Fundamentals of Acoustics
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Lecture – 71
Calculation of Reverberation Time and Sound Transmission Class (STC)

Hello, welcome to Fundamentals of Acoustics. Today is the 5th day of this course and today we will continue our discussion on reverberation time and actually figure out a way to compute the absorption coefficient of the room and once we know how to calculate this absorption coefficient of the room, we can use it to compute the reverberation time.

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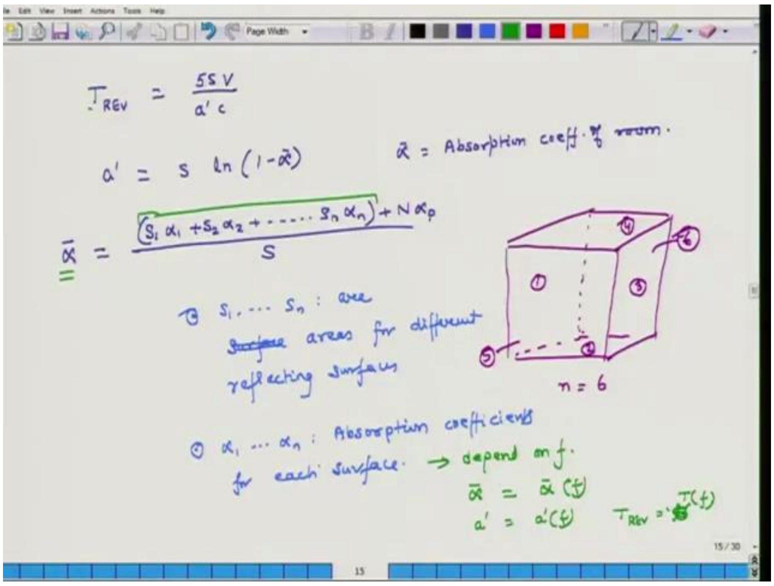

What we had discussed yesterday is that the reverberation time of a room equals 55 V divided by a prime c where a prime equals S times natural log of 1 minus alpha bar and S is the internal surface area of the room and we have to know what is alpha bar.

Alpha bar is called absorption coefficient of room. So, alpha bar equals. So, we can calculate it using this relation S 1 alpha 1 plus S 2 alpha 2 plus dot dot dot S n alpha n plus N times alpha p divided by S and I will explain that. So, let us consider let say this is a room now this is a rectangular room, but this relation is not valid, but just for explanation purposes I am showing this as a rectangular room because I can draw a rectangular room easily. So, this rectangular room as 6 reflecting surfaces 1 2 3 4 and then this is 5 and the back surface is 6. So, in this case n lower case n is 6.

Now, each surface may be made up of a different material may be surface 2 which is made up of which is the floor it may be made of wood surface 4 which is the roof it may be made up of concrete and then these walls may be covered with some acoustic tiles or curtain or some plastic sheet. So, for S 1, S 2, S 3, S 4, S 1 till S n are surface areas are areas for different reflecting surfaces.

When we look at the room, we identify different surfaces of the room and compute their areas either in cubic either in meter square or in feet square. So, those are surface areas and then alphas are absorption coefficients for each surface, how do we get these absorption coefficient? We will talk about it, but if I know alpha 1 till alpha n I can calculate this entire parameter this entire parameter.

Now, these alphas they actually depend on frequency which means alpha bar is a function of frequency and because alpha bar is a frequency function of frequency a prime is also a function of frequency and because a prime is a function of frequency, the reverberation time also changes with frequency. So, T rev is a function of frequency right. So, whenever we are computing the reverberation time, we have to make sure that not only we say that the reverberation time of this room is 2 seconds, but we also say that it is 2 seconds at 500 hertz or 1000 hertz or whatever. So, that specification has to be complete.

We know that alpha 1 alpha 2 are absorption coefficients. So, what is, what does absorption coefficient mean that if I send sound having one watts of power and this 1 watt of power is strikes this surface and if the absorption coefficient of this surface is 0.2, it means that 0.2 watts of power will be absorbed by the surface and remaining 0.8 watts which something which I will get back. So, that is what absorption coefficient mean now and then we have not discussed this, but let us first complete the discussion on alpha then we will come to n alpha p.

