine with walls having absorbers of 0.7 and ceiling with no absorber that is 0.02, you will come across 400 into 0.7 plus 0.02 into 100.

So, hopefully you all have got this 282 units; similarly with ceiling only that is 100 into 0.7 plus 400 into 0.02, you will get 70 plus 8 that is 78 sabine. In this case, the wall to ceiling ratio is 4 that is 400 divided by 100 that is 4; we have the first second and third column the wall area and the ceiling area; so, the ratio is 4. And noise reduction in dB with wall absorption only is 14 dB, reduction in dB with ceiling absorption is 9 dB, it varies from the previous one a little bit because of we have omitted the floor here.

So, the what is the total noise reduction considered in this 500 square feet of absorber of absorber with 0.7? You will see it will come around 16 dB, it will be 10 log 36. So, hopefully you have understood what we are trying to do. So, we have here we see our volume is also reported in the first column. So, we have for the first case the volume is 1000, in the next case it is 2250, where we get the wall area as 600, ceiling area as 225.

And if you can calculate it out; you will get the absorption with no absorber as 16.5 which is the reference, then with wall absorbers only 424.5, next is 169.5. And the wall to ceiling ratio is 600 divided by 225 that is 2.66 and it gives 14 dB of noise reduction and 10 dB of noise reduction, when it is ceiling. And if you total it out and find out for both the ceiling and the floor; that is summing these 2, summing these 2 into point 0.7, you will get and then dividing it with 16.5 you will again get 16 dB. If you go for 20 into 20 into 10; the volume is 4000 cubic feet; so, we get wall area and ceiling area as 800 and 400.

So, the ceiling has gone bigger and the absorption with no absorber that is 24 sabine. And with wall as absorber you see 296, with ceiling as absorber you will get 568 you must also account for the wall absorption of 0.02. And then report this value and see the wall to ceiling ratio is just 2 and the noise reduction coefficient; noise reduction sorry noise reduction in decibel is 11 dB. Whereas, it has changed with the ceiling absorption it has gone high to 14 dB, but the total noise reduction with ceiling and floor is still 16; I am reporting the value 16 it may be 15.5, it maybe 15.3 in that case I am reporting 15; otherwise I am reporting if it is more than 15.5, 15.7; I am reporting it at as 16.

So, you may find it exact values can be written, but you know in decibels we do vomit the beyond the first decimal place. So, if we have 25 into 25 into 10; we see 1000 is the wall area that is 25 into 10; 250 into 4 walls that makes 1000 and you have 25 cross 25 as your ceiling that makes 625; that is the ceiling is 25 cross 25 whereas, your box is height is 10.

So, in that case it is like this what comes next is; for this particular area with 0.02 as absorption coefficient, you get 32.5 that is that is oh that is 1000 plus 625 that is 16 16; 25 into 0.02 that make the 32.5, then with only absorber for the walls that is 1000 into 0.7 plus 625 into 0.02, you get 712.5 sabines.

For the ceiling, you get 625 into 0.7 625 into 0.7 plus 1000 into 0.02 that gives you the next value 457.5; wall to ceiling ratio is 1000 divided by 625 which comes to 1.6. And if you go for the noise reduction in decibels with wall absorption only it is 13 dB, with ceiling absorption it is 11 dB and the total noise reduction will again be around 16 dB.

Absorption coefficient (α) = 0.7 in all cases
Height of room = 10 ft

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30 x 30 x 10 (V=9000)	1200	900	42	858	654	1.33	13 dB	12 dB	16 dB
35 x 35 x 10 (V=12250)	1400	1225	52.5	1004.5	885.5	1.14	13 dB	12 dB	16 dB
40 x 40 x 10 (V=16000)	1600	1600	64	1152	1152	1	12 dB	12 dB	15 dB
42 x 42 x 10 (V=17640)	1680	1764	68.88	1211.28	1268.4	0.952	12 dB	12 dB	15 dB
45 x 45 x 10 (V=20250)	1800	2025	76.5	1300.5	1453.5	0.888	12 dB	13 dB	15 dB
60 x 60 x 10 (V=36000)	3600	2400	120	2568	1752	1.5	13 dB	11 dB	15 dB

So, you can carry out the same calculation with some more figures, for 40 into 40 into 10; you have the ratio as 1, where you see the wall absorption and the ceiling absorption are matching and the noise reduction is both 12 dB and 12 dB. But and the ceiling and the floor together its reporting together 15 little over 15; it is 15 dB, for 42 by 42 you see the ratio of the wall to ceiling goes below 1.

And also you see it is almost similar giving similar results, you can work out for 45 into 45 you will get little changes and for 60 into 60, where the ratio is 1.5 that is again increasing you see it is 13 dB and 11 dB reduction for wall and ceiling and you see the overall reduction is by 15 dB.

For all these cases you will see on this on the last column; it is always 10 log 36 hopefully you have got similar kind of result. So, after getting this if we want to plot this what we will see? Let us try to find out.

