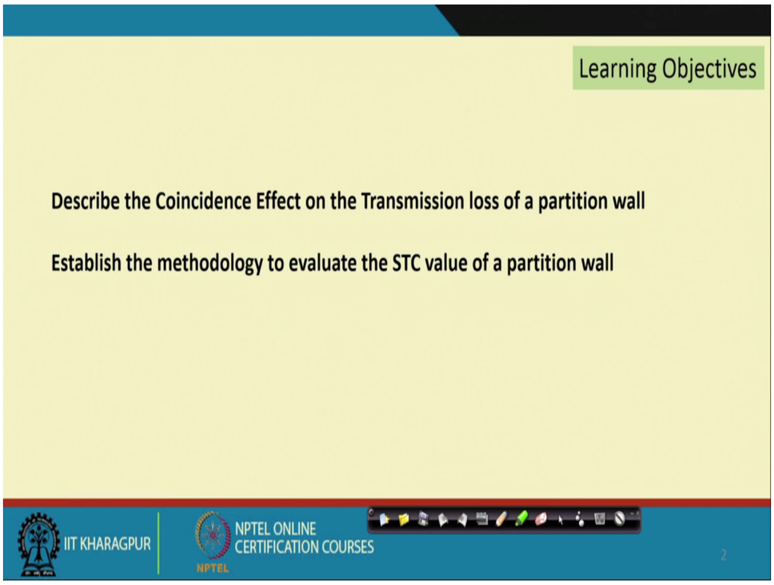
Architectural Acoustics
Prof. Shankha Pratim Bhattacharya
Department of Architecture and Regional Planning
Indian Institute of Technology, Kharagpur

Lecture – 33
Air Borne Sound Transmission (Contd.)

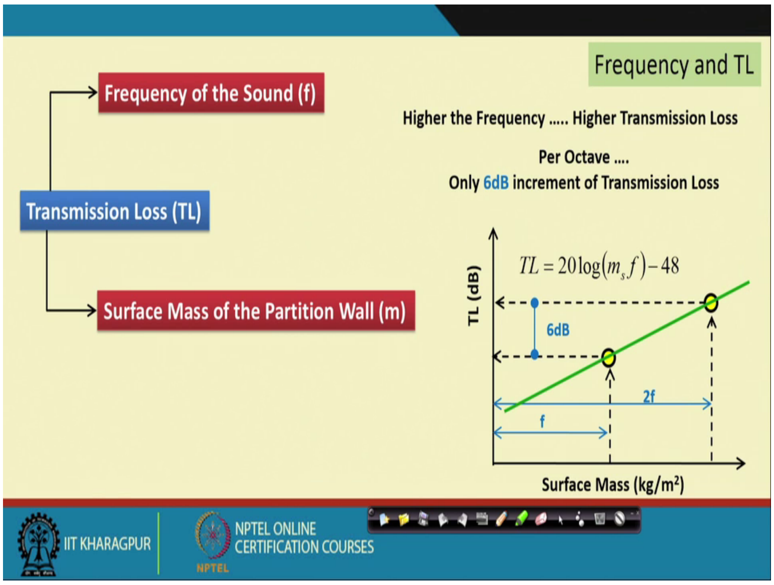
Welcome to the 33rd lecture on the course NPTEL course on Architectural Acoustics. We are in the se 7th week and this is the third lecture of the 7th week in the last lecture on the airborne sound transmission. So, the lecture title is a Airborne Sound Transmission 3.

(Refer Slide Time: 00:37)



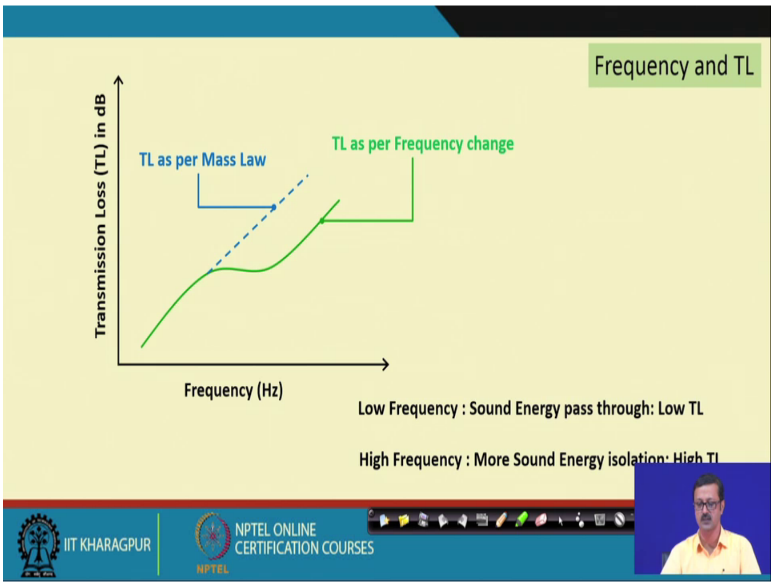
So, the learning objective of this lecture or we will describe this lecture, what is the coincidence effect and what is the impact of the coincidence effect in the transmission loss of a partition wall. And, we will try to formulate in a methodology and evaluate some value we have a partition wall that is called the STC- sound transmission loss value of a partition wall.

(Refer Slide Time: 01:06)



So, quickly go to the slide where we have already discuss this particular slide in the very first lecture of our sound transmission airborne sound transmission. This transmission loss TL is depend upon two physical parameter of course, there are various others also, but this two a very important and very significant one is surface mass of the partition wall and another one is the sound frequency. And as we understand that these per octave increase in the octave for per octave the sound frequency of if it is doubled from the lowered one the transmission loss is increased by 6 dB.

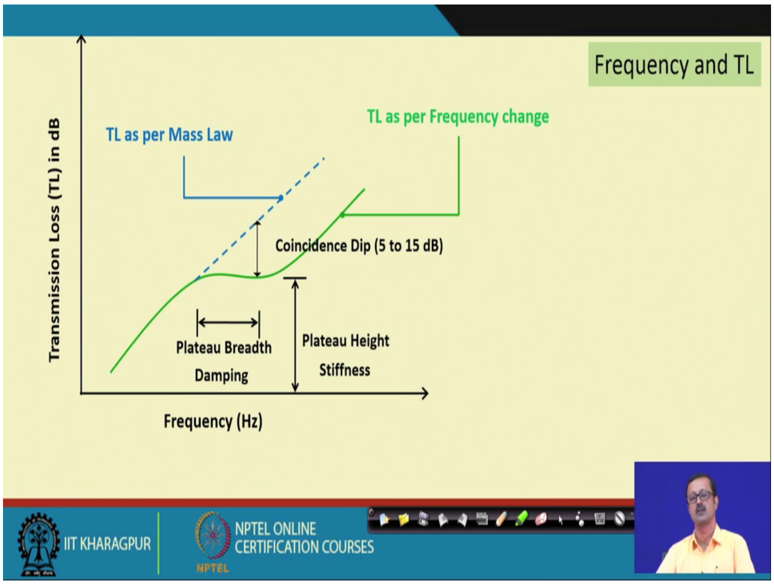
(Refer Slide Time: 01:53)



This is follow a kind of a stiff straight line graph kind of a think where we can plot the frequency in the x axis and the sound transmission loss in the y axis. And we can see their transmission loss is something like this through this particular follow this particulars straight line, but in actually in follow this green line where there is a sudden flat the plateau and they again there is a increment.

So, if you produce this line the blue dotted line this is a TL the transmission loss as per the mass law and this is green line indicate the there is a slight change in the TL as per the frequency change and there is a kind of a plateau is available here. And this is also through that the sound transmissions loss is low in case of the low frequency. So, the sound energy passes through in a low frequency less whereas, the high frequency more sound energy passes through so, there is a high TL value are sound energy isolate is isolation is very very high.