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Table 8.3.2 (a) Reverberation time (s)

Recommended Reverb Times (s) for Rooms of Different Sizes at 512 Hz

	Volume of Room (cubic feet)		
Usage	10,000	1,00,000	10,00,000
Speech	0.7	0.9	1.08
Movie Theater	0.93	1.1	1.3
Chamber music	0.98	1.18	1.4
School auditorium	1.03	1.26	1.49
Average music	1.17	1.44	1.71

These alphas you can find either from the internet or from standard books because there is a lot of work which has been done to document.

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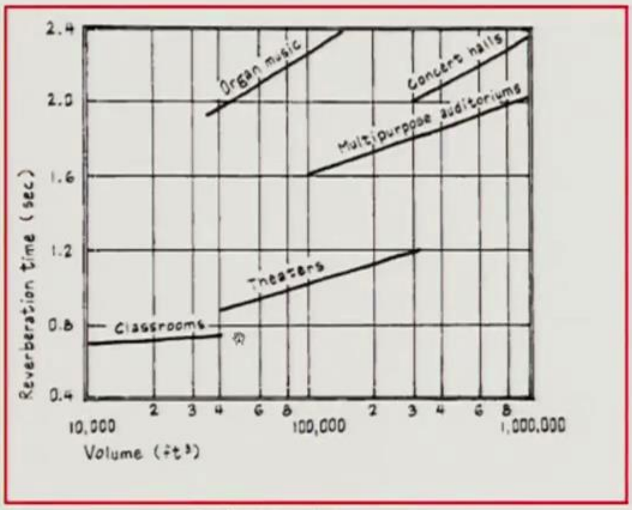

Fig. 8.3.2 Reverb time graph

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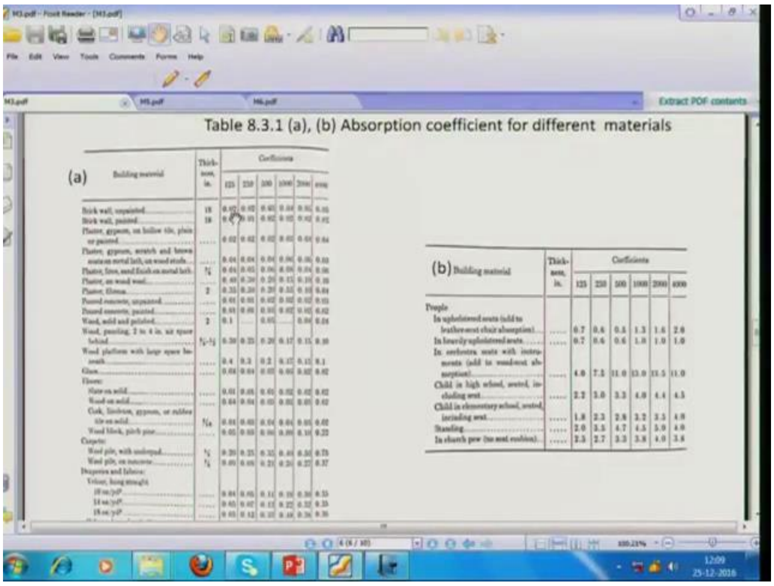

Values of absorption coefficient for different materials, now this is a table which I have taken from this book Acoustics by Beranek and this is the photocopy of that table. So, in this table you have a list of all sorts of materials brick wall printed brick wall unprinted brick wall plaster different types of plaster gypsum based plaster line based plaster on wood, wool past fibrous, plaster concrete, wood, glass, floor, cork, carpet, debris, that is curtains and so on and so forth and the absorption coefficient not only depends on the material, but also it is thickness. So, in this table they have also specified thickness, thickness for a brick wall, if it is 18 thick and so on and so forth.

For these materials with this thickness, the absorption coefficients are specified at different frequencies and these are again industry standard central frequencies. So, this is for the band and what they are reporting here is the central frequency. So, it is for instance brick wall unpainted has absorption coefficient of 0.02 at 125 hertz and it is 0.05 at 4000 hertz. So, it can change significantly.

