Basics of Noise and Its Measurements

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Lecture - 45
Reverb Time

Hello again, welcome to Basics of Noise and its Measurements. This is the third lecture for this week and today we are going to introduce a new topic called reverb time. This parameter which is known as reverberation time, you will see later in this week; that it will be very useful for all sorts of applications. But, the genesis of this reverb time parameter was in context of designing rooms, which have better listening properties.

So, what happens is that if you have a room where there are lot of reverberations, then when I talk or I speak, and suppose I say the word ‘stop’, and what happens is that the moment I utter this word ‘stop’, the first part is ‘st’, second part is ‘a’, third part is ‘pa’. So, I have pronounced ‘sta’, and that sound ‘sta’ reaches your ears. Then I pronounce ‘a’, then it again reaches your ears. But by the time it reaches your ears directly, the reflected sound in a highly reverberant room corresponding to ‘sta’, it also goes and reaches your ears. So while you are hearing ‘a’, you are also hearing ‘sta’ and you get confused.

And, so the perception of sound and speech becomes blurry and unclear. So, in that context people wanted to know, what is the reverberation time? How do you quantify this particular parameter? And, in that context there were some relations which were developed for measuring reverberation time. So, this is what we are going to discuss today but downstream, this reverb time was also used to characterize a lot of materials and for other applications as well.

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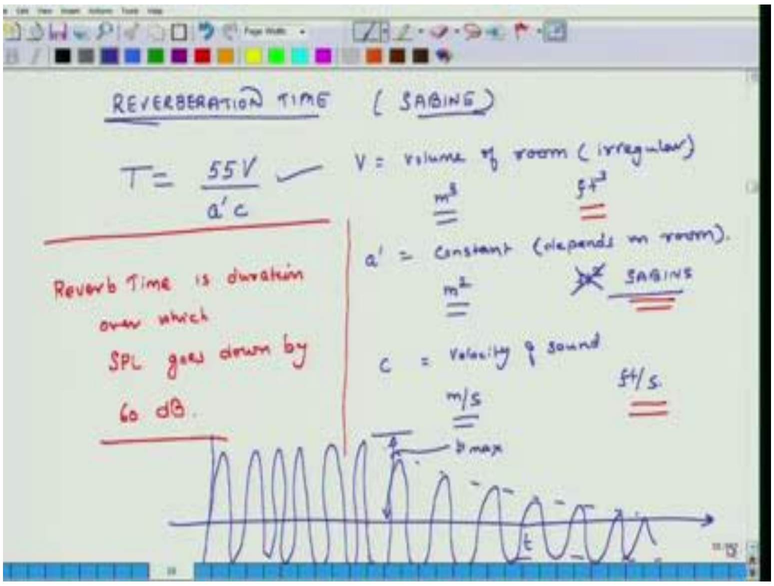

So, we will discuss reverberation time. So, at least in this lecture I am not going to give you a lot of theoretical background. But this, relation for this was developed by one scientist or a (Refer Time: 02:46), his name was Sabine. So, that is why the relation which we use to calculate reverberation time of a room is known as Sabine's relation. The relation is pretty simple. So, this is equal to 55 V over a prime c. What is V? V is the volume of room. It is the volume of the room. Suppose, I am in this room, and this room has to be irregular; what does irregular mean that does not have to be a perfectly rectangular room. Then, this formula may not be very precise. But, if there are some obstacles and lot of furniture is there and the walls are not higher, you know, highly regular and things like that then this formula works reasonably well.

So, V is the volume of room. And, you can either do it in meter cube or you can also have it in feet cube, but you have to be consistent in terms of units. Then, you have a prime. And, this is some constant and it depends on room. And, we will figure out how to calculate this constant. But, at least for the context of this lecture, we just keep it at that. This again, you can either have it in units are meter square or the units for this are feet square. But, we do not use this term 'feet square', rather we call it Sabine's. If I am in the feet system and then c is velocity of sound, it is velocity of sound. And that is either in meters per second or it is in feet per second. So, either I can use these units to calculate room constant or I use these units to calculate my room constant.