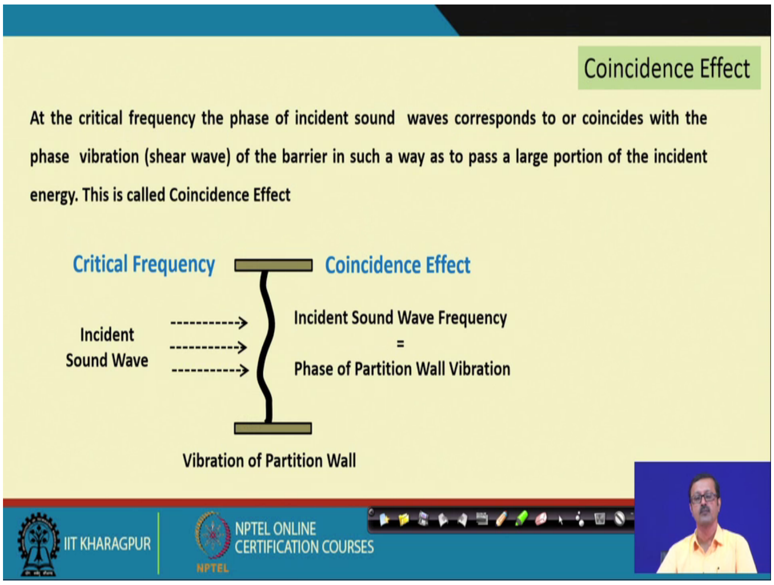
(Refer Slide Time: 03:12)



So, next is in this case again if I see this try to find out why there is point depression, why this particular kind of the change is occur and what are the significant role of this particular change in a partition wall. We say there are we can see that third 3 such the geometric parameter one is the this depth which is called the coincidence dip which is almost about 5 to 15 dB and this is a width of the plateau how much plateau will be long it shorter or the longer plateau.

It depends upon the damping of the this partition wall how much damping of the sound is going to create and this plateau height or this coincidence dip is 2 plateau height in this particular coincidence depend upon the stiffness of the partition wall how much it is stiff, how much it is rigid.

(Refer Slide Time: 04:21)

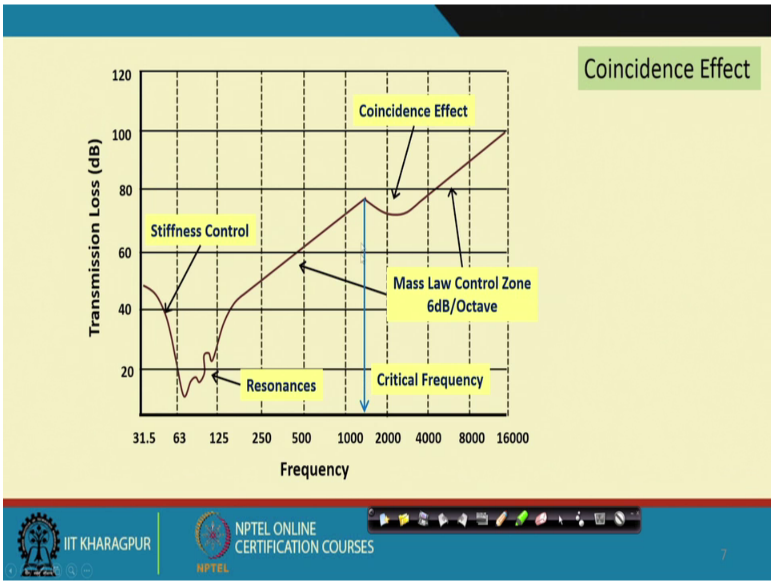


So, this 3 phenomena gives us a kind of a the kind of a understanding that, the even if the frequency if a frequency increases the transmission loss is going to increase, but it is not same for all the range of the frequency some where it is kind of a jerk. And there is again it is follow a particular straight line and this particular phenomena is called coincidence effect.

The coincidence effects is that suppose there is a partition wall and by virtue of the partition wall the mass and the stiffness and the damping factor an all those the physical parameters it has a shear wave capacity or the some vibration mode and this vibration mode can be describe with it is natural frequency. And if the incident frequency of the sound which is actually the incident sound wave is matches with this shear wave or the face of this particular vibration then this frequency the incident frequency. And it is own natural frequency matches together then there is a resonating effect then the sound will going to pass through the a maximum amount. So, that is why there is a sudden dip in this particular the par the TL value of the partition wall.

So, what happened is that. So, in any particular object has it is own natural frequency and if that matches with the incidence sound wave it is passes a huge amount of sound because of the resonance. And this vibration of this particular partition wall will coincident when it is coincident with the incident wave this called as a coincident effect coincident effect an due to that there is a gradual change or there is a sudden dip in this frequency and TL carve.

(Refer Slide Time: 06:27)



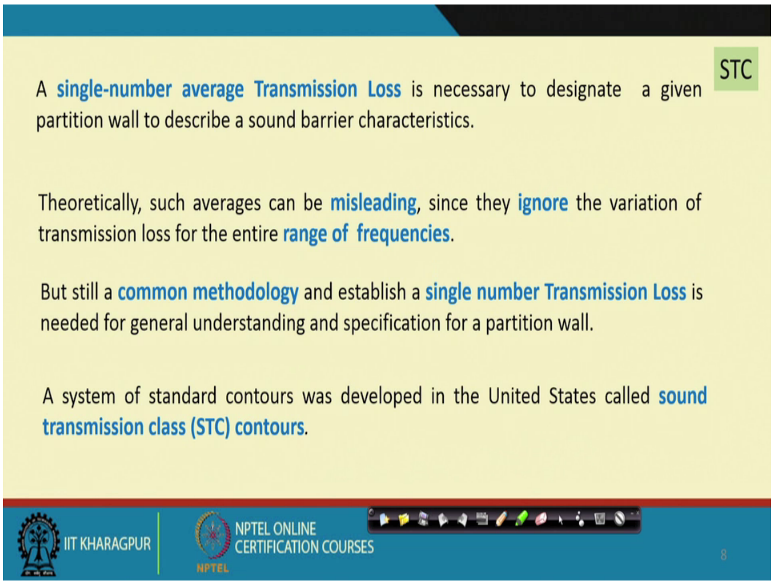
So, a normal frequency TL curve will look like this, the initial in short frequency range there is a lots of dips and undulations. This can be described as there are some kind of a stiffness control and there some kind of a localized resonated resonance is can be happened. So, that is whether is a some undulations.

Stiffness control means suppose a wall having the same surface mass, but it is stiffen by some regular interval by some structurally strengthen material then this particular the partition wall can be act as a very stiffen varied rigid and it can have a kind of a control in the particular frequency particular transmission loss. But if it is not stiffen the it is not in regular only in the ages or may be only one in between only in the ages then it is not that much of stiffen. and there is a decrease in the stiffness, and the TL values also, but after certain amount of the frequency after certain initial frequency band if you leave this kind of a disturbances then it is follow a straight line.

A follow straight line and this is your mass law, as per the mass law 6 dB increase as per the octave or the 6 dB increase as per the doubling of the mass also. It will continue in some portion and then there is a dip there is a coincidence effect, but is coincident effect will initiate in certain point. And it will follow a dip follow a plateau and that again it will follow the curve which is 6 dB per octave or the 6 dB is the doubling of the mass curve. So, this line and this line is parallel, but there is a offset between these two line there is offset between this two line.

Now, this frequency where this particular coincidence effect is initiated it is called the critical frequency or that is the frequency of the natural frequency or the face frequency of the particular wall which matches with the incident frequency. So, if we have a different partition wall and different material this critical frequency point may be somewhere here may be 500 or may be in 4000. So, this may change this may change depending upon the critical frequency point the changing, because of the nature and the material of the partition wall.