Similarly, one more example plaster on wood wool is or fibrous plaster let us look at this row at 125 hertz 2 inch thick plaster 0.35 and at 4000 hertz, it is 0.01. So, these numbers can change very significantly. So, from tables such as these you can get information on all these alphas and then you can compute this term. So, S 1 you have to measure and alphas you have to get from literature then in a room you can have people you can have 2 situations, you will have people or you will not have any people and when people are there they also absorb sound. So, this capital N is number of people in the room and alpha p is a constant associated with people and in this alpha their surface areas is also included. So, that you do not have to measure surface area of individuals it is already taken care off.

Here you have S times alpha, but here it is n times just alpha where. So, the unit of this is meter square the unit of this entire term is also meter square, but alpha n unit is dimensionless. So, let us look at this table again. So, it says for people, we have people and they are different types of people, people in seats with upholstery which means they have lot of questions and things like that or in simple seats leather seats or in wooden seats and for different frequencies the absorption coefficient alpha p are indicated here. So, from here you can get alpha p for different situations.

With this information you can calculate n times alpha p and from that you can find out the value of alpha bar once you know alpha bar then you can compute a prime and from a prime you can get the reverberation time.

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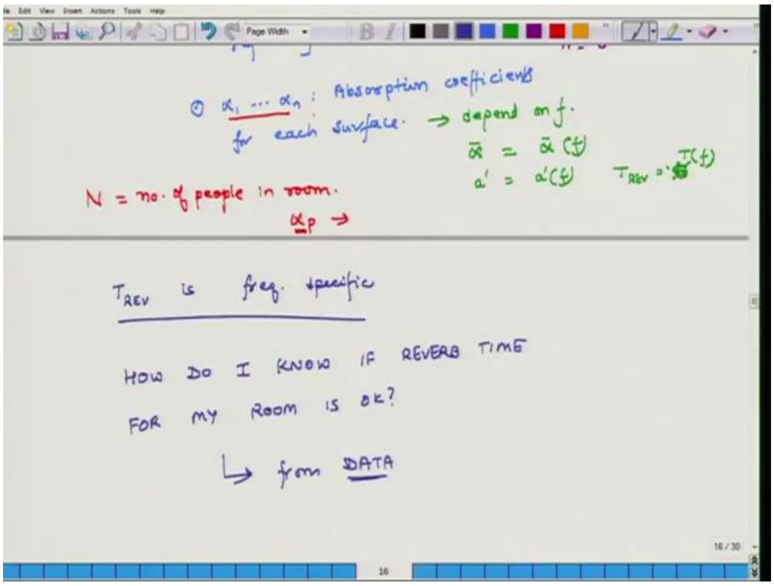

Once again it is important to remember that T rev is frequencies specific. So, now, what I have explained to you is that if you have a room and you know all the materials in the room and it is areas you can compute it is reverberation time using this method and it gives you fairly good results.

The next thing is what do you do with this? So, let say I have a reverberation time of 2, how do I say that this reverberation time is good for the room which I am going to use. So, the question is how do I know if reverb time for my room is suppose I am able to calculate reverb time, but I have to make sure that for the room which I am going to use is it or not. So, the answer to that is from data you have to go and search for data and I will show you some pieces of data. So, this is 1 chart and let us looks at what this chart tells us?

I think this chart as been conciliated for 500 hertz. So, what does it say on the x axis you have volume of the room. So, may be a small room will have a volume of 10000 cubic feet and a medium size room we will have volume of 1 lakh cubic feet and the other extreme is very large room or an auditorium may be have it may have one million cubic feet or something like that. So, and then you say that what is going to be my application am I going to use my room as a classroom or should I will I be using at theater or will I use it as a place where I will just play music organ music organ you know or I will play a lot of musical instruments. So, in that case it will be a concert hall or will it be a multipurpose auditorium where I will do dance drama lectures all everything.

Based on this and based on a lot of experiments and experience people have said that for is given the size of a room and also it is application there is an optimal reverberation time. So, if the reverberation time of your room is closed to that optimal number then your room as been correctly designed if the reverberation time is significantly different then maybe you have to change the layers and the surfaces of your room. So, that it is consistent with whatever requirements are.