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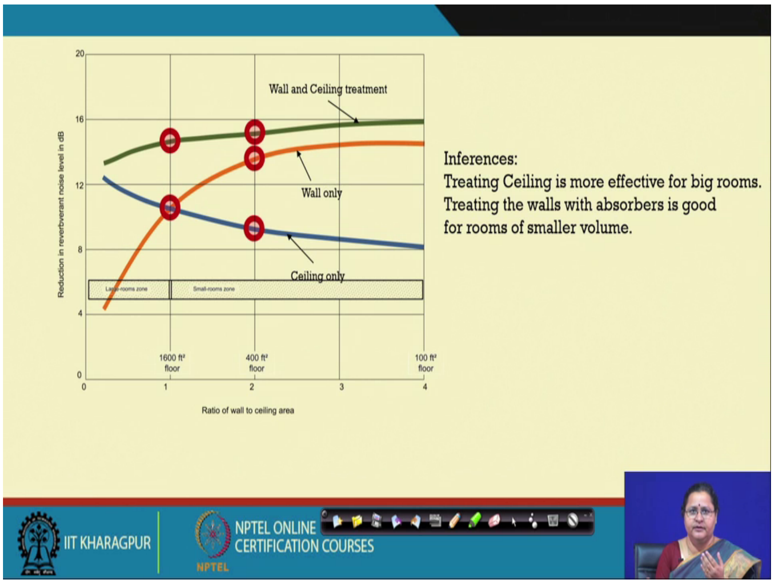

So, this is your graph where we are reporting 1600 square feet floor area that is 40 cross 40. And 400 here that is 20 cross 20 where the ratio of wall to ceiling is 2 and beyond 1600 square feet, we are talking telling these are classifying them as large rooms, below 1600 square feet of floor area we are classifying them as small rooms or small room zones. And you have at the age end in the first test case that is 10 by 10 room where the ceiling is to the wall is to ceiling ratio was 4.

So, on the x axis you see apart from the square feet area of the ceiling you get the ratio of the wall is ceiling that is 0 starting from 1 2 3 and 4. So, we have all the cases in our hand that is we have 1 we have 2 and I think we have 4 and let us try to plot it plot whatever value we had got in the previous slide; we will see that if we plot the last column that is wall and ceiling treatment.

You will see it is coming like from wall to ceiling wall and ceiling it is gradually growing and getting static at 16; starting from 15 little less than 15 it is going, you can go further down. And if we look into the wall absorption, if you look into the ceiling absorption only you will see gradually with smaller areas the curve is decaying down

So, the ceiling is not effective when we are going for smaller and smaller size rooms and when we are looking into walls only, we are seeing that walls are more effective when we are looking into looking for smaller size rooms. And for bigger size rooms the ceiling is more effective. However, if we can make a mix and match this is for the entire room getting treated, but in actual we do not treat the entire room.

So, we can actually develop such curves considering how much part of the ceiling or how much part of the wall surface we are actually treating and what will be the total reduction. So, if we can plot for particularly for big spaces, auditoriums and all we can see how effective is the application.

So, what we see here is that at 1 the wall area and the ceiling area is same so; obviously, it is giving it is merging at 12 dB at around 12 dB. And we will see that around 400 that is 2 when the ratio is 2 between wall and ceiling, we see that ceiling is effect feeling is less effective, but as wall is more effective. And hence the inference is treating ceiling is more effective for big room whereas, treating the walls is with absorbers is a better solution for rooms of smaller volume and we can leave the ceiling in cases.

But for each and every case by if we can develop this particular table we will be in a position of increasing or decreasing the area or increasing or decreasing the absorption coefficients such that we can compromise with the we do not make any compromise with the design criteria and we can actually find out what is the total absorption happening within that room and leading to the noise reduction.

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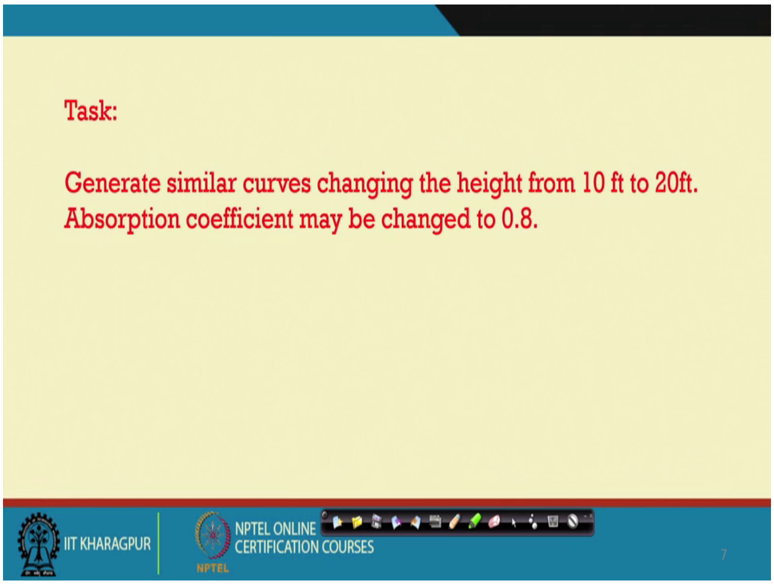

So, our objective is to fulfill the reverberation time. And if that is our objective then we can actually control all these factors through excel sheets, simple running excel sheets and we can solve our purpose. So, you task would be to generate similar curves changing the height from 10 feet to 20 feet; may be one case changing the absorption coefficient 2.8 you can go for even 50 percent of the wall being covered you can see the behavior because you know first part of the wall is helping to reinforce sound through reflection.

So, you can work out another with 50 percent coverage and these will actually enrich you with or develop you help you develop the understanding how the walls and the ceiling should be treated to get a good acoustical quality; when you know what is your target. Whether it is for speech, whether it is for music what is the performance going to happen in that particular space.

So, depending on so many parameters you have to create this table. So, hope you understood the purpose of this lecture and we will again continue with some more of the absorbers which we can actually make use without taking help of the structural support that is of the boundary condition.

So, we will discuss on those in the next lecture.