(Refer Slide Time: 09:27)



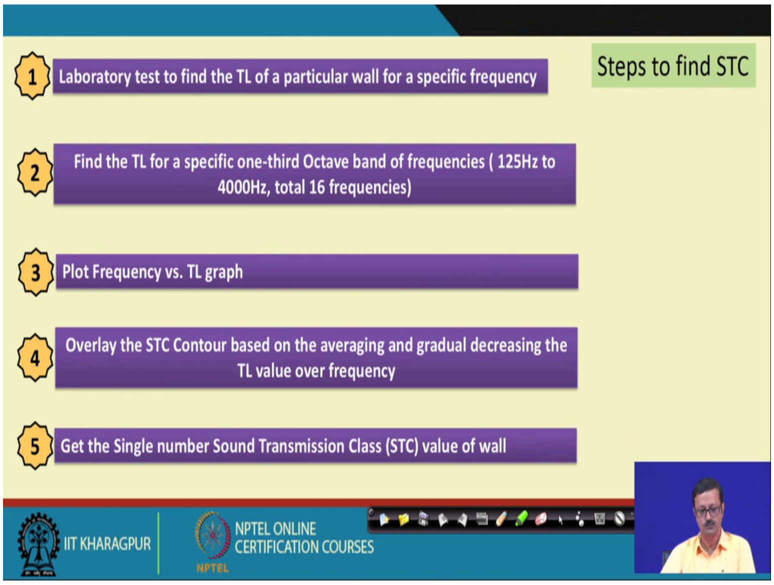
So, we are landed of in a problem the problem is the number one is the I need a single value of a transmission loss to design a particular noise beerier or a partition wall single value, why single number average value, because that is help me to decide to give it is some kind of decision, but which partition wall I will use for my purpose for my noise reduction, but a single value average value of the transmission loss is always going to be misleading, why it is misleading, because it is depend upon various frequency and not only it is depend upon various frequency there is a critical frequency also where there is a coincidence dip and initially there is some kind of a disturbance because of the stiffness and the damping.

So, if I calculate the average value for all the TL over the range of the frequency it will definitely going to misleading, but what is the way I can find out. So, still it is we are depending upon a single numbers transmission loss, it is some methodology as to establish that can the decrease this particular misleading phenomenal or it will just dilute some way may not it will be accurate in nature. But still is single number transmission loss can give me a kind of understanding, it is some method that yes this particular partition wall. If I use average in a term in a average term it may be a 10 percent error 10 to 15 percent error maximum, that give me this much amount of the sound reduction or the transmission loss.

So, for that a stranded system has been develop in united states that is called the sound transmission class STC via a STC contours and this particular STC contours was develop with a proper straight forward a worry the step by step order methodology by the ASTM, the American society for testing an material. So, will discuss that how this particular the steps the way is STC value of a partition wall can be formulated can be found out an any kind of the product the partition wall product manufacturer. And lot of the organization the those who are actually providing those kind of a solutions for the partition wall solutions or may be the noise acoustical solution for the room, they actually go for this STC number or the STC rating of the partition wall while designing any kind of the encloser.

So, there are 6 or 5 or 6 steps, the first one we have to test a particular partition wall in a laboratory for various frequencies also.

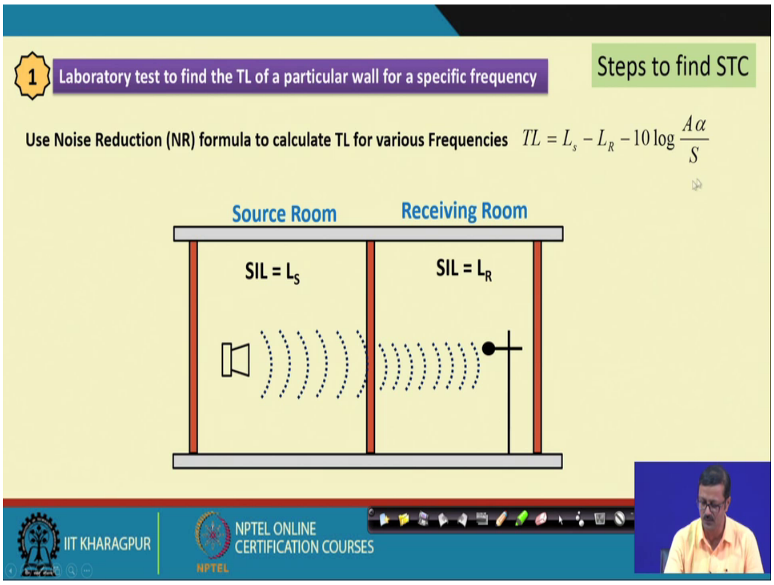
(Refer Slide Time: 12:54)



The frequencies as 16 frequencies it starts from 125 hertz to 4000 hertz. So, this one this 16 frequencies are all one - third octave band of frequencies in between 125 to 4000 hertz. Then we have to plot a graph in between the this frequency and the TL, then we have overlay the STC contour because this graph which is will plot in the state number 3 will be a very very haphazard kind of a graph. So, I have to actually slice of some of the points and I have to go with a smoothening this graph with kind of a contour, with kind of the different segment of a straight line and I find out the STC contour.

And the fifth and final the step is that from that STC contour I can get the single value that single value I am wanting for the STC value of a wall. So, all the 4 steps or this 5 steps has some typical methods or some kind of a rules and we will describe that rules one after another.

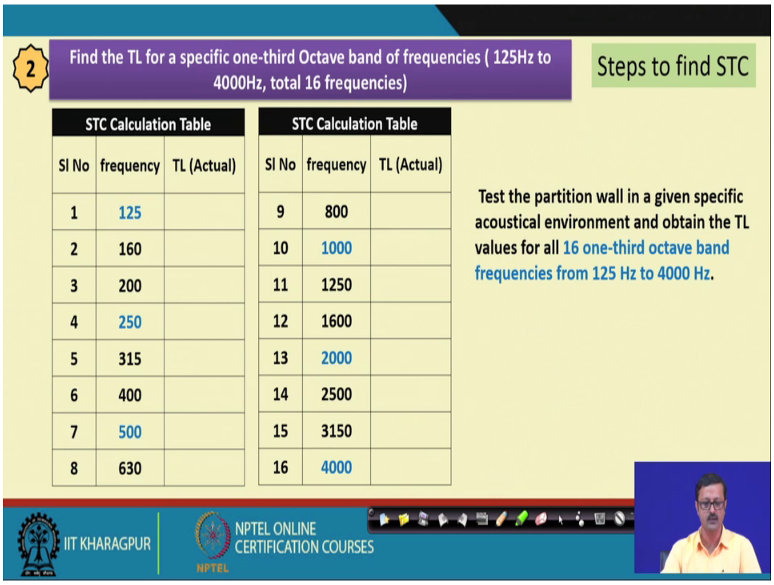
(Refer Slide Time: 14:09)



So, what is the first step is that you have to test the partition wall in a laboratory. So, we use that particular formula what we are use in the second lecture, the previous lecture, TL is equal to L S minus L R minus the 10 log alpha into S. So, this is the particular equation and if I have a microphone at the particular receiving room and a loudspeaker in the source room

; so I can find out with a d b meter, but what is the L S, that is a source room intensity of the sound and what is a level of the sound in the receiving room, I can find out this I no those values and A a S and alpha A s every think I can find out the TL values.

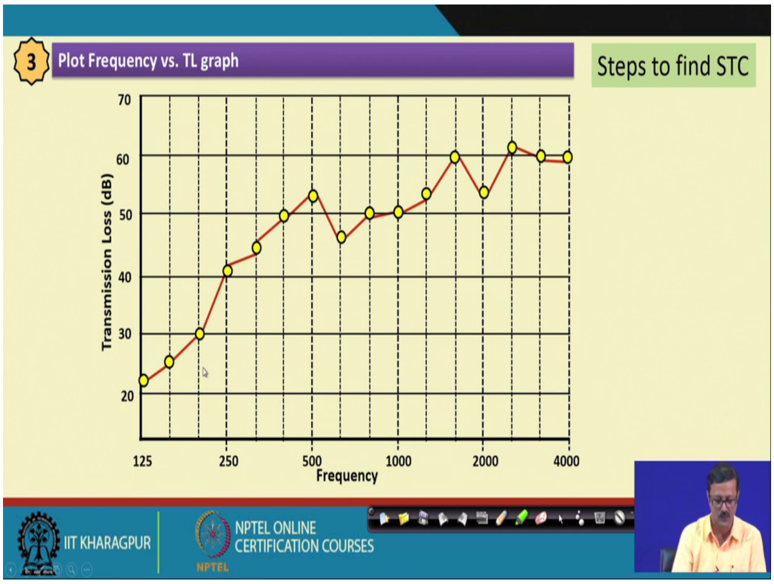
(Refer Slide Time: 15:01)



An if I know the TL values I now have a table where all the 16 frequencies are listed down and the I will I will find out all the corresponding actual TL value of all the 16 frequencies and all the frequencies 16 is form 125 to 4000 hertz actually cover in the one-third octave band and out of that this blue colour was at the octave band, the 125 250 in between that there are two one-third and 250 to 5000 there are 2 octaves us one - third octave like that.