For instances, if you have a classroom, what is the requirement in a classroom? All the discussion which happens is for speech, speech people do not play music or do drama and do not play all sorts of complicated music and all that is in the classroom. So, in a classroom all the frequencies associated with the spectrum of a speech they should be clearly understood. So, with that understanding in mind if the reverberation time is may be point seven seconds then it is good enough.

Now if you find that reverberation time in your room is not 0.7 seconds, but rather 2 seconds then it is a bad room because then there will be lot of echoes and people will not be able to hear what the teacher is speaking clearly. So, then you go and fix you room by putting in more curtains or carpets and things like that and change the thing for theaters the reverberation time is a little larger. So, for small theaters it can be may be point nine for large theaters it can go up to one point 2 seconds and so on and so forth. So, this is 1 chart, this is another table which gives you similar information. So, this says that recommendation reverb times for rooms of different sizes at 512 hertz and this is another chart.

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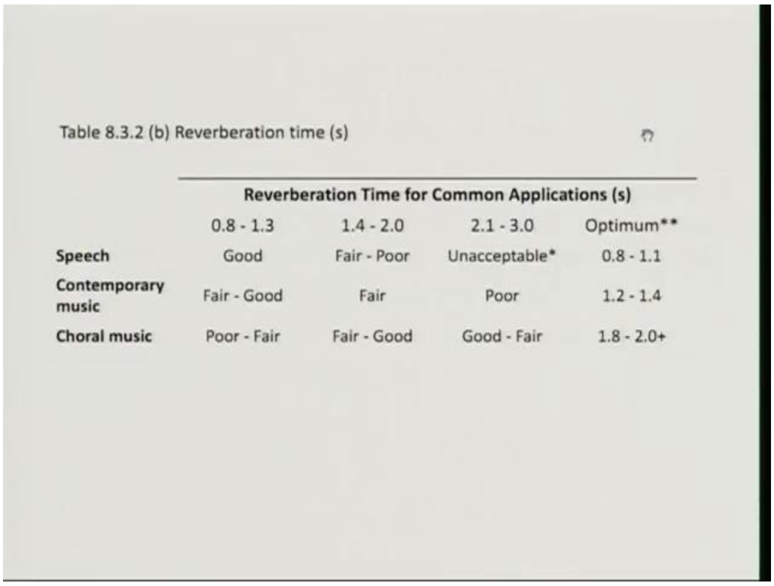

Table 8.3.2 (b) Reverberation time (s)

	Reverberation Time for Common Applications (s)			
	0.8 - 1.3	1.4 - 2.0	2.1 - 3.0	Optimum**
Speech	Good	Fair - Poor	Unacceptable*	0.8 - 1.1
Contemporary music	Fair - Good	Fair	Poor	1.2 - 1.4
Choral music	Poor - Fair	Fair - Good	Good - Fair	1.8 - 2.0+

Based on all these charts and data which are available in the industry you can design your room appropriately. So that your room sounds good and the most important parameter for to ensure that your room sounds good is this think called reverberation time. So, what you have learnt in this class is how to calculate the reverberation time and also how to ensure that it is consistent with your needs. So, that closes the topic for reverberation time and now we will move to a different topic. So, the second topic which we are going to discuss in today’s lecture is called sound transmission class.

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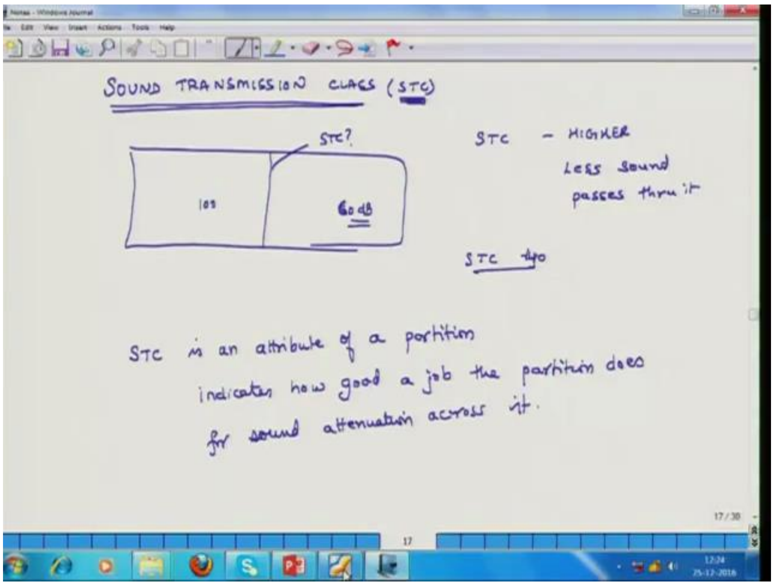