What is room constant? Because I have introduced this topic, but there is a mathematical definition for room constant. So, if I am in a room and I say something that sound will be heard by microphone directly; that will be the first thing. And, the microphone will record some sound pressure level. And then, there will be some sound from my mouth which will also go to the walls, it will hit the walls, reflect and reach your ears or the microphone. So, that will be reflected sound. Then that reflect, then over all what happens is these reflections keep on happening. And, your ear keeps on listening to the sound for some duration of time.

But after each reflection, the amplitude of the sound goes down a little bit; because while it is getting reflected, some of the sound gets absorbed. So after each reflection, the amplitude keeps on going down. So, reverb time or reverberation time is the duration over which sound pressure level goes down by 60 decibels. Basically, the energy level goes down by a million; a factor of million. So, that is what happens.

So, how do you measure the reverb time of a room? What you do is you have a room, you put a microphone in it and you do some very careful measurement. And then; so, you; this is time and let see you a play a signal. Let say a 1000 hertz tone. So, your 1000 hertz tone, you play. And, you will keep on playing it for some time, so that everything becomes steady. And then, you stop the signal. And then, what happens? This tone, as sensed by the microphone it starts decaying. So, your tone starts decaying. So, you make this recording of the pressure signal. And then, you say, this is my p max. And then, it has decayed, maybe after a time.

So, from this p max, I start counting time and then the duration it takes for this p max to go down by 60 decibels. That is the time which I identify. And then, I say that is reverb time of the room. So, that is how I physically measure the reverb time of a room. But, I can also calculate the reverb time of a room using some other methods. So, I calculate that the reverb time of the room using this formula; using this formula 55 V over a prime c. And, we will discuss this further.

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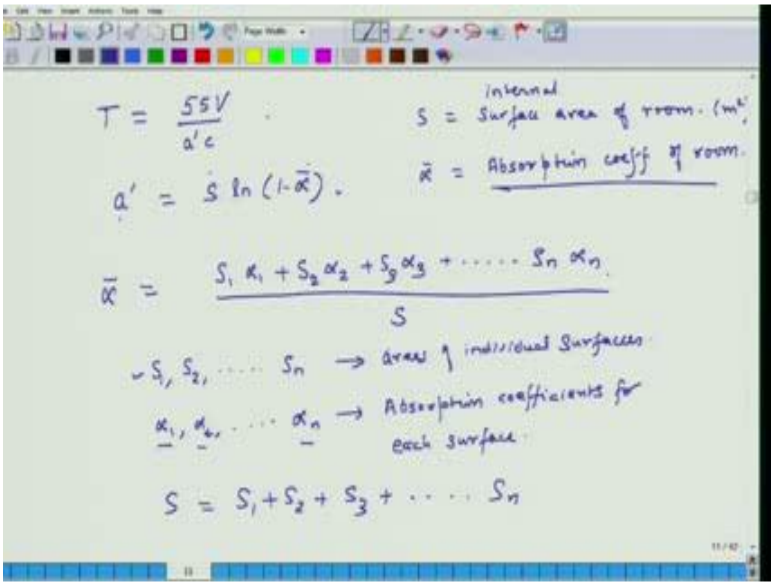

So, we had written that reverb time of a room is 55 V over a prime c. And then, you will say what is a. So, a prime is equal to s natural log of one minus alpha. Actually, it is alpha bar. And, what is s? s is the surface area; internal surface area of room. So, you take all the room walls and all the shapes inside the room and we calculate the surface area, internal surface of the rooms. So, that is this thing. So, this is in meter squares or it could be in feet square. And, alpha is the absorption coefficient of room, it is a dimensionless quantity. It has no dimensions. So, the dimensions of a are mathematically same as that of s.