So, these 16 frequencies are those TL actual value has to be plotted.

(Refer Slide Time: 15:45)

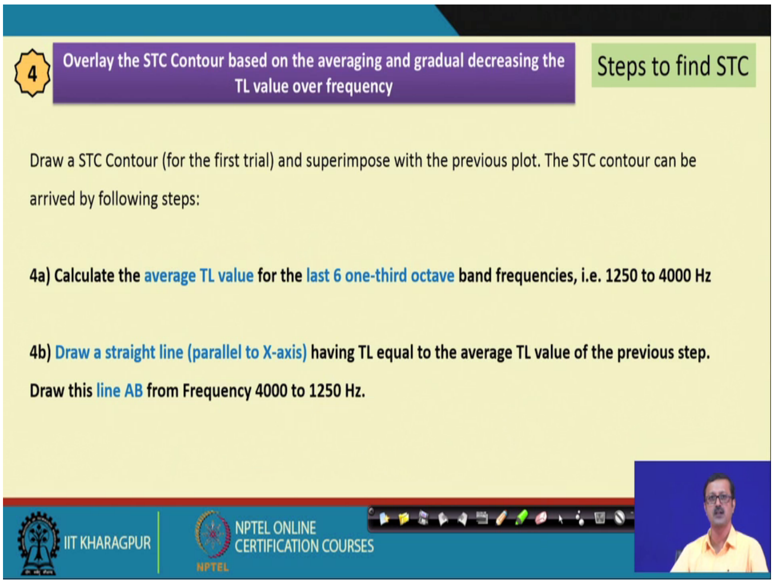


So, after plot in the frequency verses the TL plot for those 18 sorry 16 octave frequency, we will get the graph of this nature very haphazard kind of a graph, but even though this is a very haphazard there is a tendency of moving up I mean which is a in the positive kind of a graph. So, as in way in the frequencies increases you have TL value is increases, but it may not follow a straight line, probably at this particular point there is a follow is straight line there is a kind of a disturbance over here there is a deep and disturbance and there is another disturbance because of maybe there is coincidence effect.

So, there may be one or two coincidence effect in also. So, there are by virtue of the actual plot in grade those graph. But as I told in earlier first taking the averaging of all those values will not going to help me, because there are some the phenomena the coincidence phenomenon and all.

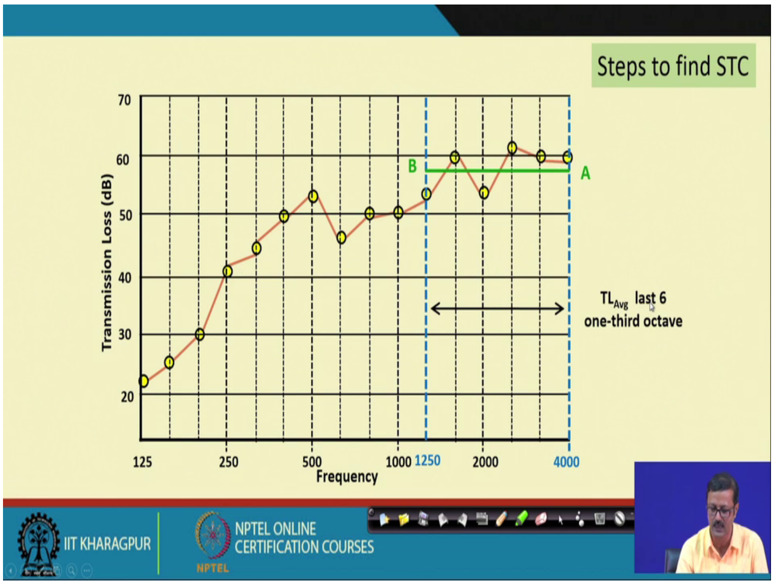
So, we have to go to the step number 4.

(Refer Slide Time: 16:56)



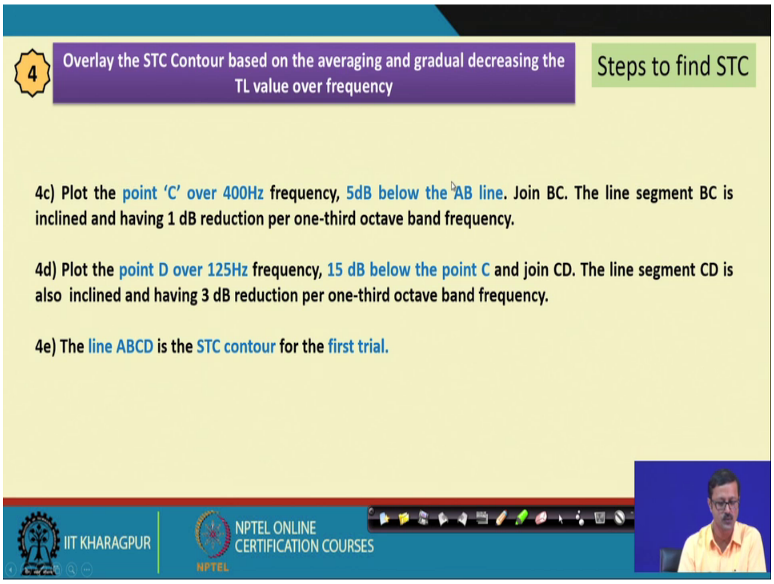
Where I will going to overlay a STC contour on that I will just going to cut off some of the points and try to fix some straight line in a some the method with their some method. What are the method? So, the first in this 4 the state number 4 calculate the average TL value for the last 6 one - third octave that is 1250 to 4000.

(Refer Slide Time: 17:22)



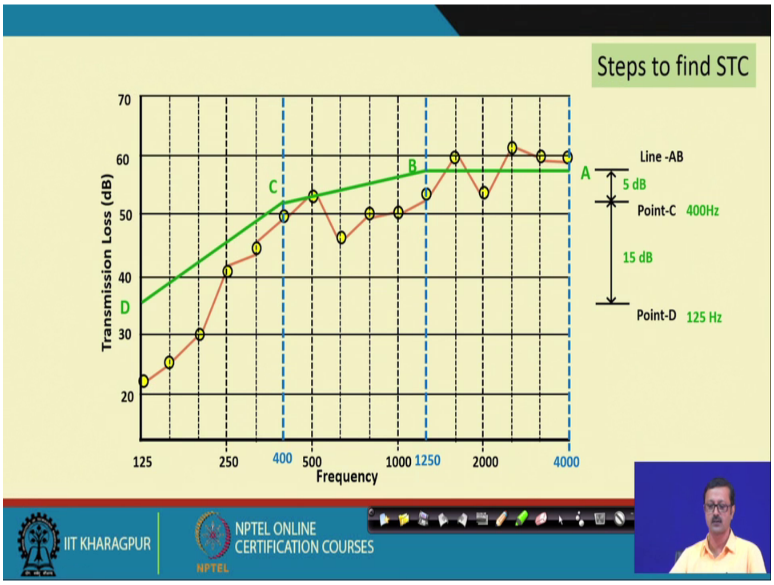
So, what I did is that you have to find out the what are the average of this 1 2 3 4 5 6 this last 6 TL value and find out the what is the average of that and you plot the you plot the line. So, draw a straight line parallel to x axis of that particular and find out this A B line is actually the average of those. So, some points should be above A B, some points should be below A B.

(Refer Slide Time: 17:54)



Now, let us go to the point number 4 c, plot the point c over 4000 hertz frequency and 5 dB below A B line.