And a lot of times, it is also abbreviated as STC where do you come across this term sound transmission class.

Suppose you are constructing a house and you are going to put some windows in the house. So, you can make the windows in the for your house in 2 ways you make a frame and buy glass and buy and assemble it yourself or nowadays a lot of times you can also go and buy get readymade windows now if you get ready made windows and if your aim is to make sure that window not only provides you protection against heat and air and dust, but it also does a good job in terms of protecting you from external noise. So, it does not let noise from outside come inside easily.

Then you should ask the supplier or the vendor, what is the STC of the window, what is the STC of the window? Sound Transmission Class; you can also measure if you make window yourself you can also measure Sound Transmission Class for your own window and if you are buying it from some other person and if they have information they may for readymade windows you may want to ask what is the sound transmission class for the window, we are buying or for that sake if you are putting a door they may have a sound transmission class. So, or another thing is I am having a long room and I want to break it up into 2 rooms by putting a partition you know using some not necessarily a rigid wall, but some partition what is the STC for this by partition.

The higher this STC less sound passes through it, in general if the STC is 40 what that means is that if there is 100 decibels here then you will hear only 60 decibels on this side, but this is not an exact relationship this is approximate relationship in general because it also depends how the sound is coming from other walls you know because and from other areas so, but in general you know broad speaking sense like in Hindi [FL] STC number rating. So, this is a STC rating 40 corresponds to how many decibels sound can go down as it gets transmitted through that particular partition.

STC is an attribute of a partition and it indicates how good a job the partition does for sound attenuation across it. So, higher STC means higher sound attenuation higher STC means higher sound attenuation now let us get some physical understanding what these STC rating mean.

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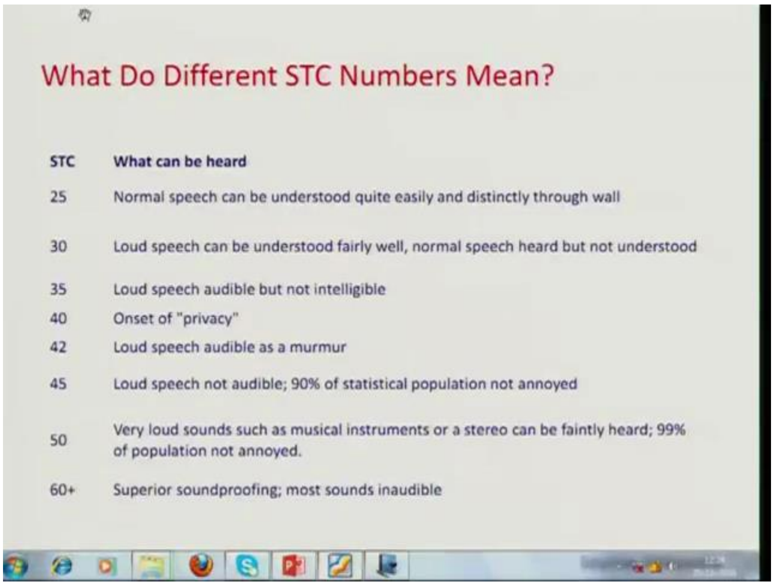

Suppose there is a long room and I divide this long room through a partition and let us say all the room walls of the room are rigid. So, no sound is coming from outside except through the partition. So, you have a long room in this room there is some noise source people are talking and all that and then I put a partition here and in this room I am observing what kinds of sounds I am listening too. So, if their STC rating of this partition is 25, if it is 25 then what it means is that whatever is been talked on the other side it will be understood easily and distinctly.