But, in foot square system, at least when we prescribe a prime, we call it Sabine's. But, mathematically it would be foot square. But, the proper term to use is Sabine's because it is not the internal surface area. It is that multiplied by lan; natural log of one minus alpha. So, if I know s, which I can very easily, calculate for a given room because I can measure. And if I know alpha bar, then I know a a prime and I calculate T. But, when, what is alpha bar? So, alpha bar is given by another relationship; s 1 alpha one plus s 2 alpha 2 plus s 3 alpha 3, till keep on doing this over s. So, this is the formula. Where s 1, s 2, s n, they are all surface areas of, excuse me, they are areas of individual surfaces.

So, if I have a room which has 7 or 8 internal walls, then I or surfaces, roof, floor, different walls, door, window, I have to calculate each separately. Then, I calculate the area of each of these in meter square and make a list of those. And then, what I do is I find out alpha 1, alpha 2, alpha n. What are these alphas? These are absorption coefficients for each surface.

So, you have to identify each surface in the way that it is; the material of that surface has to be same. You cannot club the surface of a window with that of a wall because the absorption characteristics of window may be different than that for the wall than that for a curtain. Suppose, there is a wall covered with the curtain, that is a separate thing because there you have to calculate; you have to find the absorption characteristic of the curtain. If there is a wall without a curtain, then you have to find out or identify the absorption characteristics of the wall itself. If you have a floor which is of a wood, it is a different surface. Then, if you know these alphas namely alpha 1, alpha 2, alpha 3, alpha n, all these, then you can calculate the numerator. And, s is nothing but s 1 plus s 2 plus s 3 s n. So, s is the total surface area; internal surface area of the room.

Again, I can very easily find out s 1, s 2, till s n. I can calculate s. Though, the only thing now we are missing is how do I know what are alphas. If I know alphas, then I can calculate this prime. From a prime, I can calculate the reverb time.

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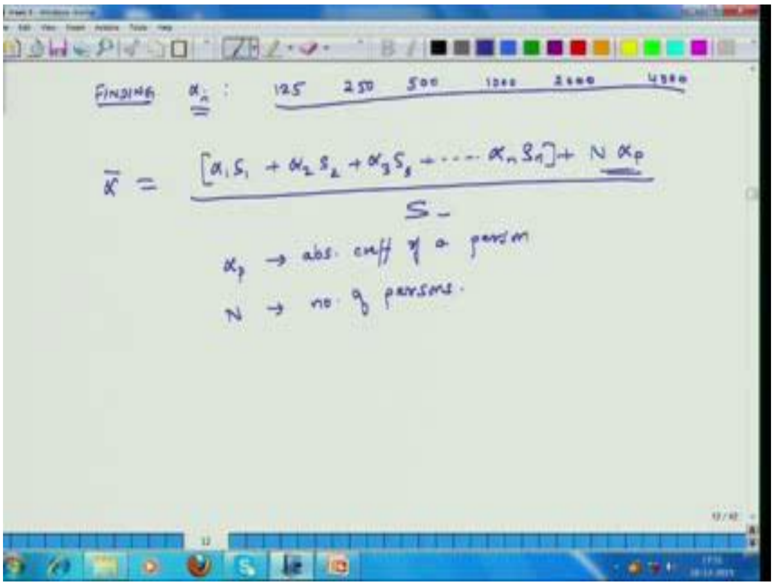

So, that is finding; this you do not calculate. You find it; Alpha i for the i'th surface and how; what you do? So, first thing we will actually show some tables. One thing to understand is that alpha is absorption coefficient. And, we had disused this earlier also that it can change with frequency. So, typically we identify alphas at 5 or 6 standard frequencies. So, what are these frequencies? Finding alphas, standard frequency is which you measure them at 125 hertz, 250 hertz, 500 hertz, 1000 hertz, 2000 hertz and 4 kilo hertz. At these different frequencies, you try to figure out their values and then for each frequency, you have a different value of reverberation constant for the room.