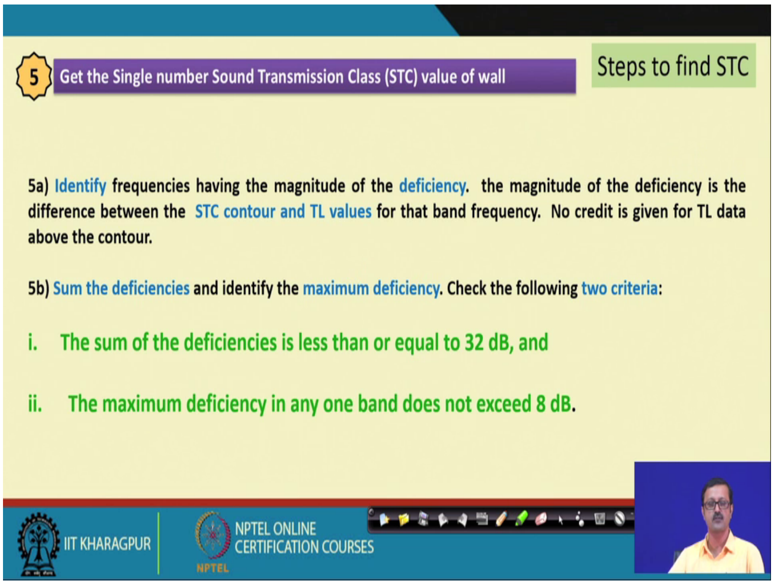
(Refer Slide Time: 18:09)



So that means now, you plot a point C over a 4000 frequency line and this will be below B how much below now 5 dB below B. So, you have you see this from 1250 this blue line to this 400 this blue line there are 1 2 3 4 5 gaps. So, the 5 gaps means per octave pa per frequency one - third octave there is a decrease of 1 dB. So, I got the point C the, I will join the line B, C also the line segment B C is inclined and having 1 dB reduction per octave one - third octave.

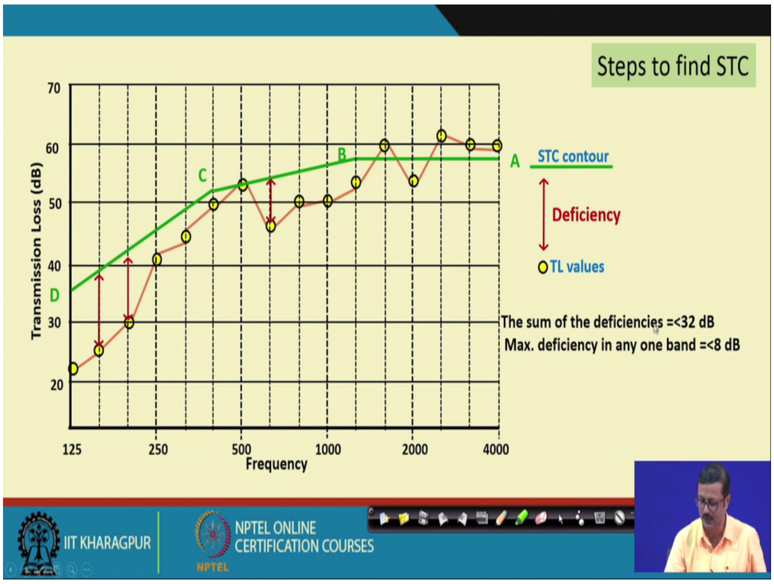
Now, I have to go to the point D, point D will be at this 125 the last line and the drop will be now 15 dB now this is again incline line to C to D and again from 400 to 125 there are 1 2 3 4 5 gaps. So, per one-third octave there is a 3 d b decrease per one third octave. So, if u go to that you see plot the D over 125 15 dB below and join this point C D the live segment C D is also inclined having 3 dB reduction per one - third octave. So, you are A B C D is the STC contour is completed. So, what I did is that, all those haphazard point is now strictly in a discipline manner a formulated a contour green contour line which is STC contour.

(Refer Slide Time: 19:54)



But this is not final you have to see some criteria, it is see a get a single number of this STC we have to find out some of the criteria, what you have to do in the state number 5 a is that, identify the frequency having the magnitude of the deficiency. What is the deficiency? The deficiency is that the difference between the STC contour and the TL value.

(Refer Slide Time: 20:20)

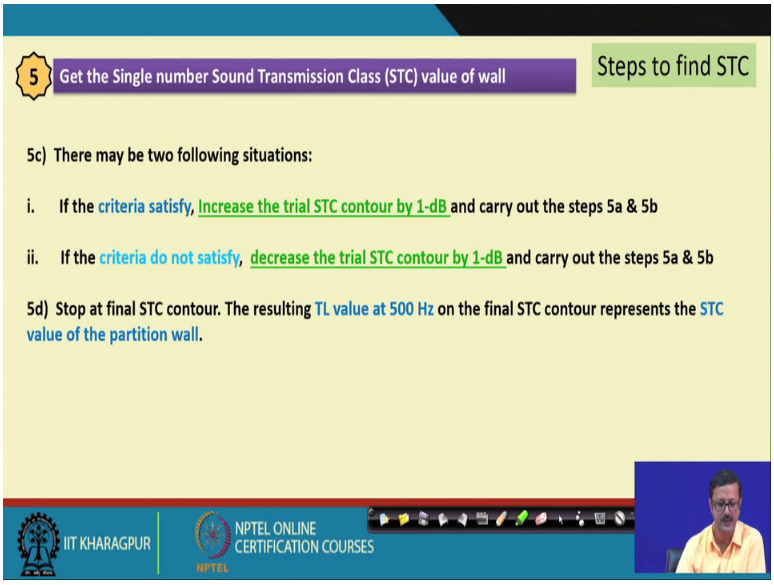


So, I got this contour ABCD and this line is somewhere it is plotting above and somewhere may be it is dipping below you are actual TL points. So, if it is plotting above so, there is a deficiency. So, deficiency is defined as STC minus actual TL. So, these are the deficiencies point, these are the deficiency point, but this is not the deficiency this is where the TL is above in your STC contour.

So, you have to find out this deficiency in the 5 b state number 5 b, sum of the deficiency is has to be calculated, what is the total amount of deficiency for all the 16 and we have to find out the total amount of deficiency is and you have to check this 2 criteria. The first criteria is that, the sum of the deficiencies is less than or equal to 32 dB and second criteria is that the maximum deficiencies in any one band does not exceed 8 dB this two criteria as to be full filled.

So, if these two criteria has to be full filled like so, the first some of the deficiency. So, these sum the amount of these deficiencies plus this plus this. So, this all sum of the deficiencies should be less than or equal to 32 and any one I mean you have to check everyone. So, the maximum deficiency it will be this one or may be this one, should not be less than 6 dB less than 8 dB.

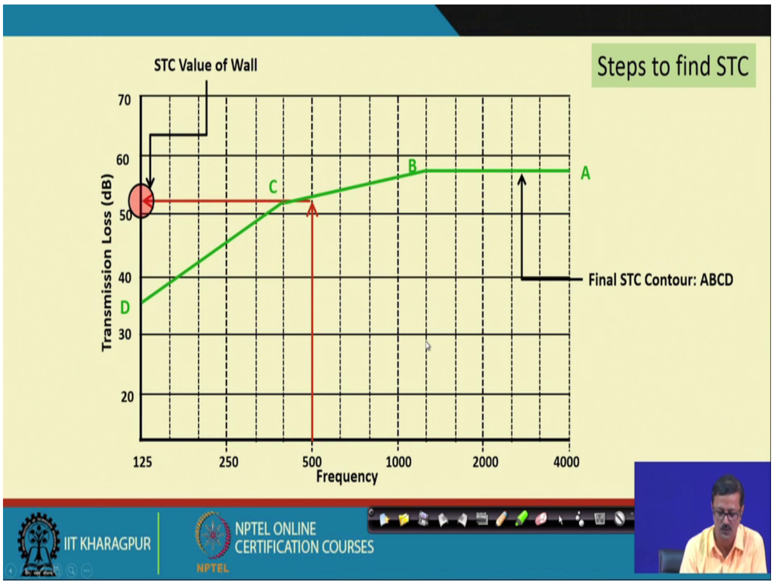
(Refer Slide Time: 22:03)



And at the final stage in the 5, 5 c we have to there are 2 situation, if all criteria both the criteria is satisfied a both the criteria satisfied we go to next trail of the STC contour we will increase the trail STC contour by 1 dB. And we will recalculated the recheck the criteria are the step 5 a and 5 b and come again and sometime is criteria does not match with the criteria the actual this deficiency or may not match.