If you want just the partition, just for as a physical barrier, but not as a barrier for noise then the barrier with an STC rating of 25 will not do your job because whatever is been told here will be heard here, if the STC rating is 30 then only if the guy on the other side is talking loudly he will be heard clearly normal speech is not heard and understood if the STC is 40, if the STC is 40 then the other room is somewhat it says onset of privacy somewhat private compared to the adjacent room.

So, whatever is happening in that room, you may not be clearly aware what is going on in this other room, where would these type this privacy requirement be important? Suppose you want to have a confidence and you are want to discuss some confidential things you and you do not even want that the person in the next room is aware that some discussion is happening. So, in that kind of a situation this is important in hotels, you have divides between 2 adjacent rooms and for safety and security of people who are living in adjacent rooms you do not want that person in room A knows whether there is person in room B or not. So, that is there.

If STC is 50 then very loud sounds such as musical instruments or a studio can be faintly heard, but 99 percent of the population, does not get annoyed even with these small faint sounds. So, these are different types of. So, this is the meaning of STC. So, based on your application you can, I want a partition with 45 STC rating if you want that only loud speech even loud speech should not be audible. So, this is what is based on requirement now what kind of partitions give what kind of ratings.

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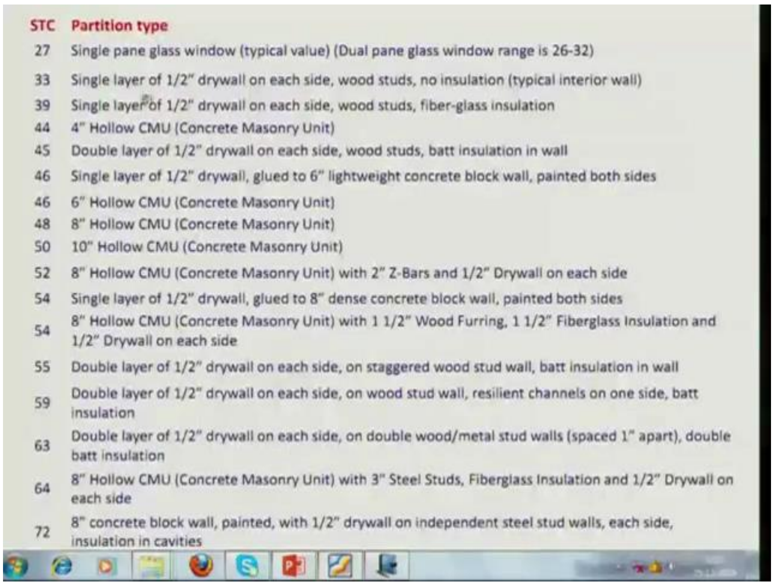

STC	Partition type
27	Single pane glass window (typical value) (Dual pane glass window range is 26-32)
33	Single layer of 1/2" drywall on each side, wood studs, no insulation (typical interior wall)
39	Single layer of 1/2" drywall on each side, wood studs, fiber-glass insulation
44	4" Hollow CMU (Concrete Masonry Unit)
45	Double layer of 1/2" drywall on each side, wood studs, batt insulation in wall
46	Single layer of 1/2" drywall, glued to 6" lightweight concrete block wall, painted both sides
46	6" Hollow CMU (Concrete Masonry Unit)
48	8" Hollow CMU (Concrete Masonry Unit)
50	10" Hollow CMU (Concrete Masonry Unit)
52	8" Hollow CMU (Concrete Masonry Unit) with 2" Z-Bars and 1/2" Drywall on each side
54	Single layer of 1/2" drywall, glued to 8" dense concrete block wall, painted both sides
54	8" Hollow CMU (Concrete Masonry Unit) with 1 1/2" Wood Furring, 1 1/2" Fiberglass Insulation and 1/2" Drywall on each side
55	Double layer of 1/2" drywall on each side, on staggered wood stud wall, batt insulation in wall
59	Double layer of 1/2" drywall on each side, on wood stud wall, resilient channels on one side, batt insulation
63	Double layer of 1/2" drywall on each side, on double wood/metal stud walls (spaced 1" apart), double batt insulation
64	8" Hollow CMU (Concrete Masonry Unit) with 3" Steel Studs, Fiberglass Insulation and 1/2" Drywall on each side
72	8" concrete block wall, painted, with 1/2" drywall on independent steel stud walls, each side, insulation in cavities