So, a reverberation constant changes from frequency to frequency. And these, for each frequency you can find the value of alpha from some standard literature, which is available in, you know, books or data sets and things like that. So, I will show you one example.

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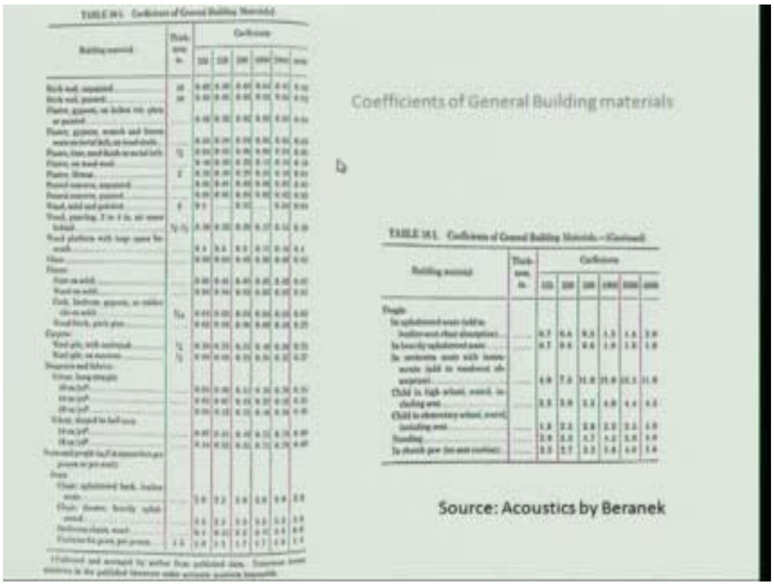

So, these are the absorption coefficients for general building materials. And this is; I have taken this information from this text ‘Acoustics’ by Beranek and what you have is a table. The part of the table is also produced here. So, suppose you have an unpainted brick wall and it is 18 inch, one and half inch, one and half feet, then its absorption coefficient people have determined at 125 hertz it is 0.02; 250 it is 0.02; 500 is 0.03 and so on and so forth.

Let us look at something else. Suppose on the floor you have carpet then, what is the absorption coefficient for carpet? You can have two types of carpet; woollen carpet with under pad; there is a lining below it. Then at 125, it is 0.2; 250, it is 0.25; at 500, it is 0.35 and so on and so forth.

If you have curtains, you have day freeze, and different types of day freeze. So, they are also mentioned here. If you have a wooden floor it could be solid and polished or it could a panel. So, again their absorption coefficients are listed here. If you have plastered, wall with a plaster, then again you have. So, the point is that there are all sorts of materials, which are used to make rooms. If you have a glass, then this is the absorption coefficient. So, using this table or if you have some special material to identify what is its absorption coefficient, then once you have done this, you can calculate all the values of this alpha bar. From alpha bar you can calculate a prime and from this you can calculate the reverberation time of the room. So, that is a fairly straight forward process.

Now there may be some cases; where suppose you have an auditorium, so there are lots of chairs. And, you can have two situations; when, what is the reverberation time when there are no people inside the room and what is the reverberation time when there are people inside the room. And, that can change significantly. So, if there are people inside the room, then the relation for alpha bar, it changes somewhat. So, what is it? It is alpha 1 s 1 plus alpha 2 s 2 plus alpha 3 s 3 plus, so, this is the same stuff which we had seen earlier, plus we will put some other term and that is N times alpha p divided by s. So, alpha p is absorption coefficient of a person and N is number of persons. The definition of s does not change. It is still s 1, s 2, s 3, till s n. But, in the numerator we have this extra term. So, there are people have measured, taken measurements from these parameters also. So, let us look at that.