So, then we will decrease the STC by 1 dB and again we recalculate or re do the step number 5 a and 5 b an it is a again a trail and in our process. And finally, we have to stop at a particular point where both the criteria is full filled matches and we will find out the STC value for the 500.

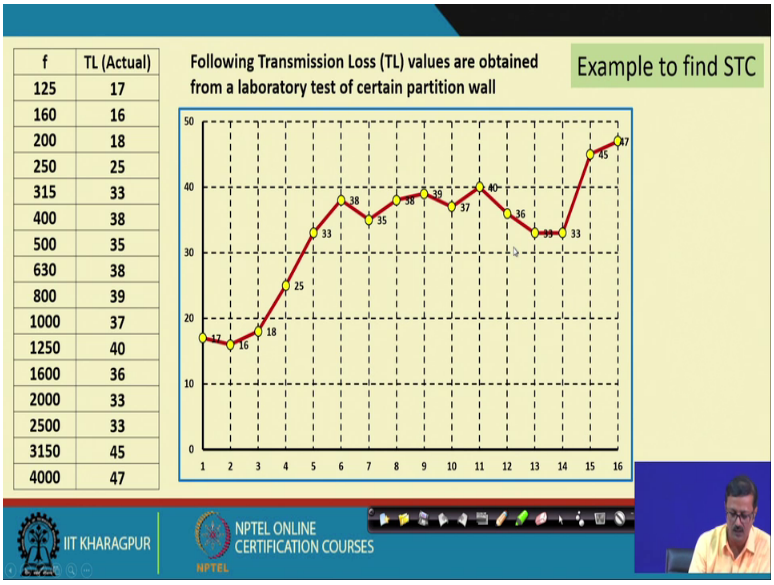
(Refer Slide Time: 23:08)



So, suppose this criteria is matches. So, I have remove those points and this is the final STC contour A B C D and then correspondingly 500 hertz frequency the value corresponding TL value will be my single value STC value of the wall.

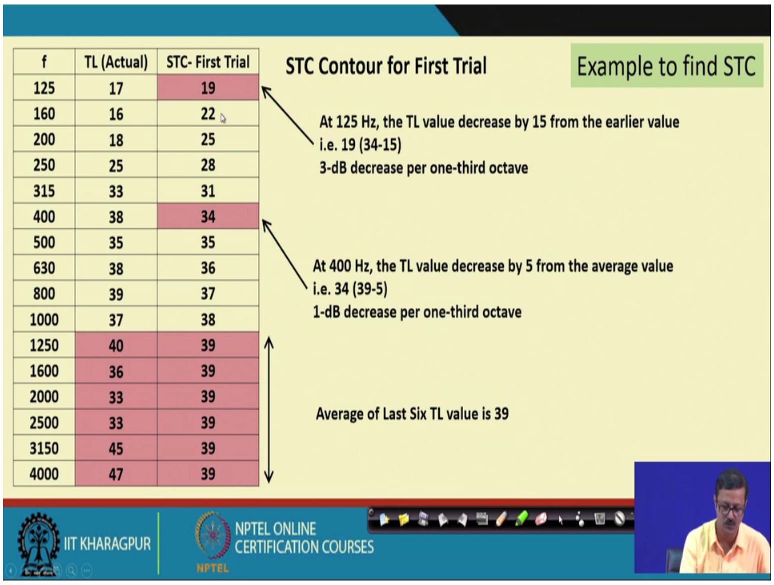
So, let us have a small example.

(Refer Slide Time: 23:29)



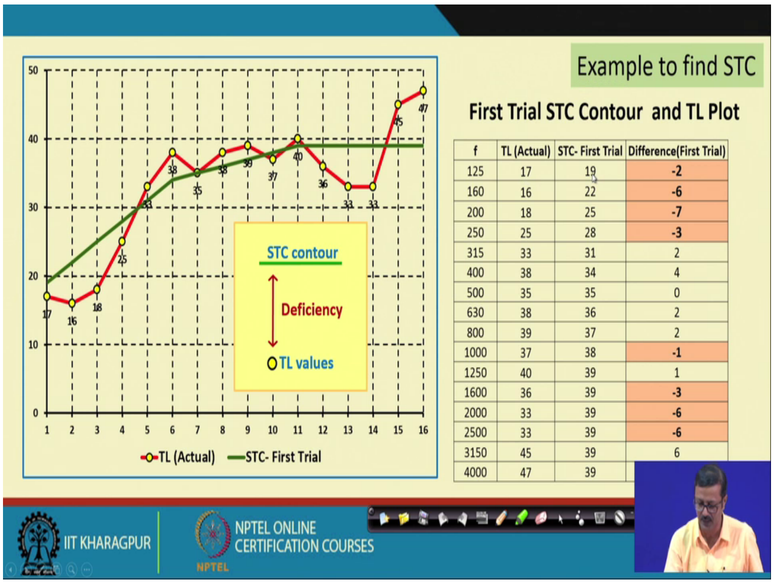
In this example what I did is that I have written down the actual TL value of a partition wall from 125 hertz to 4000 hertz all the 16 one - third octave band. So, by virtue of that if you plot will get a plot like this and you will see in this plot where some disturbance there is a straight line portion. And there is again a straightening got this may be a coincidence dip is a coincidence dip and I have written down all the values for all the 16 frequencies for and in the x axis I just mention the number of the frequency number the band number.

(Refer Slide Time: 24:14)



Now, you if you remember the first what I have to did is that, this last 6 this 40 36 33 33 45 and 47 just find out the average the average is 39. So, average of the last 6 frequencies 39. So, the next is that next point is that this 400 frequency here, the 400 frequency TL decrease the 5. So, this 35 minus 5 and 1 dB decrease per octave. So, 38 37 36 like that and this is 34 and then at 125 there is 15 dB decrease from the earlier and that is 19 why, 19 because 34 minus 15 is 19. So, there is a 6 dB decrease per one - third octave band so, 34 31 28 25 22 and 19.

(Refer Slide Time: 25:15)

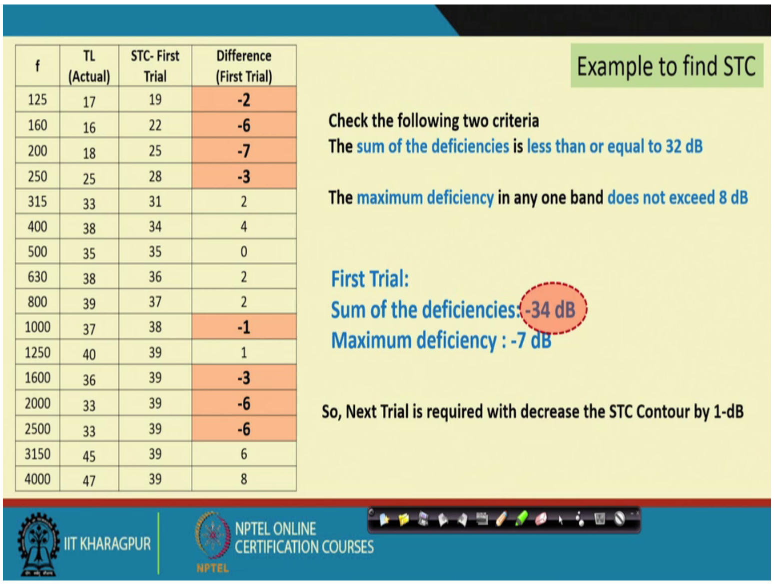


So, I can plot my STC contour overlay over my actual TL plot.

And now next step is that step of finding are the deficiencies see here, this is above this is also above this is again above there are again this 2 are above the STC. So, the above I do not want to take above, I do not have any interest I have only interest in this dips, this is a deficiency from the STC line to this the actual TL line, this is the point this is the coordinate where I have to find out.