If you have a simple glass window, a simple glass window and it is not leak proof and all that thing then, it gives you STC rating of 27. So, whatever is someone is talking on the (Refer Time: 23:22) side it will be easily heard here. If you have a STC rating of 45 then what you want in terms of the partition is, this is what a double layer you want 2 layers of half inch wall though drywall in each side and then they are connected with wood studs, batt insulation if batt insulation, there is some insulation in between. So, based on these different types of constructions you can get different STC ratings. So, if you want a STC ratings of 72 then what you really want is 8 inch concrete wall painted and then on top of that. So, you have an 8 inch concrete wall and then separately in front of that you have a drywall you know of this type material which is half inch thick and in and there is a space between the concrete wall and the drywall and that has to be filled with some insulation glass wool or some insulation things like that.

This is what STC rating means. So, the next thing in this context I wanted to talk about is how is STC rating evaluated?

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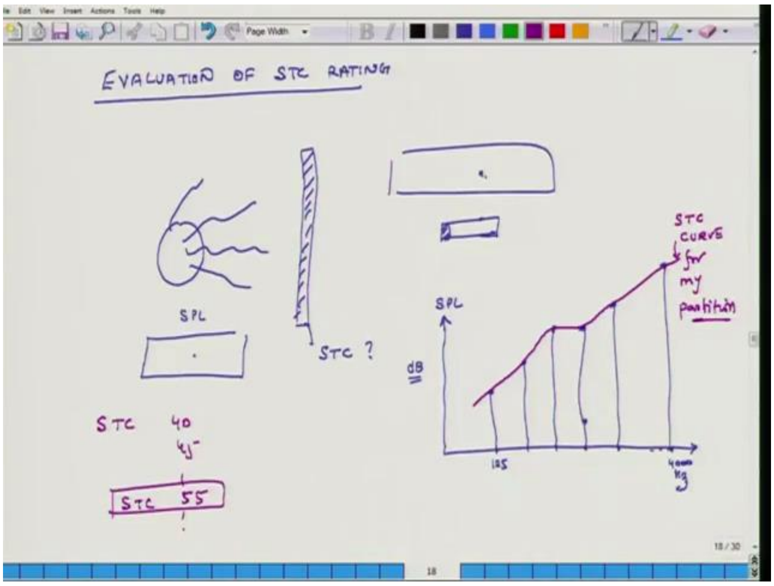

Evaluations of STC rating; so, what is our goal here, suppose I have a partition and I want to evaluate its STC rating. So, I want to know what is it is STC value.

What do I do? What I do is I play some sound here and using a microphone I measure the sound at on this side and so, I measure it here also. So, I measure the sound SPL here and I also measure the SPL here and then I make a graph and I plot data for different one-third octave bands, it starts from 125 hertz and it goes up to 4000 hertz for different octave bands, I plot how much sound as been reduced. So, maybe it is reduced like this, maybe it is reduced like that, how do I find this? So, here I found. So, this is in decibels how much sound is reduced how do I find it? I find the SPL as a function of frequency, here SPL has a function of frequency here and then I find I do octave band analysis here or one-third octave band analysis here I get or do octave band analysis on the other side take the difference of those 2 curves and I will get this difference curve.

Let us say that this curve looks like. So, if I join all these it looks something like this. So, this is the STC curve for my partition. So, now, I look at this curve and then there are if you go to standards there are several standard curves. So, there is a standard STC curve for 40 45 and so on and so forth. So, you say this curve looks very close to STC standard curve for STC 55. So, then you say that my partition as a STC rating of 55. So, that is how STC rating is measured and accessed.

That concludes our discussion on STC and that also concludes our discussion for today. Tomorrow we will cover 1 or 2 additional areas; one term is known as noise reduction coefficients, we will talk about that and we will also talk about reverberation chambers and anechoic chambers and with that we will close the discussion for this course.

We will meet once again tomorrow and with that have a great day, bye.