So, this is people and it depends whether it is a person or a child; I mean, it is a big person or a child and if the person is sitting in a regular chair or a chair with lot of gurdy and upholstery, then the absorption coefficients are different. If the persons are seated or if they are all standing or if there are seats with no cushions; so there are all sorts of situations. So, using this you can find the role of people on the absorption coefficient also. And, you can calculate this thing.

So, once you have calculated the reverberation time for a room, then you would like to see whether it meets your needs or not. So, mathematically you have calculated it. And, let say that you are in an auditorium and you are designing an auditorium and you want to make sure that for the needs of the auditorium is the right reverberation time. So, then there are some guidelines to figure out whether the calculated reverberation time is correct; appropriate for that application or not.

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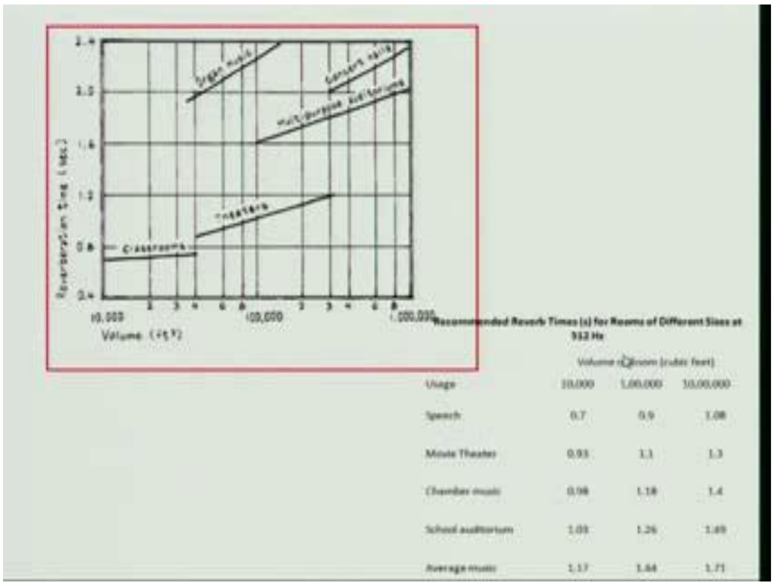

So, there are again some more tables. So, this is one table and let us look at this table, this column is usage. So, I can have a room where I am just talking regular speech or I can have a room where which is like a movie theater or where lot of music is played or an auditorium or some regular music is played. And then, this room could have different sizes; 10,000 cubic feet, 100,000 cubic feet, 10,00,000 cubic feet and so on and so forth.

So, recommended reverberation times for rooms are of different sizes. And, this is again at 512 hertz. So, you calculate 512 hertz and see that if your reverberation time is close enough to this, then may be you have done a good design. So, you have a table like this or you can have charts like these also. So, on the x-axis you have volume of the room and on the y-axis you have reverberation time. So, you have one curve for class room, another for theaters another for multipurpose and so on and so forth.

So, this is not necessarily the final word. There are more guidelines and more recommendations. But, the point is that once you have this reverberation time, then you can make sure that; verify whether it meets your needs or not.

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	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+

This is another table. So, what does it say, Reverberation time for common applications. If it is between 0.8 and 1.3, then it is good for speech where people have just having conversation. But, if it is between 1.4 and 2, then for speech purposes it is not good enough. If it is higher, then it is unacceptable. And, the optimum values somewhere here.

For contemporary music, again there are some recommendations. For choral music; they have again some recommendations. So, you will have to figure out what will be the right reverberation time for your need. But, the calculation of the reverberation time will be based on the relationship, the Sabine's formula which we have discussed till so far.

So, this is what I wanted to discus in this particular lecture. And, what we will do in the next class will be an extension of this and we will introduce this thing; anechoic chambers, noise reduction coefficients, sound transmission coefficients, some of these terminologies. So, that is what we are going to cover in next couple of lectures. But today's discussion, I think it is over and we will see you tomorrow.

Thanks.