So, I found out for all the this is the frequency one third octave band actual TL value by first proposed STC first trail values and this 19 and the this difference between 17 minus 19 suppose this is the first 17 and this is 19. So, deficiency is minus 2, minus 6, minus 7, minus 3, but here it is not deficiency is some increment of suppose it is the 315. So, this 33 and 31 33 and 31; so, those are positive and not at all interested with these positive values this positive values only I am interested in those in negative values.

(Refer Slide Time: 26:51)

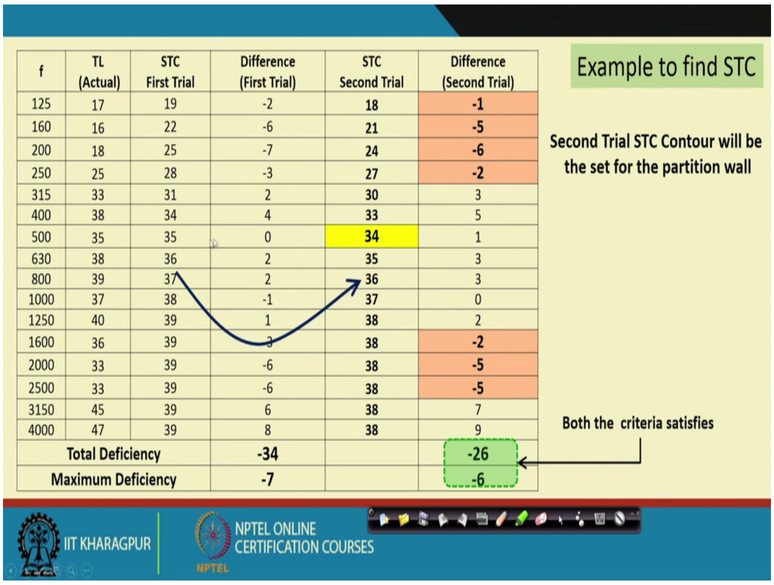


f	TL (Actual)	STC- First Trial	Difference (First Trial)
125	17	19	-2
160	16	22	-6
200	18	25	-7
250	25	28	-3
315	33	31	2
400	38	34	4
500	35	35	0
630	38	36	2
800	39	37	2
1000	37	38	-1
1250	40	39	1
1600	36	39	-3
2000	33	39	-6
2500	33	39	-6
3150	45	39	6
4000	47	39	8

So, what I did is that, I got the full range of the deficiencies and all those read or this colored cell I got the summation of that. So, in the first trail my all the summation or minus x. So, total deficiency is minus 32 dB and the maximum deficiency among this is minus 7. So, what are the criteria, if you remember the criteria the first criteria is that sum of the deficiencies is less than or equal to 32 is 34 minus 34.

So, I have to read do the things, but the second criteria is fulfilled it is not exceeded minus 8 it is just minus 7, but the first criteria is failed over here it is minus 34 I should have I mean there should be it is should be restricted to minus 32 dB also. So, what I have to do, the option is we have to go to the next option next trail second trail of STC contour. So, this STC line, the grill line I have developed that has to be lower down by 1 dB and if I lower down by 1 dB the deficiency is will be less and we have to recalculate.

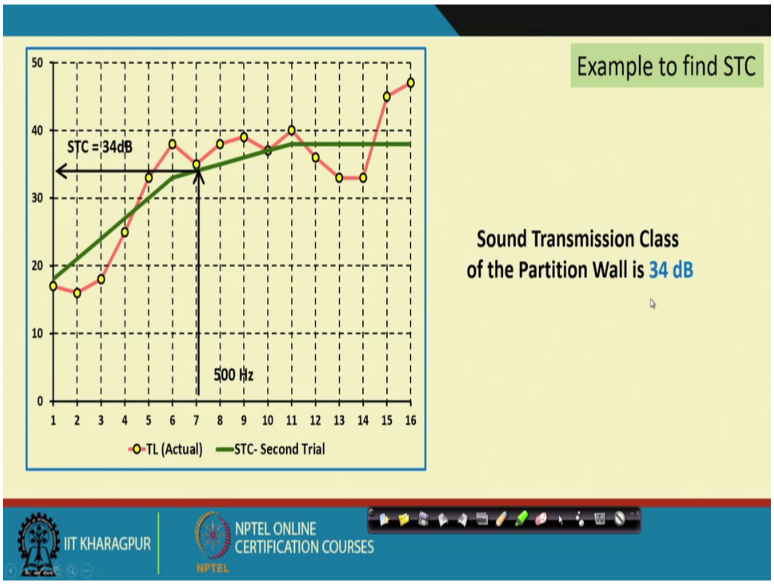
(Refer Slide Time: 28:04)


f	TL (Actual)	STC First Trial	Difference (First Trial)	STC Second Trial	Difference (Second Trial)
125	17	19	-2	18	-1
160	16	22	-6	21	-5
200	18	25	-7	24	-6
250	25	28	-3	27	-2
315	33	31	2	30	3
400	38	34	4	33	5
500	35	35	0	34	1
630	38	36	2	35	3
800	39	37	2	36	3
1000	37	38	-1	37	0
1250	40	39	1	38	2
1600	36	39	-3	38	-2
2000	33	39	-6	38	-5
2500	33	39	-6	38	-5
3150	45	39	6	38	7
4000	47	39	8	38	9
Total Deficiency			-34		-26
Maximum Deficiency			-7		-6

So, I have the second trail with me it was a first trail and the first trail I had deficiency is are calculated minus 34 minus 7 and all. So, my second trail what I did, I have just decrease the value the STC contour by 1 dB c, this is 39 over here, this is 38 last 36 38 in this 34 that is to 4 sorry this 35 I go on decreasing by 1 dB and from 400 onwards decreasing by 3.

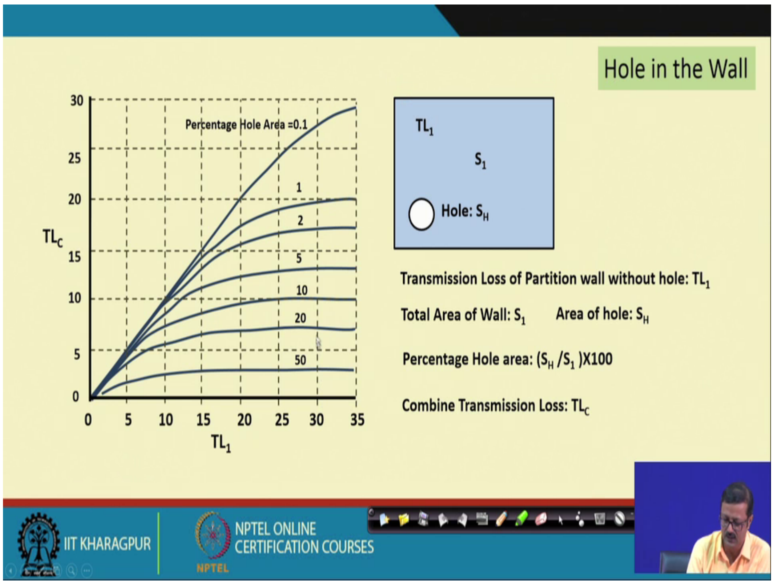
There is similarly what I did over here and let us see in this case these are the deficiency for the second case and if you add up this is minus 26 and the highest is minus 6 both satisfied the criteria. Now both satisfied criteria and I can stop here because I do not want to go to the further one less because definitely that will be again classify satisfy the criteria. So, my second trail of the STC contour satisfy the criteria. So, on that lying second trail the corresponding the TL value corresponding to 500 hertz is my is single digit STC value and that is 34.

(Refer Slide Time: 29:30)



So, 500 line hertz line striking to my this 34 this STC contour, that is give me the STC value this 34 dB that is how I found out this particular transmission sound transmission class of a wall.

(Refer Slide Time: 29:45)



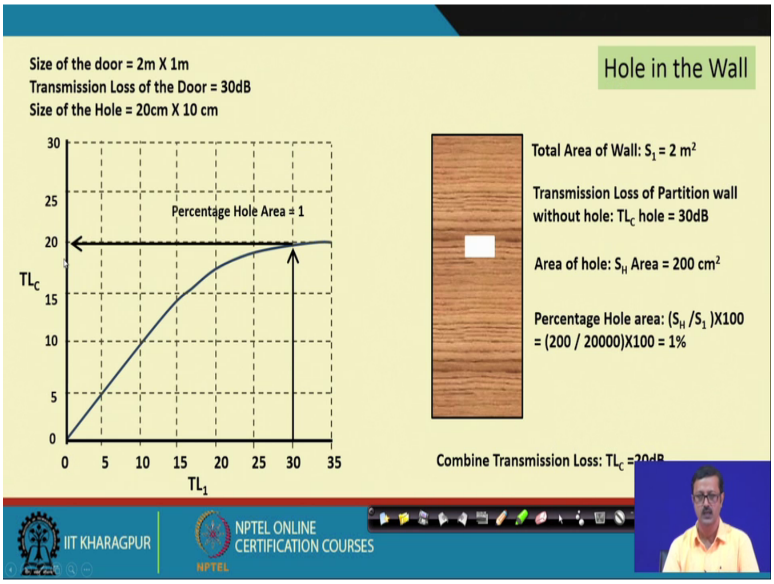
The next one is if there is a whole in the wall. So, this whole will actually try to leak the noise. So, it is depend upon how much amount of noise will be leaked through the hole, suppose it is a very wonderful partition wall made by double leaf and all those. And there is a hole that miss failure total the amount of effort an all to the reduce the noise from one source room to the receiving room. So, it is depend upon the percentage of whole area S H by S 1 into 100 what is this S H, the area of the hole. What is S 1, the total area.

The total area is S 1 and the S H is the amount of hole is ratio into 100 and what is TL 1, TL 1 is the transmission loss of the partition wall this partition wall and what is TL C, is a combined transmission loss of hole when it is a hole. So, the TL wall and the partition transmission loss of the partition wall is placed in the x axis an a combine partition the transmission loss of the partition wall with hole is plotted in the y axis. It is again the sum set of graph has been standardized by virtue of some experiment.

Suppose there is a graph. So, this is for the whole area is 0.1 percent. So, if it is 0.1 percent so, if can go with this graph suppose 25 percent of the 20 TL of the partition wall is 25 if there is a 0.1 percent of the hole it is little less than 25 may be around may be around 22 20 24 or something like that if it is 10. So, this is almost 10 there is no significant change.

So, as the whole area is increase and the percentage whole area also increases this particular graph is now lower down. So, if it is 1 percent you have to followed take this graph 2 percent this think. So, 50 percent of you see there is a 50 percent whole. So, then there is a huge reduction with 30 is equivalent almost 3. So, if there is a 5 percent of the hole is there a 30 actual gives you almost about 12 and also.

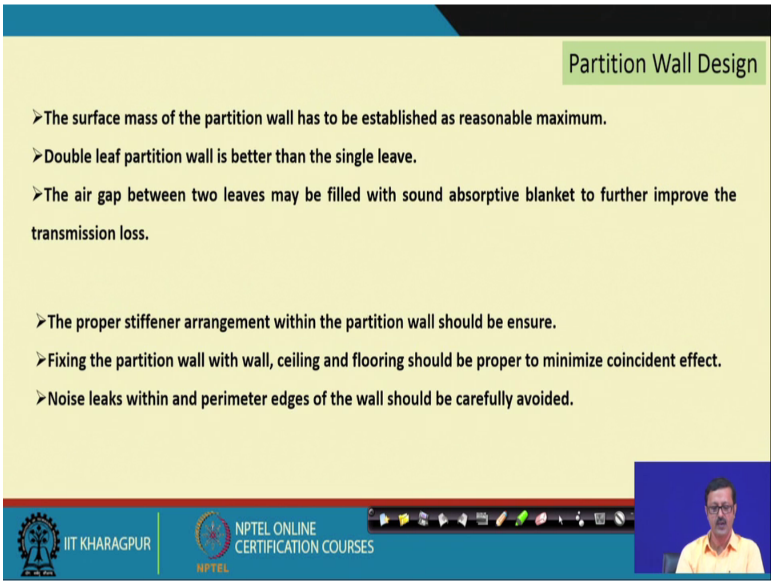
(Refer Slide Time: 32:25)



So, let us have a numerical problem we have a door of 2 meter by one meter and in this door the that is door is have a 30 dB TL and there is a size hole size there is a hole in that particular door which is having 20 centimeter by 12 centimeter. So, the total area of the door is 2 meter square is one and total area of hole is 200 centimeter square and transmission loss of the partition wall without the hole is 30 dB. There is a small the typological area this should be TL 1 is 30 dB and this percentage of the whole area is this so, this is almost 1 percent.

So, in that I have to see this 1 percentage curve percentage of whole area is 1 percent curve and as this is 30 dB this transmission loss of the actual the wall is 30 dB. So, this TL 1 you have to actually this is TL 1 TL values 30 dB. So, 30 dB is this and corresponding to that percentage of the hole area is 1 percent hole area gives you the combine transmission loss as 20 dB this is 20 dB. So, actually this the this particular hole of 20 centimeter by 10 centimeter over a door of 2 meter by 1 meter destroy almost 10 dB sound there is a leakage of 10 dB sound. So, that is all that this particular portion.

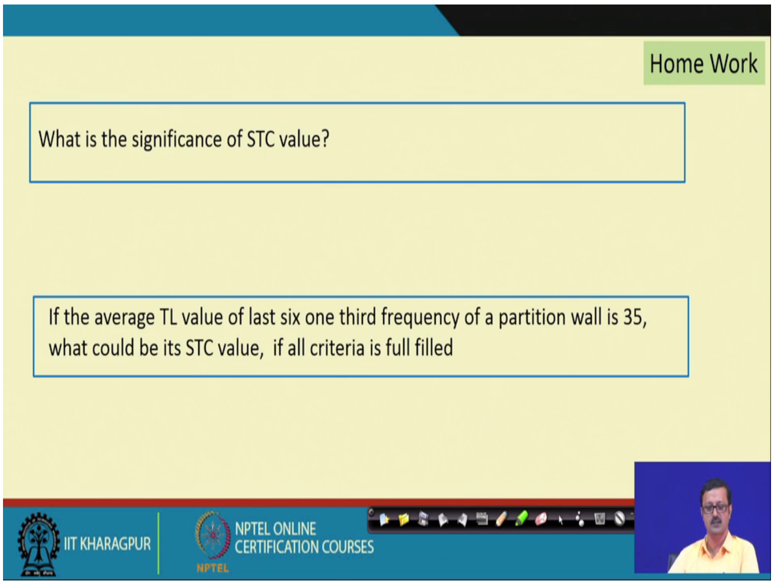
(Refer Slide Time: 34:07)



So, I have noted down some of the partition wall significant character the we have to increase the surface mass of the partition wall to established reasonable maximum to get a good amount of TL, these are the some of the partition wall design criteria or the guide lines double leaf partition wall is better than the single leave because there is aircushion in between. So, doubling of the mass is also and happening there is a internal aircushions that also improve the quality of the partition wall are the TL value of the partition wall. So, this is very important if we go with a double leave kind of think the air gap between 2 leaves may be filled with some kind of a acoustical blanket.

So, it also in hence the total amount of the transmission loss the proper stiffeners as you know the stiffener at attachment will actually reduce of those kind of initial disturbance. So, the stiffener arrangement is required and this fixing of the partition wall with the wall or the ceiling has to be proper, because of the minimizing the coincidence effect in the zone of the actual middle fix frequency and noise leaks that has to be checked. Because, as you know if there is any kind of hole or a any kind of a noise leak there is a decrease in the potential amount of the TL value.

(Refer Slide Time: 35:31)



So, let us go to the last page I have again to homework for you, one is you please write down or try to understand what is the significance of the STC sound transmission class value and the second one is that if the average TL value of the last 6 control the last 6 the frequency one - third frequency of a partition wall is 35 dB then what could be it is STC value if all the criteria is full filled. So, that is all for today. So, the air borne sound transmission is within with this 3 consecutive lecture number 31 32 and 33 is now to an end.

(Refer Slide Time: 36:18)

The next lecture on what 34 lecture and the 35th lecture we will discuss about the structure borne sound in this week.

Thank you very much.